Promoting Students' Motivation and Use of SRL Strategies in Online Mathematics Learning

By

Peidi Gu

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Committee members

Young-Jin Lee, Chairperson

Ronald Aust, Professor

Susan Twombly, Professor

Richard Branham, Professor

Jeremy Martin, Professor

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The Dissertation Committee for Peidi Gu certifies
that this is the approved version of the following dissertation :

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Young-Jin Lee, Chairperson

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Abstract

Computer and information technologies have brought revolutions to many aspects of our lives. Online learning is one of the new learning methods that have emerged with the development of new technologies. Even though the advantages of online learning are very attractive to students and educators, when they are applied in real educational settings, not all individuals that participate in online learning are successful; not all programs that are offered online attain their academic goals.

This study was based on an experiment involving high school students from two high schools in China over about two weeks' time. It evaluated the effectiveness of motivational and SRL design implemented in the online trigonometry function instructional system. Two hundred and thirty-six students participated in the study to test the effectiveness of the instructional design and 183 students completed the tasks through to the end. Participants were randomly divided into four groups: the motivational design group (MD); the SRL intervention group (SI); the SRL intervention and motivational design group (MDSI); and the control group (CT).

Three sets of two-way ANOVA (Analysis of Variance) were used to test the effectiveness of the motivational design and SRL intervention with the independent variables of group membership and gender. Research results showed that the motivational design using the ARCS (Attention, Relevance, Confidence and Satisfaction) model for students to learn trigonometry online is effective in enhancing students' learning motivation online. The IMPROVE method was effective as an SRL intervention in the instructional design to promote students' use of SRL strategies during their online learning activity. Both motivational design and SRL intervention were positively correlated to students' academic achievement. But for students learning math online, motivation played a more important role in improving students' academic achievement than SRL intervention. However, the group with both motivational design and SRL intervention showed the highest academic improvement compared with other two treatment groups.

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Chapter 1

Introduction

1.1 Online Learning

The invention of computers has changed the way that human think; the development of Internet has redefined the concepts of time and space. Computer and information technology has revolutionized many aspects of our lives. In the last few decades it has changed the way people communicate with each other, which makes long-distance communication more efficient and convenient. Also, it has promoted global information-sharing, which helps the distribution of advanced resources. From multimedia technology used in instruction to virtual classrooms over the Internet, education has benefited from the applications of computer and information technology.

Online learning is one of the new learning methods that has emerged with the development of new technology. In the past decade, educational institutions have increasingly adopted online learning as a means of learning through the widespread use of Internet applications and technology. According to a survey of online courses over the years of 2002 – 2012, fewer than half of higher education institutions reported online education was critical to their long-term strategy in 2002, but this number increased to almost seventy percent by 2012 (Allen et al., 2016). It was predicted that even more institutions would offer online education after 2013. With respect to the number of students enrolled in online courses, the survey shows that the percentage of online enrollment against the total enrollment was 9.6% in 2002. In the following ten years, the number of enrollments steadily increased to 32% in the fall of 2011(Allen et al., 2016). In 2015, more than one in four students (28%) took at least one course online, with the year-to-year increase in the number of distance education students as 3.9% compared with the 3.7% rate recorded in 2014 (Allen et al., 2016). The Internet as a way of delivering education is making online learning more popular. Meanwhile, the formats for online-learning are diversifying as more and more topics and subjects become available to learn through the Internet. Online learning is not limited to text or videos transferred through the Internet; methodologies of learning are also being researched and applied in the hypermedia environment (Devolder et al., 2012). The design of instructional systems in the hypermedia environment should not be based on intuition and technology only. Besides the content and technology often discussed in online instructional design, theoretical support and empirical research are necessary for the formation of principles of design of hypermedia-based learning environments (Azevedo & Jacobson, 2008).

As more programs are offered online and the number of students participating in online learning increases, the potential for using the Internet to deliver education has been noticed by educators. Online instruction systems help students access content conveniently and help them interact with the material using multiple formats, encourage students to think about the deeper concepts and structure of disciplinary relations, and guide them to avoid superficial details (Kramarski & Mizrachi, 2006). Being an open source that can be reached with an Internet connection, online instruction overcomes the constraints of learning time, which is helpful for students who may not be able to invest sufficient time in classroom study, especially for students with full-time jobs (Huang, 2002). Asynchronousness is an important feature of online learning as students can access the learning content anytime over the Internet. Learning schedules are more flexible, and students can plan and manage their learning time according to their personal situations. In addition, online instruction has fewer constraints of learning space (Vrasidas & McIsaac, 2000). Unlike traditional classroom instruction, students are able to choose supportive environments where they are most comfortable to engage in online learning through an Internet connection. Nowadays, learning material can be downloaded to digital devices such as Kindle, iPads, and smart phones for review anywhere. Another benefit of online learning is that it increases levels of learner autonomy and control during the learning process (Scharma et al., 2007). Personalized learning styles enable students to control their own learning progress according to their prior knowledge and academic background. Students can control their learning pace based on their emerging understanding of the current learning material and self-efficacy for future academic performance. Diverse material display formats give another advantage to online learning. The use of multimedia technology such as images and audio & video clips makes online instruction more interesting and attractive so that it can engage students more actively in learning activities. Blogs, wikis, podcasts, and

Twitter have also been successfully integrated into online learning that facilitates knowledge construction and collaboration (Morris, 2011). In the online learning environment, interaction is considered to be one of the most important factors that improves the learning experience. Interaction between the learner and the content over the Internet is positively related to test scores and user satisfaction (Zhang, 2005). Development of simulation and virtual reality technology provides students with an immersive experience in online instruction by advanced human-computer interactions, motivates students to participate in learning, and thus improves learning outcomes (Monahan et al., 2008).

Even though the advantages of online learning are very attractive to students and educators, when applied in real educational settings, not all individuals that participate in online learning are successful; not all programs that are offered online reached their academic goals. Effectiveness of online learning is still under debate (Azevedo & Hadwin, 2005). Unlike traditional classroom teaching, where students are guided by instructors through the learning session and have very few opportunities to deviate from instructors' presentations and learning materials, students learning online are more easily distracted by environmental influences such as friends visiting and online chatting, and it is difficult for them to concentrate on learning materials in these situations. What's more, even though various kinds of information are available over the Internet with different kinds of formats, which are beneficial to students' learning online, there is also a lot of allure such as shopping websites and online games that may distract students' attention from learning (Tsai & Shen, 2009). Compared with the traditional face-to-face classroom environment, the Internet learning environment requires learners to better control and self-regulate their learning activities due to the extensive amounts of information available, the non-linear structure, and technological inconsistencies and limitations (Narciss et al., 2007). Students often find it difficult to adapt to and integrate various learning content over the Internet when they experience browsing technological problems (Martens et al., 2007). Thus, how students can utilize the pool of information during online learning and how they can efficiently participate in online learning with the nonlinear structure of the hypertext learning environment still need to be discussed.

1.2 Online Math Learning Problems

Mathematics is one of the most commonly used sciences in people's daily lives. In scientific fields, the requirement of accurate computation is increasing as most of the engineering and computer technologies have developed based on the language of numbers. Mathematics permeates many branches of science, such as physics, chemistry, biology, and computer science. In universities, mathematics is important for students from various subjects not limited to science, engineering, and mathematics majors, and it has become a core academic subject (NMAP, 2007). Basic mathematics courses are required for degrees in different majors by universities. Students from various majors with different prior knowledge and background enroll in those courses, which makes teaching math more difficult. Teaching students about mathematics not only teaches them how to apply an algorithm to a particular class of problems, but also helps them to generalize concepts and build problem solving skills (Stanic & Kilpatrick, 1989).

Within the trend toward online-course distribution, evidence shows that online math courses are much more problematic than other disciplines, and the drop-out rate is much higher (Smith & Ferguson, 2005). High drop-out and fail rate present major challenges for college level mathematics educators. According to Smith & Ferguson (2005), three major reasons for the high attrition rate in online math courses are: first, many students participating in online courses are full-time or part-time workers, thus their math backgrounds may not be sufficient for the course requirements; second, current online learning environments are not well adapted to mathematics; and third, certain unique challenges, such as problem solving in mathematics education make it harder to teach and learn math online, especially in an environment where problem solving in mathematics is becoming increasingly important.

With regard to the online learning environment, instructors and students frequently complain that the current online math instructional systems lack the support for math notations, formulas, and diagrams (Smith & Ferguson, 2005). Unlike other subjects such as literature, where communication over the Internet through general language typing is sufficient for learning, mathematics has its own language that requires special notation. When communicating through online instruction systems, if there is no support for math language, there is frequent inconsistency in notation. One example of the inconsistency is when dealing with x^2. On the computer, one can either use x^2 or x^2. Even though they have the same meaning, the different ways of presenting the term may produce notation trouble for students learning online. The inconsistency in notations can raise difficulties in communication between the instructor and students, and emotionally de-motivate students. These issues become more problematic in an online learning environment because of the absence of physical presentation, fewer ways of communicating, and longer turn-around time to answer questions (Smith & Ferguson, 2005).

Another problem which is common in existing online math instruction systems is the asynchronous communication methods provided as the format of forums and threaded discussion (Smith & Ferguson, 2005). Without doubt, the forums and threaded discussions provide a communication method for students to learn online and decrease the sense of isolation for online learners. However, when solving math problems online, students tend to panic when encountering difficulties and give up quickly (Smith et al., 2014). Students who post questions over the Internet may wait hours for responses from others, which may impede their motivation to learn and cause frustration. In order to solve such problems in online math learning, various online tutoring systems have been developed to support communications between the students and learning materials. Online tutoring systems for math achievement have been proven to be effective in improving students' academic performance. But research results show that even high proficiency students gain less improvement than expected from using interactive systems online (Beal et al., 2007). Research in the mathematics field about how the new technologies, such as online learning, can benefit mathematics education is still limited (Kramarski & Mizrachi, 2007).

Trigonometry, a combination of geometry and algebra, is one important branch of mathematics. Basic trigonometry is easily pictured based on right triangles. Trigonometry functions, on the other hand, define trigonometry through pure numerical descriptions. Among the basics of mathematics knowledge, trigonometry functions are especially challenging for many college students to learn. Trigonometry functions are important for the future study by mathematics, science, and engineering students. However, basic understanding of angles in a triangle will not be enough to learn trigonometry functions (Moore & LaForest, 2014). The knowledge of trigonometry functions is based on the knowledge of functions. Thus, before learning trigonometry functions, students need to have solid background of functions, such as the characteristics of basic functions, the relationship between independent variables and dependent variables, and properties of inverse functions. Most of the time, trigonometry is introduced over a unit circle, which is a circle on the $xy-plane$ with the *origin* as its center and *radius* as 1. For example, $f(\theta) = \sin\theta$ is defined as the ratio of the y coordinate of the point (a,b) on the unit circle and the radius of the unit circle, which is 1. The angle between the ray, which is across the origin and point (a,b), and the positive side of the x coordinate is θ. Hence, the value of $f(\theta) = \sin\theta$ corresponds to the y coordinate of the point on the unit circle, and accordingly the value of $f(\theta) = \cos\theta$ corresponds to the x coordinate of the point on the unit circle (see Figure 1.1). Students usually have problems with the angles over the unit circle and cannot relate sine and cosine functions to the coordinates of points (Barrera, 2014).

On the other hand, inverse functions of trigonometry functions are also difficult for students to learn because of the restriction of domains to define inverse trigonometry functions. A function is defined as a relationship between the independent variable and dependent variable that one value of the independent variable (*input*) map to at most one value of the dependent variable ($output$). However, not all functions have an inverse. A function is invertible if and only if the function is injective, that is to say, each value of the dependent variable corresponds to

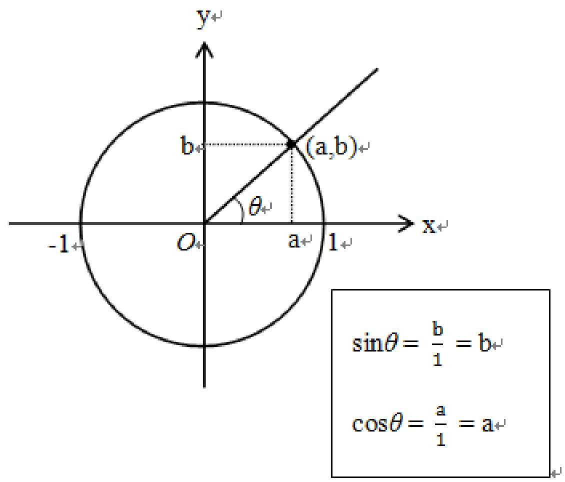

Figure 1.1: Definition of $\sin\theta$ and $\cos\theta$

at most one value of the independent variable. However, trigonometry functions are periodic functions which do not satisfy the injective condition. In order to be invertible, restrictions are imposed on the input of trigonometry functions. For example, $f(\theta) = \sin\theta$ is invertible if its input is restricted to the set of values within the closed interval $[-\frac{\pi}{2}, \frac{\pi}{2}]$, and this restriction of inputs confuses students. Thus, when solving inverse trigonometry functions, students often have problems with the range and domain of those functions. As a result, learning trigonometry functions becomes more challenging for students to learn online in the absence of instructors.

1.3 Self-Regulated Learning

Self-regulated learning has become an important topic in educational and physiological fields during the last two decades. There are various definitions of Self-Regulated Learning (SRL), but they share the common concept that SRL students are active participants in their own learning. SRL is an active, constructive process in which learners set learning goals, monitor their learning activities, regulate and control their cognitive and meta-cognitive processes directed to the goals, and actively evaluate their learning outcomes (Azevedo et al., 2009). The theory of SRL assumes students proactively engage in their own learning with confidence, diligence, and resourcefulness (Zimmerman, 1990; Pintrich, 2004; Winne, 1995). Self-regulated students are meta-cognitively, motivationally, and behaviorally active in their learning activities. More importantly, they seek out information purposefully and take necessary strategies to approach their learning goals (Zimmerman, 1990).

Online learning requires self-regulated behavior of students (Lee, 2004). One of the reasons that SRL attracts researchers' attention is that the capability of students' self-regulation is predictive of academic outcomes (Steffens, 2006). Students who are self-regulated in their learning activities are aware of their effort towards the learning goals; they deploy learning strategies purposefully and monitor their activities; and they make efficient adjustments by adopting more appropriate learning strategies, and evaluate their outcomes frequently by comparing them with their learning goals. Thus, self-regulated learners are more successful at gaining knowledge than those who do not regulate their learning (Tsai & Shen, 2009; Narciss et al., 2007; Azevedo & Cromley, 2004). However, students often do not know that they need to regulate their ideas during online learning and how they can regulate their behavior productively (Kramarski & Mizrachi, 2006). In the absence of an instructor, the abundance of information available, and various distractions over the Internet, students often have difficulties selecting information and managing their own learning in aspects of cognition, motivation, and behaviors. Insufficient self-regulated behavior from the students will end up with inefficient learning outcomes (Scharma et al., 2007). Students have difficulties in deploying efficient SRL processes and strategies that are necessary to learn the content. Insufficient evaluation of their learning outcomes ends up with inaccurate feedback and adjustment for further learning goals. Also, given the autonomy and control over their own learning, students usually don't know how to manage learning time efficiently. Additional time spent learning online does not guarantee better achievement. Research indicates that online courses with more sessions do not produce better academic results than those with fewer sessions (Tsai et al., 2011). When learning over the Internet, especially when learning about complex and challenging topics, students need to regulate their cognitive and meta-cognitive processes throughout the learning activities (Azevedo et al., 2011).

Within the information technology environment, learning across a broad time span is required. The purpose of education is to teach students how to master their own learning instead of imposing knowledge upon them by pedagogical force. One important aspect of education is teaching people not only knowledge, but also self-regulated skills that will prepare them for further education after compulsory education is concluded (Nota et al., 2004). "Self-regulated learning (SRL) refers to self-directive processes and self-beliefs that enable learners to transform their mental abilities into an academic performance skill" (Zimmerman, 2008). Within the online learning environment, the center of learning has shifted from instructors to students. Students are given the autonomy and control over their learning activities. Universal access to multiple sources of information and nonlinear structure of the learning material, as well as interactivity of open information systems, pose additional requirements for the students (Narciss et al., 2007). Online-learning students need to self-regulate their learning through the learning process. Within the pool of information, students need to know what kind of information they need and how they can search for information efficiently. To avoid redundant information, self-regulated students search for information that is relevant to their learning goals and check the usefulness of the selected material by actively monitoring and regulating learning activities (Narciss et al., 2007). The non-linear structure of online learning requires students to carefully plan ahead of time and monitor their learning activities. Self-regulated learners plan their learning, set learning goals, enact learning strategies that will support achieving academic goals, monitor their learning, make adjustments when necessary, evaluate their learning outcomes, and generate feedback that can be merged into the next loops of self-regulated learning activities. On the other hand, students usually exhibit two problems in the learning process: regular signs of detrimental motivation, such as low self-concept and symptoms of helplessness when facing learning failure, and deficits in self-regulation, which include using inappropriate cognitive strategies and insufficient meta-cognitive control over the learning process (Dresel & Haugwitz, 2008). Hence, the role of instructors in online learning could be guiding students into the SRL processes and helping them to enact efficient SRL strategies.

SRL has been widely researched in different academic fields, such as computer science, psychology, biology, language learning, etc. (Azevedo et al., 2011; Barak, 2010; Chang, 2005; Greene et al., 2010; Narciss et al., 2007; Schraw et al., 2006; Tsai et al., 2011). Research about SRL has focused on questions of how to facilitate students' abilities of self-regulation in aspects of cognition, meta-cognition and motivation. Motivation is considered to be an important factor that is positively related with students' academic achievement (Kim et al., 2014). However, motivation is dynamic and occurs in different stages of the learning process where type and intensity change accordingly (Spratt et al., 2002). It is suggested that interventions to promote both motivation and self-regulated learning are helpful in instructional design (Dresel & Haugwitz, 2008). In Winne and Hadwin's (2008) model of SRL, motivation is defined as the behavior of change among students. Students are motivated to change conditions, operations, or standards as they move on to the next round of a task. In SRL theory, student learning and motivation have an interdependent relationship in which they cannot be understood apart from one another (Zimmerman, 1990). Students are motivated to learn if they find the material to be useful, interesting, and possible to handle. When learning a difficult topic, students may lack the motivation to persist in learning if they lose interest (Moos & Azevedo, 2006). The concept of motivation in many studies is involved with interest, attrition, and other dependent variables, such as self-efficacy and self-regulation (Keller & Suzuki, 2004). Accordingly, students making efforts to learn and achieve academic goals motivate themselves to set higher task goals.

Research has shown that motivation is positively related to learning goals. Students with higher motivation tend to set higher learning goals for themselves, a quality that is called self-motivation (Zimmerman, 1990). Intrinsically motivated students may not necessarily put more effort into their learning or spend more time on it, but their work is efficient and they produce high quality learning outcomes (Martens et al., 2007).

1.4 Study Purpose

The purpose of this study was to test the effectiveness of interventions that are based on the ARCS model and the SRL theory. The study aimed to find an effective instructional design method to promote students' sense of self-regulation and learning motivation when they are learning trigonometry functions over the Internet, and to find out which factor is more important in improving their academic achievement. This study focused on two aspects of learning online: motivation and self-regulated learning. Motivation has been investigated as one of the factors that leads students to fail in mathematics courses (Treisman, 1992). Promoting motivation in mathematics learning will be helpful for improving students' academic performance in mathematics. Motivation, which is a critical factor when learning with hypermedia, has gained limited research attention in Hypertext Learning Environment (Azevedo et al., 2011). Also, in studies of SRL, self-efficacy, self-attributions, and intrinsic task interest are reported as motivational factors of SRL (Zimmerman, 1990). Self-efficacy, which is defined as one's beliefs about one's ability to produce designated levels of performance (Bandura, 1997), has been studied by various SRL researchers (Lee & Hwang, 2007; Bates & Khasawneh, 2007; Hall & Ponton, 2005). Enhancing mathematics self-efficacy is important in aiding students enrolled in lower level math courses to improve their academic performance (Hall & Ponton, 2005). Keller & Suzuki (2004) proposed a model for motivational design which is called ARCS (Attention, Relevance, Confidence and Satisfaction): gaining learner attention, establishing the relevance of the instruction to learner goals and learning styles, building confidence with regard to realistic expectations and personal responsibility for outcomes, and making the instruction satisfying by managing learners' intrinsic and extrinsic outcomes. The ARCS model not only identifies four conditions that need to be fulfilled to enhance motivation, but also provides systematic guidance for motivational design, which incorporates the motivational design into the instructional design. Four phases — defining, designing, developing and piloting — are the key processes of the ARCS model for motivational design (Cheng & Yeh, 2009). Following the ARCS motivational design model, the study aimed to design an online trigonometry function instruction system that could motivate students in their learning.

Furthermore, self-regulation is, in itself, an important purpose of mathematics education and a crucial factor of successful mathematics learning (De Corte et al., 2000). Self-regulated training has been proven to increase success in student learning. Also, if the learning outcome is sufficiently attractive, students tend to be more motivated to self-regulate their learning activities (Zimmerman, 1990). Additionally, students' use of high quality SRL strategies will enhance their motivation to continue additional cycles of learning (Zimmerman, 2008). Appropriate use of SRL strategies also improves students' perception of efficacy, which is a widely-used measure of students' motivation to self-regulation (Zimmerman, 1990). Research by Chang (2005) showed that embedding self-regulated learning strategies in web-based learning can efficiently promote students' motivation in terms of goal orientation, self-value, and self-efficacy. How to scaffold SRL processes and strategies in hypertext environments has been examined by various studies (Azevedo et al., 2011, 2004, 2005; Chang, 2005; Dabbagh & Kitsantas, 2005; Dresel & Haugwitz, 2008; Kramarski & Gutman, 2006; Moos & Azevedo, 2008; Tsai & Shen, 2009).

Most of these studies were conducted by separated SRL training to the students and collected SRL data through self-report questionnaire or think-aloud protocol data. These training methods and collection of data are very time consuming and require extra personnel resources during the research, which is not efficient or feasible in an online learning environment where students may be scattered around where the nation and the number of students is very large. Thus, this study tried to develop efficient and feasible SRL intervention in the instructional design that helped students to self-regulate their online mathematics learning.

1.5 Significance of the Study

Currently, many online programs are offered in the format of websites or video streaming. As more course subjects are combined into the online learning programs and more participants are joining in online learning, users of online learning programs are expressing dissatisfaction with the simple forms of material delivered through the Internet. This study should encourage online instructional designers to pay more attention to the educational methodologies which support SRL and promote learning motivation. This study tried to find low-cost and easy-to-implement instructional design patterns that can both promote motivation and SRL skills for students learning online. This study provided an example of an online math learning system in the format of a website for teachers and instructional designers, which can be easily delivered over the Internet and does not require high-level computer skills for course designers and teachers. Meanwhile, the methodology adopted in this study can be expanded into traditional classrooms with multimedia devices installed, as motivation and SRL skills are also important for students in regular classrooms.

1.6 Research Questions

With regard to the problems introduced above, this study tried to solve the problems of how to design a course of online trigonometry function instruction with the aid of multimedia and web technologies to increase students' motivation, and how to promote students' ability to engage in SRL through the instructional design. Hence, the research questions are:

1. Can motivational design promote motivation for SRL learners in mathematics?
2. Can embedded SRL interventions promote the use of self-regulated learning strategies in online mathematics learning?
3. Can the use of motivational design and self-regulated learning intervention implemented in a computer-based learning environment foster knowledge acquisition?

The following hypothesis will be investigated:

H1: Students participating in the online course with the ARCS design model show enhanced learning motivation in terms of self-efficacy, learning interest, and task value expectation compared with students not using an ARCS model designed online course.

H2: Students participating in the online course with SRL intervention show improved SRL strategy use compared with students without SRL intervention.

H3: Students participating in the online course with either the ARCS design model, the SRL intervention or both show better academic achievement by the end of the experiment compared with those without either of the two features. Students studying through the online course with both the ARCS design model and SRL intervention have the highest academic gain compared with other students.

Chapter 2

Literature Review

2.1 SRL Definition

How do students learn independently? Why are some students successful as independent learners while others are not? Self-regulated learning has been researched over the last two decades as one of the reasons for the differences between successful students and grade level students. Self-regulated learning is defined by Zimmerman (2008) as a self-directive process that transfers one's mental ability into academic performance skills. It is a learning process that requires learner initiative. SRL researchers view students as proactive and strategic learners, who proactively participate in learning activities cognitively, meta-cognitively, and behaviorally (Zimmerman, 2008). According to the definition of self-regulated learning, learners who participate in SRL are defined as self-regulated learners. Self-regulated learners take control of their own learning and accept greater responsibility for their learning outcomes (Zimmerman, 1990). They cognitively seek out information that will support their learning, and, more importantly, they enact corresponding strategies to reach their goals and they know why these strategies are helpful for their learning, which is called self-metacognition of the self-regulated learners. In real educational settings, every student, to some extent, is self-regulated, which is exhibited by planning learning to some extent, checking the learning evaluative grades from time to time, and making adjustments to learning methods if something goes wrong during the learning process. However, very few students are fully self-regulated. Furthermore, students with better self-regulated skills learn more with less effort and have better academic outcomes (Pintrich, 2000; Zimmerman, 2000). According to Winne (1997) and Winne & Perry (2000), SRL can be treated as two properties: aptitude and event. Aptitude “is a relatively enduring trait of an individual, and measurement of this trait can be used to predict future behavior” (Moos & Azevedo, 2008). When viewed as aptitude, the ability of SRL is initiated from the individual. Self-report protocol is frequently used in research to measure SRL as an aptitude; on the other hand, researchers who treat self-regulation as an event usually suggest using think-aloud protocol to examine SRL in real time because they view SRL as an ongoing process that unfolds within a particular context (Winne & Perry, 2000).

Self-regulated learning is a highly autonomous learning process. Self-regulating from a social cognitive perspective refers to the extent that students can actively participate in their own learning process meta-cognitively, motivationally, and behaviorally (Zimmerman, 2000). Learners constructively develop learning plans and behaviors, and learners control their own learning activities in SRL. Generally, SRL can be divided into three phases: planning, monitoring, and evaluating. During the planning phase, learners usually analyze the learning task, set learning goals and plan learning strategies. Goal setting refers to a process by which students make detailed decisions about learning and performance outcomes (Locke & Lantham, 1985). Research indicates that students who have clearly defined learning goals and who process these goals accordingly show higher skill achievement and motivation for their assigned work than those with general goals who only focus on the outcomes of the learning task (Zimmerman, 2000). Self-monitoring refers to an individual's deliberate attention to behaviors of learners making efforts to learning-tasks and evaluating the outcomes of these efforts (Dabbagh & Kitsantas, 2005). When monitoring the learning process, learners mediate the strategy as planned, make adjustment to their learning habits, and self-manage learning time. Self-evaluation refers to the process that learners compare their learning outcomes with the standard or learning goals (Zimmerman, 2000). During the evaluation phase, learners re-evaluate strategy use, such as whether the strategies are used properly, how well the strategies work, and whether the learning goal is achieved.

Different models of SRL have been developed by many researchers. Pintrich (2000) defined his model of SRL, combining social cognitive theory with other theories, such as cognitive information processing theory, as four phases:

1. Forethought, planning, and activation — during this phase of SRL, learners set goals, activate prior knowledge and self-efficacy beliefs, plan meta-cognitive knowledge, and perceive the learning context.

2. Monitoring — The learner monitors his actions and outcomes during this phase, including meta-cognitive strategy use, interests and anxieties, time and effort management, and contextual conditions;

3. Control — In this phase, the learner controls cognitive, motivational, behavioral and contextual factors based on the monitoring in previous phases to enhance learning;

4. Reaction and reflection — The learner self-evaluates and judges the effectiveness of the strategy use and learning outcomes compared with the learning goal, and make corresponding changes according to the differences (Schunk, 2005).

Winne and Hadwin's (1998) COPES model of SRL in the information procession prospective categorizes the learning process into four phases, namely, task definition, goal setting and planning, studying strategies, and reflection. In the task definition phase, learners identify what the task is based on the outside environment and their prior knowledge in the long-term memory. In the second phase, learners frame the goal and build up plans to approach the goal. After goals are set, corresponding learning tactics and strategies are enacted accordingly, which is a transition from phase 2 to phase 3. In the last phase, learners compare the learning product with the standards or criteria to evaluate the efficiency of the strategy use. Reflection and feedback are made by comparison, and adjustments can be made tracing back to phase 3 (Winne, 2001).

Based on Winne and Hadwin's (1998) model of SRL, Azevedo et al. (2008) developed a model of SRL with 5 macro-level SRL processes: planning, monitoring, strategy use, handling task difficulty and demands, and displaying interest. Within each macro-level, they identified a total of 30 micro-level processes, such as sub-goal setting, feeling of knowing, judgment of learning, memorization, and note-taking. The advantage of Azevedo et al.'s SRL model is that it provides an easy code scheme for think-aloud protocol. A complete list of the macro- and micro-levels of SRL can be found in Appendix A.

Schraw et al. (2006) described a self-regulation model for science education and partitioned SRL into three components: knowledge (cognition), meta-cognition, and motivation. (a) The knowledge component is subdivided into three general types of learning skills: cognitive strategies, problem solving strategies, and critical thinking skills. Cognitive strategies "include a wide variety of individual tactics that students and instructors use to improve learning" (Schraw et al., 2006). In mathematics learning, one example of the cognitive strategy would be drawing graphs to understand the characteristics of functions. Problem-solving strategies focus on the development of a general problem-solving strategy and practicing of how to use that strategy (Schraw et al., 2006). A typical example of the problem solving strategy in mathematics education is the method of induction for proving a statement of a function $f(n)$, where n is equal to natural numbers. Critical thinking involves various kinds of skills, such as one identifying the source of information, checking the credibility of the information, comparing the information with prior knowledge to see whether they are consistent, and drawing conclusions based on critical thinking (Schraw et al., 2006). (b) Meta-cognition includes two main sub-components: knowledge of cognition and regulation of cognition. Knowledge of cognition consists of declarative knowledge, procedural knowledge, and conditional knowledge, while the regulation of cognition includes planning, monitoring, and evaluation. (c) Motivation has two important sub-components: self-efficacy and epistemological beliefs. Self-efficacy is defined as one's beliefs about one's ability to produce designated levels of performance (Bandura, 1997). Epistemological beliefs are those beliefs about the origin and nature of knowledge (Schraw et al., 2006). Schraw et al. (2006) suggested two ways of increasing students' self-efficacy, using both expert and non-expert models and high frequency informational feedback.

Zimmerman (2000) introduced academic self-regulation as a cyclical process consisting of three phases: (1) forethought, which refers to goal setting, planning, self-efficacy beliefs and motivation; (2) performance, such as self-monitoring, and self-instruction; and (3) self-reflection, such as self-evaluation and self-reactions. These models provide theoretical supports for research in SRL.

Barak's model of SRL for technology education consists of three components: cognition (learning, problem-solving and creativity); meta-cognition (goal setting, self-monitoring, and reflective practice); and motivation (interest, intrinsic motivation, and self-efficacy beliefs) (Barak, 2010).

When defining SRL, Zimmerman (1990) suggested distinguishing SRL processes from strategies designed to optimize these processes. SRL processes can be categorized as meta-cognitive processes, motivational processes, and behavioral processes (Zimmerman, 1990). Meta-cognitive processes refer to learners' planning, setting goals, self-monitoring and self-evaluation of their learning activities at different points during the process of acquisition. Motivational processes refer to learners' perception of self-efficacy, self-attributions, and intrinsic task interest. Behavioral processes refer to learners' behaviors in adjusting themselves to the learning context, such as selecting, structuring and creating environments that support their learning, and seeking help from peer students, instructors, and other resources. SRL strategies are the specific cognitive steps self-regulated learners adopt at certain points in the learning process. They refer to “actions and processes directed at acquisition of information or skills that involve agency, purpose, and instrumentality perceptions by learners (Zimmerman, 1990).” Zimmerman (1990) concluded that there are 14 key self-regulated learning strategies. Those are self-evaluation, organization and transformation, goal setting and planning, information seeking, record keeping, self-monitoring, environmental structuring, giving self-consequences, rehearsing and memorizing, seeking social assistance, and reviewing. Students who set their own learning goals show a higher mental shift than those with teacher-set goals (Azevedo et al., 2002).

However, using all of these strategies during the learning process may not be helpful in achieving academic gain. Viewing SRL as a moderator of the relationship between student characteristics and performance (Greene et al., 2010), Whipp & Chiarelli (2004) suggested that the enactment of SRL strategies is unique to the context and learning environment. Encouraging the use of meta-cognitive control strategies in the topic of mathematics is helpful to promoting self-regulated learning (Dresel & Haugwitz, 2008). Applying these principles to trigonometry learning online, this study tried to support students in their use of SRL strategies such as goal setting, time management, note taking, prior knowledge activation, summarization, and help-seeking by inserting SRL intervention into the instructional design.

2.2 Measurement of SRL

In the early stages of SRL research, the self-report has been used frequently to record the SRL behaviors of students during their learning (Duncan & McKeachie, 2005). However, Winne & Jamieson-Noel (2002) have shown the unreliability of the self-report as students usually are poor reporters of their SRL activities. Compared with the self-report, there are four innovative alternative methods for measuring SRL: trace logs of SRL processes, think-aloud protocol measures of SRL, structured diary measures of SRL, and observation and qualitative measures of SRL (Zimmerman, 2008).

Trace logs of SRL processes

Trace logs of SRL processes are empirically used in computer-assisted learning environments to record the self-regulation of the students by software. A typical example of using this method was introduced by Winne et al. (2006) in developing the gStudy learning software, which is a learning shell that allows students to study a learning kit about any topic by using the cognitive tools implanted in the program. GStudy uses text, diagrams, photos, charts, tables, and audio & video clips to display the learning content. A more innovative feature of gStudy is the interactivity between the learner and the learning environment.

GStudy allows learners to take notes, create glossaries, label and index content, construct concept maps, search for information, chat and collaborate, and receive coaching (Zimmerman, 2008) in the learning environment. Learners can select information and construct an annotation to make a note of the selected information. Links are created automatically by the gStudy to the selection of an object. Learners can navigate from one object to another through the links. Key elements in the domain of knowledge in the gStudy can be added to the glossary using the same method of taking a note. By labeling, learners can add descriptions to the selected information. Labels are categorized so that learners can navigate labeled information with shared attributes. On the other hand, learners can create their own concept map within the learning environment by using the templates stored in the gStudy. Notes, glossaries, labels, and concept maps are created by learners to enhance retrievability of the knowledge (Winne et al., 2006). Chat and collaboration are realized through scaffolding. Both chats and collaboration artifacts can be saved to analyze co-regulation of individual and group learning (Winne et al., 2006). GStudy provides several methods to coach learners. One method is called gLiza, which exposes learners to study tactics and conditions that are helpful for learning and collaboration. Another method uses an expert system modeled from an intelligent help system (Winne et al., 2006) to engage learners in a quasi-conversation by diagnosing problems of learning and collaboration.

GStudy contains a log analyzer, where the interactions between the learner and information are unobtrusively recorded. When an interaction happens, gStudy records the action, including information related to the action and the time when the action is taken. Data is stored so that researchers and learners can use the log analyzer tool to investigate how the learners study. The trace information can also be used by researchers to help learners see which strategies work best for them and make adjustments for better learning (Zimmerman, 2008).

Trace logs of SRL process assisted by the computer environment have been investigated by Winne & Jamieson-Noel (2002) for their effectiveness. During the experiment, the computer traces the frequency of students' using SRL. Compared with the self-report, which has been tested to produce an over-estimation of learners' self-regulation, tracing logs more accurately track learners' self-regulatory judgments. However, the validation of the trace measures should be confirmed by other measures of SRL. According to Winne and colleagues (Winne et al., 2006), a high frequency of note taking traced by computer could result from students' selecting information without comprehensive understanding of the subject. Also, it is difficult for trace logs to track learners' motivational aspects, such as personal interest in the topic, test anxieties, and self-efficacy, which are also important factors in self-regulation. In this situation, combined with other measures, such as interviews (Zimmerman, 2008), more valid conclusions can be drawn.

Think-aloud protocol measures of SRL

According to Winne (1997) and Winne & Perry (2000), when viewing SRL as a series of events, think-aloud protocol can be used to measure self-regulation as an ongoing process. Think-aloud measures have recently been used in SRL research (Azevedo et al., 2004, 2005, 2011; Moos & Azevedo, 2006, 2008; Greene et al., 2008) to capture the SRL processes verbally from the learner during the learning activities in hypermedia learning environments.

In recent research, Greene et al. (2008) used the think-aloud protocol to explore the differences between gifted students and grade-level students' use of self-regulatory learning processes within the hypermedia environment. Participants in the study used Microsoft's $EncartaReferenceSuit^{TM}(2003)$ hypermedia environment to learn about the circulatory system. After filling out the questionnaire and pretest, participants were given access to the instructional materials. The purpose of the study was for students to learn all they could about the circulatory system in 40 minutes. General learning goals were given at the beginning of the study. During the learning process, an experimenter remained nearby to remind participants to verbalize what they were thinking while learning. The whole process was tape recorded, transcribed, and coded through the coding scheme created by Azevedo et al. (2008). At the end of the study, a post-test was given to the participants without notes or any other instructional materials.

The think-aloud data collected from the study consisted of 3,920 minutes of audio and video tape recording from 96 participants (Greene et al., 2008). A graduate student transcribed the audio tapes and created a text file for each participant. Then Azevedo et al.'s (2008) model of SRL was used to group the data into segments. The coding scheme developed by Azevedo et al. (2008) contains 5 macro-level SRL processes: planning, monitoring, strategy use, handling task difficulty and demands, and displaying interest; while 27 micro-level SRL processes can be inferred from verbal reporting. Results of the study showed that gifted students outperformed the grade-level students by using various SRL processes and strategies, such as prior knowledge activation, setting sub-goals, content evaluation, identifying adequacy of information, feeling of knowing, summarization, selecting new informational sources, taking notes, inferences, re-reading, expecting adequacy of information, and control of context (Greene et al., 2008).

The think-aloud data provides an effective way to assess learners' self-regulatory processes in a hypermedia learning environment (Zimmerman, 2008). It effectively captures the emerging SRL behaviors of learners during the learning process. However, the disadvantage of such protocol in online learning is that collecting data is time-consuming and the method is not feasible in large online learning classes with students in different locations. Collecting think-aloud data requires tape recording the whole learning process of the students, and a large amount of human resources is needed to transcribe and code the huge amount of information collected. Furthermore, the think-aloud protocol still has difficulties in capturing the motivational factors of the students during the learning process.

Structured Diary Measures of SRL

The structured diary measures of SRL use online diaries of students with a sequence of structured questions to record the SRL process during the learning activities. An example of using this method is Schimitz and Wiese's (2006) study of civil engineering students at a German university over a 5-week period.

This study adopted interventions by conducting four weekly 2-hour training sessions that focused on key self-regulatory processes. Each week, new self-regulatory processes were introduced in the sequence of planning, monitoring, and self-motivation. At the end of each week, diaries were collected.

The SRL diary was structured using a series of event questions (Zimmerman, 2008). Before the learning, questions regarding goal setting and planning were asked. In the middle of the learning, motivational questions were displayed to capture the interest and affection of the students. At the end of each study, questions involving time management and self-evaluation were asked. Examples of the questions are: how much total time was spent in studying, how much time was spent studying effectively, and whether the students reached the individual goals that they had listed before studying.

The research results were positive. Students who received self-regulatory training displayed significant improvements in studying motivation, self-efficacy, time management, planning, and concentration (Schmitz & Wiese, 2006). The structured diary method was proven to be effective in assessing SRL behaviors online. But there are no research results about the correlation between the improvement of SRL skills and academic outcomes.

Observation and qualitative measures of SRL

Observation and qualitative measures deal with the question of whether teachers can adapt their regular classroom activities and assignments to increase their students' use of SRL skills (Zimmerman, 2008). The basic idea of this method is to train teachers about SRL. A variety of quantitative and qualitative measures, such as observation forms and interviews of teachers and students, were used to measure the changes in SRL during classroom learning events.

This assessing method measures a broad range of the SRL aspects of the students by collecting different types of data. But it is designed for classroom learning, and such observation is hard to conduct for online learning, and it is therefore not feasible for online SRL assessment.

2.3 Current research on SRL

2.3.1 Promoting SRL

Computer-based learning environments, such as online learning, have provided important opportunities and advantages for education. Development of computer and information technologies, such as the Internet, multimedia, and artificial intelligence, provide various ways of learning. Learners benefit from online learning due to the variety of information available over the Internet, freedom from time and space restrictions, and attractive interaction formats. However, research has shown that students have challenges in learning in a computer-based learning environment, especially in hypermedia environments such as the Internet. In order to be successful in online learning, students must have effective self-regulatory skills to control the sequence of instructions, manage study time and personal motivation, and make decisions about non-linear multiple representations of the learning material (Azevedo & Cromley, 2004). Even though SRL has been proven to be effective in learning, students still have difficulties with SRL behaviors (Kramarski & Mevarech, 2003; Veenman & Van Hout-Wolters, 2003).

Kramarski & Mizrachi (2006) proposed that SRL is teachable, and students who are exposed to meta-cognitive guidance have more knowledge about orienting and judging themselves. Training students to be self-regulated learners is challenging and time consuming because students have not previously taken the responsibility for their own learning, and current school environments are not yet prospectively supportive of SRL (Tsai & Shen, 2009). Even when trained to be self-regulated learners, students show a decrease in their ability of SRL over time, as suggested by the muscle metaphor proposed by some researchers (Pintrich & Zusho, 2003), which means the enactments of SRL processes require self-control "strength" but this strength is limited (Moos & Azevedo, 2008).

However, web-enabled SRL has been proven to be effective in promoting students' learning, which leads to better academic results (Tsai et al., 2011). Research shows that, when learning in the hypertext context, not all students are capable of getting a deep understanding of conceptual knowledge. For example, even when provided with a general learning goal, students do not always grasp large gains in conceptual understanding due to the differing abilities at self-regulation (Azevedo et al., 2004). They conducted research with 24 undergraduate students to learn about the circulatory system in the hypermedia environment. General learning goals allowed "high-jumpers" (who gain more sophisticated conceptual understanding) to strategically plan their learning relative to their prior knowledge and the context. It also facilitated their ability to monitor their learning and deploy effective self-regulated strategies. Then these high-jumpers, who had comparatively higher academic gains than average, could generate feedback from their learning outcomes and establish appropriate sub-goals through the feedback (Azevedo et al., 2004). In contrast, "low-jumpers", who had fewer academic gains, had difficulty in gaining conceptual understanding because of their inability to engage the necessary mechanisms for regulating their learning (Azevedo et al., 2004). They typically used ineffective strategies, such as memorizing and copying information, and didn't monitor much of their learning. Azevedo et al. (2004) raised questions about whether presenting students with a series of questions as sets of sub-learning goals would facilitate students' understanding of the topic, or whether it would hinder students' ability to self-regulate their own learning. Also, in Azevedo et al.'s research (2011), which provided adaptive contents and process scaffolding, students tended to be more self-regulated and associated with better conceptual understanding. Adaptive scaffolding is defined as tools, strategies, and guides during learning to support students' understanding based on an ongoing diagnosis of the student's level of understanding of the topic. Adaptive content scaffolding aims to assist students in learning by assessing their emerging understanding of the content to make sure that they meet their overall learning goals; while adaptive process scaffolding tries to help students by enacting self-regulatory processes such as planning their learning, monitoring their emerging comprehension, and using various self-regulated learning strategies to learn. Scaffolding is critical to sustain and foster learning in the hypermedia environment. Scaffolding emphasized four attributes: diagnosis, calibrated support, fading and individualization (Azevedo & Hadwin, 2005). However, it is difficult for researchers to decide what to scaffold and whether it should be content based or process based. Students' characteristics are one of the factors that affects the use of scaffolding. Research suggested that students with low prior knowledge are in needs of both kinds of scaffolding compared with students with higher prior knowledge, who needs more process scaffolding (Azevedo & Jacobson, 2008). Research was conducted with 123 undergraduate students, who were required to learn about the circulatory system using either adaptive content and process scaffolding or adaptive process scaffolding with the help of human tutors. Adaptive content and process scaffolding effectively helps students learn complex knowledge in the hypertext environment (Azevedo et al., 2011). Adaptive scaffolding has been proven to be effective in improving students' academic outcomes and self-regulated learning skills within hypermedia learning environments. However, complex interaction between students and the system is needed for the application of adaptive scaffolding. It is difficult for current technologies to trace, model, and monitor students' emerging understanding of knowledge and provide adaptive scaffolding accordingly (Azevedo et al., 2002).

Students learning under both content and process scaffolding conditions had the most sophisticated mental model shift when compared to those in either process scaffolding or no scaffolding conditions, while students in the no-scaffolding condition showed no shifts in their mental models. Students in the content and process scaffolding condition deployed key SRL processes, such as prior knowledge activation, meta-cognitively monitoring of their cognitive systems, such as Feeling Of Knowing (FOK), and emerging understanding, such as Judgement Of Learning (JOL), drawing, and help seeking. However, research has proved that these students showed a high dependency on their tutors to regulate their learning (Azevedo et al., 2011).

Narciss et al. (2007) developed the Study2000 project to support teachers and students in web-based learning and instruction. They did research with 72 college students by using the Study Desk in a self-regulated learning setting at the university level. The Study Desk is a working space for learning and studying designed by authoring tools. It complements instructions by presenting multiple materials and pieces of information. Students were able to use the Study Desk to prepare for lessons and improve knowledge in a self-regulated manner. Results indicated that students used almost the same learning strategies in the web-based environment as they did with textbooks. Instructional interventions, such as highlighting, note-taking, and learning tasks of varying complexity, were tested to be effective in promoting learners' self-regulated learning (Narciss et al., 2007). According to the results, direct interventions of SRL might help inexperienced students to adapt to the SRL learning setting, but they also might hinder the learning process of those with greater experience (Narciss et al., 2007). Thus, future research is suggested to discuss how direct intervention of SRL can be adapted to the levels of learners' expertise.

2.3.2 SRL Process and Strategy Application

As students engage in more SRL processes, the positive effects of students' characteristics are amplified (Greene et al., 2010). Greene et al. (2010) did research on the relationship among college students' prior knowledge, implicit theories of intelligence, and self-regulated learning in a hypermedia environment. The findings suggested that SRL worked well as a benevolent moderator that magnified the positive effects of prior knowledge and decreased the negative effects of the *entity Implicit Theories of Intelligence (ITI)*, which is the belief that knowledge is fixed at birth and unchangeable (Greene et al., 2010). Thus, SRL can work as a moderator between student characteristics and learning content. Research showed that more successful students reported significantly greater use of SRL strategies, while less successful students showed a lack of self-regulatory initiative (Zimmerman, 1990).

Dabbagh & Kitsantas (2005) recognized the key SRL processes that affect students' achievement and motivational beliefs are goal-setting, self-monitoring, self-evaluating, task strategies, help-seeking, and time planning and management. They did research on how distinct categories of Web-based pedagogical tools (WBPT), such as collaborative and communication tools, and content creation and delivery tools, support different self-regulated learning processes. Sixty-five students enrolled in 3 college distributed courses participated in the study. The Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich et al., 1993) was used to measure the differences among students in their self-regulation across the three courses. Results showed that content creation and delivery tools supported the SRL processes, such as goal-setting, help-seeking, self-evaluation, and task strategies;

collaborative and communication tool, supported task strategies, self-monitoring, and self-evaluation (Dabbagh & Kitsantas, 2005). SRL strategy use has been researched as an important process of SRL. In the online learning environment, it is suggested that students have the SRL strategies necessary for learning. Otherwise, they are more likely to drop out (Kogo & Nojima, 2004). Self-regulated learning strategies have been proven to be effective in improving students' academic achievements in previous research studies. However, students seldom apply these strategies effectively in non-experimental environments (Zimmerman, 2008). In a particular academic context, even though a student knows a strategy on an SRL aptitude questionnaire, he may not know how to apply it to a specific situation (Zimmerman, 2008). This rises the question of how to train students to initiatively use SRL strategies in regular learning activities.

Numerous studies have been conducted with regard to the SRL strategy use of students in different domains. SRL skills and strategies are highly context-dependent (Schunk, 2001). However, the level of students' self-regulation is significantly correlated to their academic outcomes (Barnard-Brak et al., 2010). In Barnard et al.'s research about students' levels of self-regulated learning skills and strategies over the online learning environment, students who exhibit more skills and strategies in self-regulated learning have better GPAs than those showing fewer self-regulated learning skills and strategies. Evidence shows that all students use different SRL strategies in the learning process. However, more successful students use more effective and efficient strategies than lower-achievers. In Azevedo's (2004) research, high-achievers used proportionately more effective strategies, such as summarizing, re-reading, knowledge elaboration, selecting additional information sources, making inferences, and hypothesizing, while low-achievers used more ineffective strategies, such as goal-free searching and copying information. For example, inferences have been demonstrated to be effective when learning challenging topics, especially science-related topics (McNamara, 2004); and prior domain knowledge could compensate for knowledge gaps in the learning content, thus positively affecting students' learning outcomes (Pieschl et al., 2008). Activating prior domain knowledge is essential in the stage of planning for self-regulated learners. Successful students in the hypertext-based learning environment tend to more frequently activate prior knowledge and examine the context according to the general learning goal. They strategically plan their learning, monitor the learning process, adopt effective learning strategies, and generate feedback to dynamically enact subgoals to match the overall learning goals (Azevedo et al., 2004). In the hypertext-based learning environment, failure to deploy key SRL strategies, such as prior knowledge activation, self-questioning, and hypothesizing, will end up producing little or no gain in conceptual understanding. In this situation, providing scaffolds to students who do not regulate their learning on their own initiative facilitate better academic gains (Azevedo et al., 2005, 2011). Furthermore, students' extensive use of SRL variables related to planning, monitoring, strategy use, and task difficulty and demand accounts for better conceptual understanding in the hypertext environment (Azevedo et al., 2004). Research empirically showed that students tended to use more planning and monitoring processes when learning in hypertext environment if they were provided with content scaffolds (Azevedo et al., 2011). With regard to help seeking, more successful students ask fewer questions about emerging understanding of the topics or instructional behaviors (Azevedo et al., 2004). A tutor's role in providing both content and process scaffolding has been researched to effectively facilitate students' self-regulated learning with hypermedia (Azevedo et al., 2011). When learning in the hypertext environment, gifted students and grade-level students are researched to be different in their SRL strategy use (Greene et al., 2008). The research was conducted with 98 middle-school students from a secondary school, among which 49 students attended regular, grade-level instruction classes and the other 49 students were in a gifted program. Participants used Microsoft's $EncartaReferenceSuite^{TM}$(2003) to learn about the circulatory system. Think-aloud protocol was used to measure the SRL of students during the learning process. At the end of the research, gifted students used summarizing, selecting new informational sources, and coordinating of information sources, while grade-level students used more note-taking and finding location in the environment. However, there was no significant difference in their deployment of SRL processes, such as planning and monitoring (Greene et al., 2008).

2.3.3 Motivation in SRL

Besides SRL strategy use, promoting learners' motivation in SRL is important for SRL instructional designers and researchers. Students with initiative, intrinsic motivation, and more personal responsibility tend to achieve greater academic success (Zimmerman, 1990). Motivational measures show a correlation to students' use of SRL strategies. And SRL trained students show improved motivation in aspects of effort, task interest, and learning goal orientation (Zimmerman, 2008). Zimmerman (1990) did research on students' combined use of the 14 strategies, and found that gifted students are highly self-motivated. Motivation can also be promoted by instructional interventions. Systematic motivational design is demonstrated to positively influence learner's motivation and emotion (Keller & Suzuki, 2004). In a computer-based learning environment, computer generated attributional feedback is shown to have a positive effect on students' motivation and knowledge aquisition (Dresel & Haugwitz, 2008). The research was conducted on 151 6th-grade students working with a mathematics learning software program. Adaptive computer generated attributional feedback was presented to the students after they finished a block of tasks. Computer-based motivation training with high feedback frequency was proven to be effective in promoting domain-specific self-concepts, reducing feeling of helplessness, and enhancing knowledge acquisition when learning mathematics (Dresel & Haugwitz, 2008). However, the long-term effect of the attributional feedback on mathematical knowledge has not been proven statistically. Dresel & Haugwitz (2008) suggested that the methods educators adopt to improve motivation should be implemented continually to ensure the effects are enduring during the learning process.

Self-efficacy, which is defined as the perceived potential ability to achieve learning goals by learners, has been frequently discussed in SRL research. Self-regulated learning is highly correlated with self-efficacy beliefs about the ability to complete a task successfully, and self-efficacy beliefs are dependent on previous positive experience in dealing with similar tasks, as well as on social and emotional support (Barak, 2010).

Students with higher self-efficacy tend to have better cognitive engagement and performance, to be more self-regulated in terms of using more meta-cognitive strategies, and to persist more when confronted with difficult academic tasks (Pintrich & De Groot, 1990). In a study by Scharma et al. (2007) involving employees at four major organizations and a group of students in a postgraduate information technology course, self-efficacy was examined with regard to its impact on the performance of corporate e-learners, and MSLQ was used as the main basis for questionnaire items to assess the self-regulatory attributes. Self-efficacy for SRL was proven to have a positive impact on students' academic performance (Scharma et al., 2007). Students with higher self-efficacy are more likely to have better perceived learning strategies and are better able to monitor the effectiveness and usefulness of the strategies they adopt (Lee & Lee, 2008). In a computer-based learning environment, self-efficacy beliefs are predicted by previous success with online learning technology, pre-course training and prior acquired knowledge, where the self-efficacy itself predicts students' outcome expectations, mastery perception, and time invested (Bates & Khasawneh, 2007). On the other hand, computer self-efficacy is positively related to the use of self-regulated learning strategies in a computer-based learning environment (Lee & Hwang, 2007).

Chapter 3

Method

3.1 Participants and Design

This study was based on an experiment with random samples over about two weeks' time to evaluate the effectiveness of motivational and SRL design implemented in the online trigonometry function instructional system. The study aimed to answer the following research question: Dose the use of motivational design and self-regulated learning intervention implemented in a computer-based learning environment foster motivation, use of self-regulated learning strategy, and knowledge acquisition? The study consisted of two stages: stage 1, instructional system design, and stage 2, application of the instructional system. The instructional system design stage aimed to construct an online trigonometric function instructional website that could maintain or enhance students' learning motivation, and improve students' use of self-regulated learning strategies, and, hence, improve students' online learning experience and academic performance. In the second stage, application of the instructional system, the instructional system was applied in real educational settings to test the effectiveness of the motivational design and self-regulated learning design. Students used the online instructional system to learn about trigonometric functions, and survey data was collected for further data analysis.

3.1.1 Online Instructional System Design

In this stage, an online trigonometric function instructional system was designed in the form of a website. The instructional design adopted the IMPROVE method (Mevarech & Kramarski, 1997) and the ARCS model (Keller & Suzuki, 2004) to improve students' learning motivation and use of self-regulated learning strategies.

3.1.1.1 Participants

Fifteen first-year high school students and five high school math teachers in China who have similar experience in teaching trigonometry functions participated in the first stage of the research.

3.1.1.2 Procedure

Consent forms were signed by the participants before commencing the research activity. Web prototyping tool Justinmind (2015) was used to construct a sample system based on the research of SRL theories and the ARCS model. Then the prototype was shown to and tested by the interviewees one week before the interview. Planned interviews were given to the participants with regard to their knowledge about trigonometry functions and their opinions about the online instructional system. The purpose of the interviews was to collect ideas for the instructional design and find factors that may affect students' learning motivation and SRL strategy use when learning math online from the interviewees' perspective. A list of interview questions can be found at Appendix C. Each interview lasted about 20 minutes, and the interview had open-ended questions. Interview questions were designed to focus on study difficulty, motivation, and SRL strategy use. Interviews were audio recorded and transcribed for data analysis. The data collected from interviews then was coded and categorized into two groups: motivation or SRL strategy use. To help ensure the validity and reliability of the experimental results, the interview content was also coded independently by a peer student, who is a Chinese PhD student in the School of Education at the University of Kansas, according to the motivation and SRL strategy use protocols. There was agreement on 216 out of a total of 231 interviewee statements, which resulted in an inter-rater reliability of .94. The disagreement on whether to categorize interviewees' statements about communication online into motivation or into SRL strategy use was discussed, and it was finally decided to include them in the motivation category based on the research design. The experiment results were then reviewed by the interviewees.

Information collected from the interviews was used as guidance for designing the instructional system. Based on Krippendorff's trajectory of artifacts (Gibbons, 2011) (see Appendix B), the design of an instructional system is an interactive process between design activities and users. The trajectory describes a line of artifacts used by individuals ranging on a continuum from little social responsiveness and personal commitment to those requiring more social responsiveness and personal commitment (Gibbons, 2011). From project to discourse, each artifact from the upper level contains the properties of the lower ones. Krippendorff gave new definition to each type of artifact on the trajectory. The definitions help designers identify what kind of artifacts they are designing. Designers can thus interactively build more features into the product to reach their final design goals. This study aims to design an online math instructional system that can be used by multiple users. Informativeness, connectivity, and accessibility are important for the product, which means that this study aims to design multi-user system/networks based on the trajectory. A prototype of the instructional system was designed and then tested by the teachers and students from the Chinese high schools to evaluate the functionality of the system according to their expectations before the interviews. According to the data collected from the interviews, conclusions about which information is helpful for the instructional system design are shown in the table below. Based on the interview feedback (see Table 3.1), several changes were made to the original prototype in aspects of browsing patterns, increased video material, and enhanced practice problem settings.

Table 3.1: Information Collected from Interviews

Interview question	Responses	Example statement	System design
Trigonometry function learning difficulty	Connection between function expression and graphs; Hard to remember complex concepts; Understanding behavior of graphs; Graph transformation;	"I found it is hard to match the trigonometry function with its graph." "The graphs of trigonometry are very different from the graphs of regular functions I have learned, such as lines and parabola."	Interactive animation showing the graphs of functions and their behaviors. Embedding similar functions and their graphs within one animation for comparison.

Table 3.1 Continued

Interview question	Responses	Example statement	System design
Suggested methods for learning	Definition of inverse functions; More practice problems for familiarity; Clear instruction and learning material; Better demonstration on different questions;	“The practice problems in the website are too few to help students practice what they have learnt in class.” “I would suggest using more detailed steps to guide students solving questions.”	Increased number of practice problems. Concise text information and detailed instruction on problem solving.

Table 3.1 Continued

Interview question	Responses	Example statement	System design
Multimedia preference for learning online	Video instructions from famous teachers; Animation demonstration; Randomly selected problem practicing system;	"The animations are interesting in the website. But I would recommend using videos from famous teachers all over the country." "I found out that the practice questions are always the same. I think it will be more helpful if we can have different practice questions every time."	Embed video clips from famous teachers. Embed interactive animation.

Table 3.1 Continued

Interview question	Responses	Example statement	System design
Suggestions for self-regulation	Limit distraction over the Internet by teacher supervision; Clear learning goals for students; Clearly defined task orientation;	"The overall system design is good to me. But I doubt how can we be sure that students actually learn when they sit in front of the computer without doing other things like computer games and online shopping?"	Clearly stated learning objectives for each module and section. Allow students to set up learning goals of their own.

Table 3.1 Continued

Interview question	Responses	Example statement	System design
Factors affecting learning motivation	Unclear learning goals; Perceived hard to complete tasks; Unclear reasons for learning; Uninteresting learning material;	"The learning material is too difficult for me to learn, and I just want to give up." "I have no idea why we learn this. It's just a waste of time." "It's very boring learning these in class, I always want to go to sleep when listening to the lectures."	Clearly defined learning goals and objectives in each module and section. Create more interaction between students and learning material. Guide students to learn how trigonometry can be used in daily life.

Table 3.1 Continued

Interview question	Responses	Example statement	System design
Comments on current online math instructional systems	Unify math notation between the online material and textbooks; Boring learning material online; Poorly designed learning content; Slow internet speed to view the material; Hard to communicate with teachers over the Internet; Cannot get used to the learning pattern online;	"Sometimes it is confusing for me to read different writing styles of math symbols online, I have to double check that my understanding is right. " "The content on those websites are so boring, they basically just move the content from the textbook to the Internet." "It is difficult to ask someone when I have problems with the learning material online."	Using Latex to present math symbols the same as in the textbook. Keep the learning content as simple and concise as possible. Introduce Wechat into the study. Keep the structure of the website as simple as possible for students to browse.

3.1.2 Application of the Instructional System

The instructional system designed in stage 1 was then used by students in real educational settings to test the effectiveness of the motivational design and self-regulated learning intervention. Survey data were collected for data analysis. The goal was to find out whether students' learning motivation and use of self-regulated learning strategies were improved during the learning activity by learning trigonometric functions online through the designed instructional system. The relationship between learning motivation, self-regulated learning strategy use and academic performance would also be evaluated through the research data.

3.1.2.1 Participants

236 first-year high school students from the Hechuan High School and Yucai Vocational High School in China signed the consent form for the second stage of the research. 183 sets of data were successfully collected and 53 students were ultimately excluded from the study for various reasons, such as absence from either pre- or post-data collection, unavailable computer or Internet access, and directly withdrawing from the study. Participants were randomly divided into four groups: one group of students took the online instruction with motivational design (MD). This group of students received instruction designed by the ARCS model and assisted by a human instructor, who is a certified Chinese high school math teacher, through Wechat (2011). The second group of students took the online instruction with embedded SRL intervention (SI). This group of students received instruction with IMPROVE design, which presents as meta-cognitive questions. The third

group of students took the online instruction with both embedded SRL intervention and motivational design (MDSI). This group of students received instruction designed by both the ARCS model and IMPROVES meta-cognitive questioning. Human instructor assistance through Wechat was also provided. The control group of students took the online instruction with basic learning material presented (CT) as in the textbook; no human assistance was provided. Table 3.2 shows the examples of interventions for each experiment group. Students used the instructional system to learn as much about trigonometry functions as they could in about two weeks' time. Each student had a personal account to log into the system and personal learning information was recorded independently.

Table 3.2: Interventions for Treatment Groups

Category	Example	CT	MD	SI	MDSI
Motivational design (ARCS model)					
Attention	Digital pictures, animations, videos, hyperlinks	No	Yes	No	Yes
Relevance	General learning goal provided; Material is closely related to corresponding goals;				

Category	Example	CT	MD	SI	MDSI
Confidence	Material difficulty level increases gradually; Supplemental material provided; Human assistance through Wechat is provided;				
Satisfaction	Attributional feedbacks are provided;				
Self-Regulated Learning intervention (IMPROVE)					
Problem Solving	Metacognitive questions: What is the question about? What are the strategies/-tactics/principles appropriate to solving the problem and why?	No	No	Yes	Yes

Category	Example	CT	MD	SI	MDSI
Domain Knowledge Learning	Knowledge based questions: Can you try to compare the graph of f(x) = sin(x) and f(x) = cos(x) to find similarities and differences between these two functions? How can f(x) = sin(x) be transformed into f(x) = cos(x)? Process based questions: What is your study plan today? And how long do you plan to study for the goal? How long have you studied this time? How far away are you from the goal? Do you think the learning strategies used are effective for your learning goals?				
Others	Note-taking and note-review in the system;				

During the experiment, students were allowed to log into the instructional system as many times as they would. No instructor teaching was presented. Students were encouraged to manage their own learning activities and time for the study.

3.1.2.2 Procedure

Consent forms were signed by the participants before the study. Participants were asked to take the demographic survey and the MSLQ survey first, and then the pre-test was given to evaluate the knowledge level prior to the intervention. After the pre-test was finished, participants were given two weeks' time to learn the trigonometry functions as well as they could by using the instructional system. The survey was again given to the participants at the end of two weeks' time after students finished their learning to find the change in their motivation and knowledge of self-regulated learning strategy use. The post-test was conducted at the end of this study for academic performance evaluation.

3.2 The Trigonometry Function Instructional System (with both ARCS Design Model and IMPROVE Intervention)

In the interview session, students stated that one of the factors affecting learning motivation was unidentified reasons for learning a specific topic in mathematics. addressing that problem, information on important applications of trigonometry functions is provided in the front-page of the instructional system (see Figure 3.1).

The instructional system divided the chapters on trigonometry functions into modules: right triangle, definition, graph, and inverse functions (see Figure 3.2).

Figure 3.1: Entrance to the System

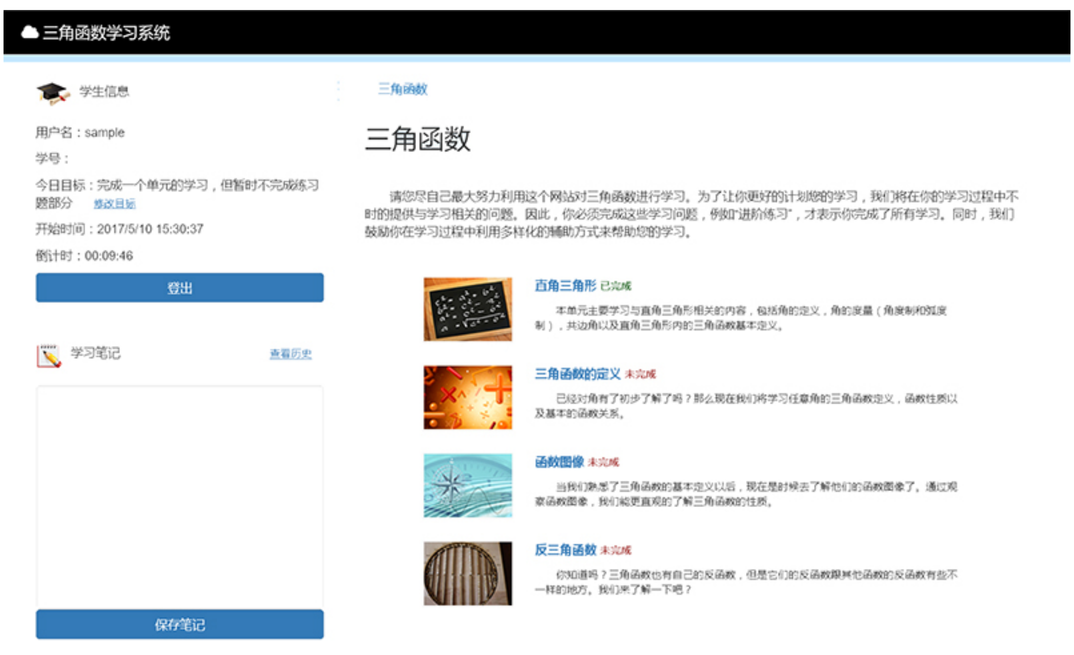

Figure 3.2: Modules of Learning

The right triangle module introduces the definition of angles, the measure of angles, and trigonometry ratio within right triangles. The definition module provided the basic definitions and properties of trigonometry functions over the real number domain; relationships between those trigonometry functions were also taught in this module. The graph module introduced the graphs of each trigonometry function and its related properties. The last module, inverse functions, focused on the definitions of inverse functions of the basic trigonometry functions such as $f(\theta) = \sin\theta, f(\theta) = \cos\theta, f(\theta) = \tan\theta, f(\theta) = \cot\theta, f(\theta) = \sec\theta$ and $f(\theta) = \csc\theta$. Each module is independent and students can choose any module to start with based on their prior knowledge about trigonometric functions. Students are required to complete all modules as completion of the study. The material for instruction was based on the textbook for Math 104: Pre-calculus in the University of Kansas and was translated into Chinese, following the standard Chinese high school math textbook.

The SRL design follows Mevarech and Karamarski's (1997) method. Mevarech and Karamarski introduced a meta-cognitive guidance method for mathematical problem-solving education which is called IMPROVE. This method focuses on guiding students through a series of self-questioning about (a) comprehending the problem (e.g., "What is the problem all about?"); (b) constructing connections between previous and new knowledge (e.g., "What are the similarities/differences between the problem at hand and problems you have solved in the past and why?"); (c) use of appropriate strategies to solve the problem (e.g., "What are the strategies/tactics/principles appropriate to solving the problem and why?"); (d) reflecting on the processes and the solution (e.g., "What did I do wrong here?"). Embedding self-metacognitive questioning in the e-learning environment has been proven to be effective in enhancing students' self-regulated learning abilities in aspects of self-monitoring and strategy use (Kramarski & Mizrachi, 2006, 2007). In this study, meta-cognitive questioning was provided to the students in the form of prompting questions and embedded interventions to promote students' self-regulated process application and use of self-regulated strategies. IMPROVE has been proven to be effective in math education, especially problem solving (Kramarski & Mizrachi, 2007). In this study, this method was extended to domain knowledge instruction. Thus, there were two types of prompting questions: knowledge-based questions and process-based questions. Knowledge-based questions try to encourage students to use self-regulated strategies such as inferences, prior knowledge activation, and knowledge elaboration during learning. For example, each trigonometry function has its own properties, such as domain, range, graph and period. Learning trigonometry functions just by memorizing each function independently will be hard for many students. The IMPROVE method can guide students to find the relationship between trigonometry functions by using prompting questions, such as "Can you try to compare the graph of $f(\theta) = \sin\theta$ and $f(\theta) = \cos\theta$ to find similarities and differences between these two functions?" and "How can $f(\theta) = \sin\theta$ be transformed into $f(\theta) = \cos\theta$?". The relationship between trigonometry functions can help students to gain more sophisticated conceptual understanding of the material. These kinds of prompting questions were embedded in the learning material. Students could read and interact with these questions while learning (see Figure 3.3). Process-based questions dealt with students' use of self-regulated processes, such as goal setting, planning, monitoring, and evaluation. For example, at the beginning of each learning session, the system asks: “What is your study plan today? And how long do you plan to study this time?” The system recorded students’ input and posted it on the screen in order to remind students of their goals. A time countdown according to the students’ scheduled plans was shown on the screen as a reminder of students to help them manage their learning time more efficiently. During the learning activities, questions such as “How long have you studied this time?” ”How far are you from the goal?” and “Do you think the learning strategies used are effective for your learning goals?” were asked as pop-out questions based on the time elapsed during learning. By the end of the learning session, questions such as “Have you completed your study and reach your goal today?” and “What do you think have you done well for this study and what do you need to improve next time?” (see Figure 3.4) were asked to students to help them self-evaluate and generate feedbacks for their study. Besides the IMPROVE method, other methods of improving students’ use of self-regulated strategies were also adopted in the instructional system (Azevedo et al., 2005, 2009; Winne et al., 2006). For example, students were encouraged to take notes while learning. A dialogue box for notes was shown to the students on the side of the screen (see Figure 3.5). Students could take notes whenever they find it is necessary. And the notes could be saved and reviewed by students each time they logged into the system.

The design for promoting student motivation combined multimedia technology, web communication technology, and relevant material required by Math 104. The design followed the ARCS model proposed by Keller & Suzuki (2004), which suggests a protocal for gaining a learner’s attention, establishing the relevance of the instruction to a learner’s goals and learning styles, building confidence with regard

Figure 3.3: IMPROVE Question in a Learning Section

Figure 3.4: Goal Setting and Time-Planning before Learning

Figure 3.5: Note-Taking Box in the System

to realistic expectations and personal responsibility for outcomes, and making the instruction satisfying by managing learner's intrinsic and extrinsic outcomes. To gain a learner's attention, various formats of instruction material were provided in the instructional system by multimedia technology. Digital pictures, animations, and videos were presented to the students to aid their knowledge acquisition. To take advantage of the hypermedia learning environment, hyperlinks to other information resources were also provided in the learning material to broaden student's knowledge about trigonometry and trigonometry functions. As to the content aspect, general learning goals were provided to the students and instruction materials were designed closely relating to the learning goals. To build confidence in students, learning materials in the instructional system were arranged from basic knowledge, such as the basic properties of $f(\theta) = \sin\theta$, to more difficult ones, such as finding properties of compound function $f(\theta) = \sin(\frac{1+\theta}{2})$ step by step. Supplemental

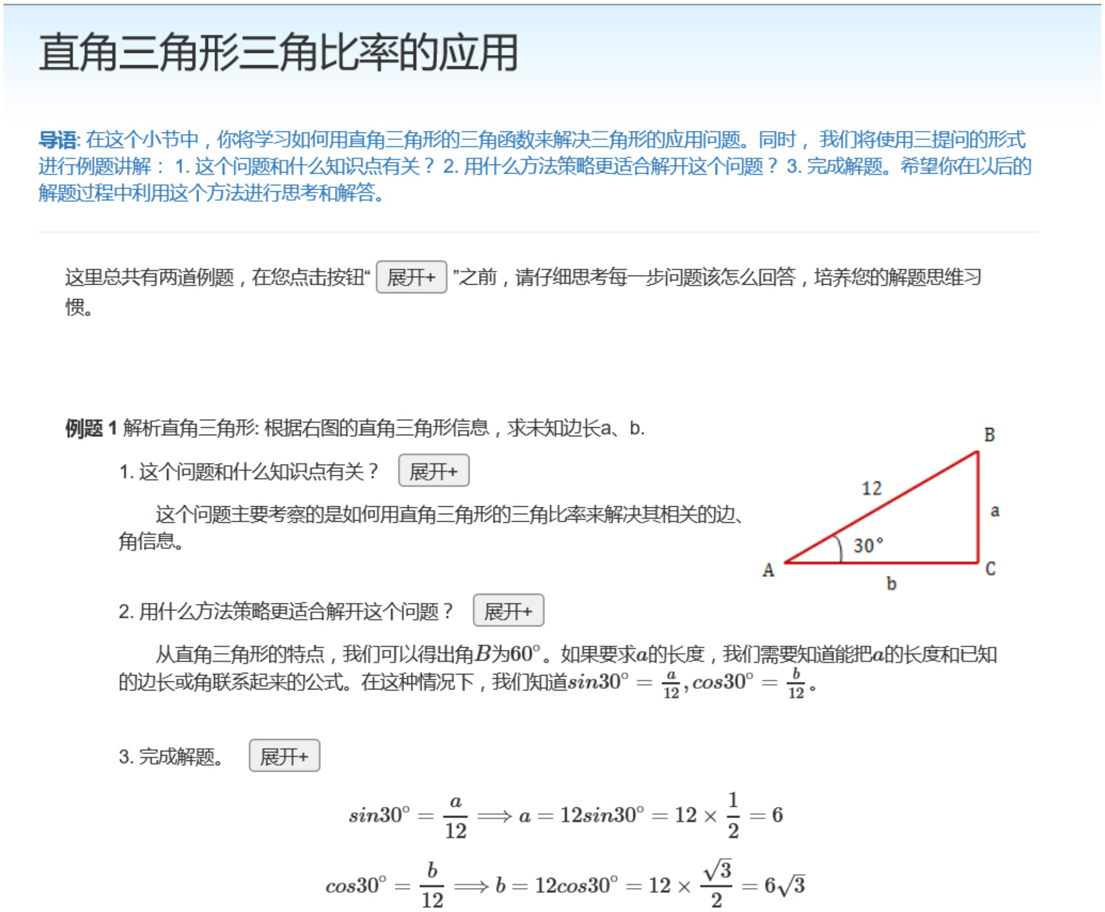

Figure 3.6: Guiding Questions in Problem Solving Examples

materials, such as the definition of the domain and range of a function, were provided to students who had knowledge gaps. When dealing with problem solving examples, prompting questions similar to IMPROVE, such as “What is the question about?” or “What do you think is the first step to solve this question?” (see Figure 3.6), were shown to the students in order to guide them from understanding the math problems to solving the final answers. By the end of learning in each module, students need to finish the practice problems to evaluate their learning. The practice problems are categorized by easy, medium, and hard, based on the required manipulation level of the course material (see Figure 3.7).

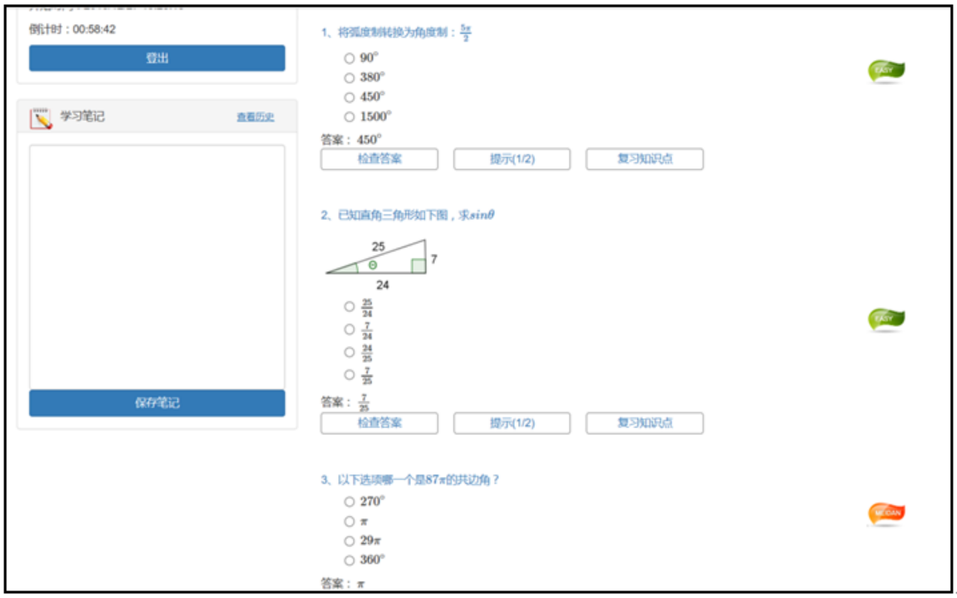

Figure 3.7: User Interface of the Practice Problem Page

Corrective feedbacks were provided to the students each time they checked their answers. Students who had difficulties in solving the practice problems could use the “hints” feature to get assistance in problem solving. Also, links to the knowledge related to the problems were provided in case students wanted to review the material. All practice problems were multiple choice questions. The study for each module was completed after students finished the practice problems for that module. And then, the system marked the module as completed for the student’s record. Attributional feedbacks, such as “I am sorry, the answer is not correct, please try to calculate it again!” if the student made a mistake or “you have done well with this section, try to solve more difficult ones for a challenge!” if the student solved the question correctly, were embedded in the system.

To avoid the feeling of isolation during online learning, human assistance by a certified Chinese high school math teacher and online discussion were also provided as a kind of virtual help room to create a sense of community for students.

The communication was conducted through Wechat, which is a free public chatting tool, to increase students' sense of community. With the fast development of Mobile Internet technology, online communication software has become popular among Internet users. MSN, ICQ, and Yahoo Messengers have developed a huge user population. Wechat is one of the new mobile internet communication tools which provide better interaction, entertainment and convenience for users by advanced mobile Internet technology (Zhu et al., 2014). Wechat supports individual communication and group discussion, and it can be installed either on smart phones or computers. Students will get an alert message if someone publishes a new message to specific students or to the group. The educational advantage of such communication tools has been noticed by many educational researchers as they not only provide similar experience to face-to-face communication in the real world, but also help students learn the convenience of virtual communication online (Zhu et al., 2014). However, the research on the effectiveness of using mobile communication tools in educational settings is still limited. The purpose of using a real time communication tool for this study was to decrease the waiting time for students to get answers from the instructor or their peer-students. When solving math problems online, students tend to panic when faced with difficulties and give up quickly (Smith & Ferguson, 2005), so real time communication tools can improve the response rate between the instructor and students, and, thus, improve students' motivation to learn. Also, Wechat supports sharing pictures, audio, and video, which to some extent can make up the disadvantage of math symbol, notation, and diagram input difficulties in current instructional systems by exchanging math information with pictures, voice messages, or videos. Group discussion will be stored in Wechat, so students can review the discussed topic whenever they need to.

The diagram below describes the complete learning process for the students (see Figure 3.8). Students first logged into the system by user name and password; then they were guided to the study-plan page to set up their learning goal and learning time; then they could start their learning by choosing any module that they wanted to learn, and the system started to monitor the learning time. Each module consisted of several sections, and there were one or two IMPROVE questions at the end of each section. After all IMPROVE questions were completed in each module, the practice problem section would be shown, and students could evaluate their learning by completing those problems. During the learning, the system gave alerts to students about how much time had elapsed and reminded them to monitor their own learning (see Figure 3.9). Students could edit their learning goals and time at any moment during their learning progress. On the other hand, students could take notes any time they thought it was necessary and reviewed the note history to help them learn new concepts. Students could use hyperlinks embedded in the material to read extra curriculum material that might support the learning content in the system; they could also use various search engines to find useful information during learning. By the end of the learning process, students might choose to log out the system, but before that, they were led to the summarization page to self-summarize their learning by comparing the learning outcome and learning goals, amd evaluate their time management and learning strategy use (see Figure 3.10). Then students can successfully log out of the instructional system.

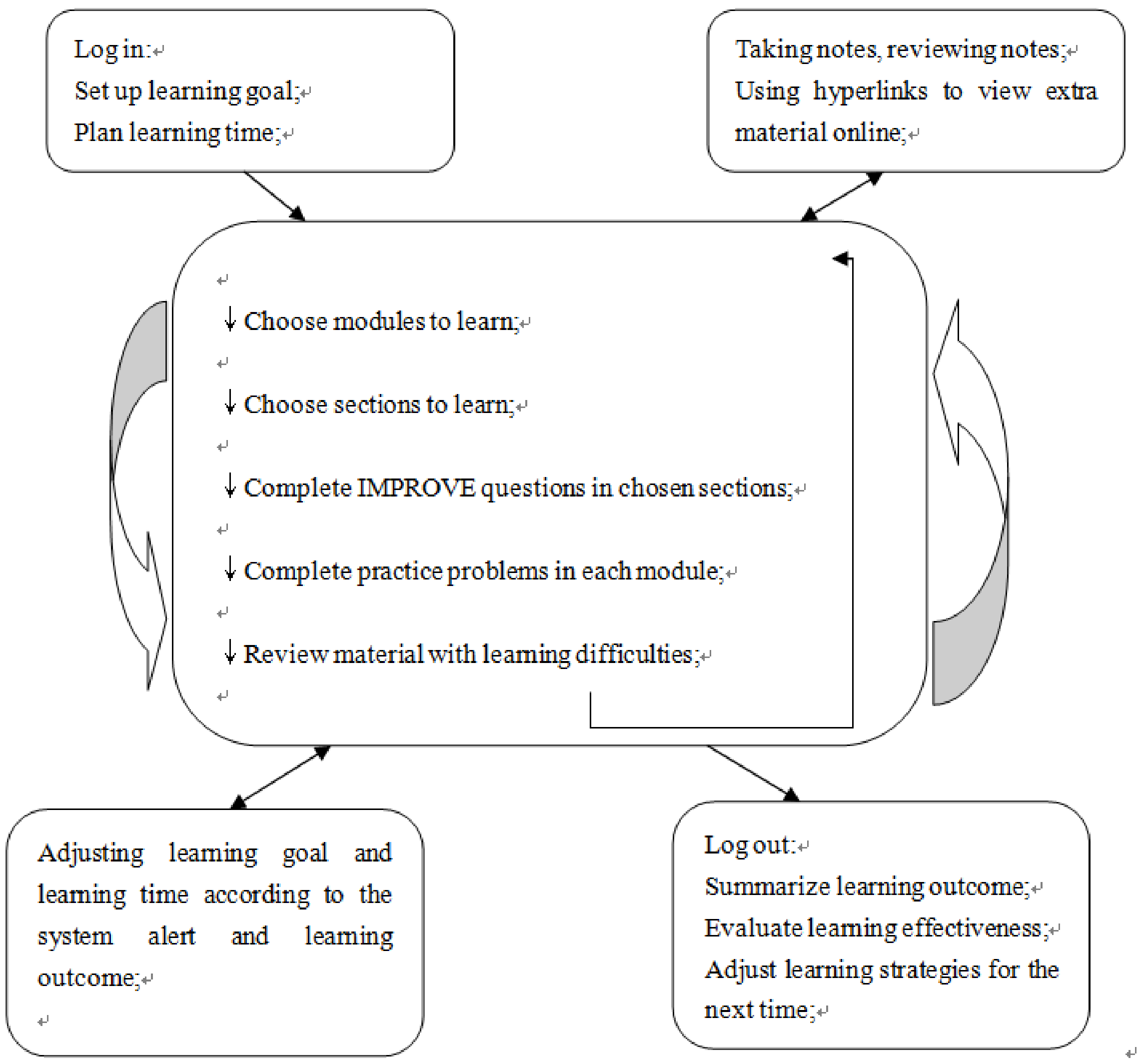

Figure 3.8: Learning Process of the Instructional System

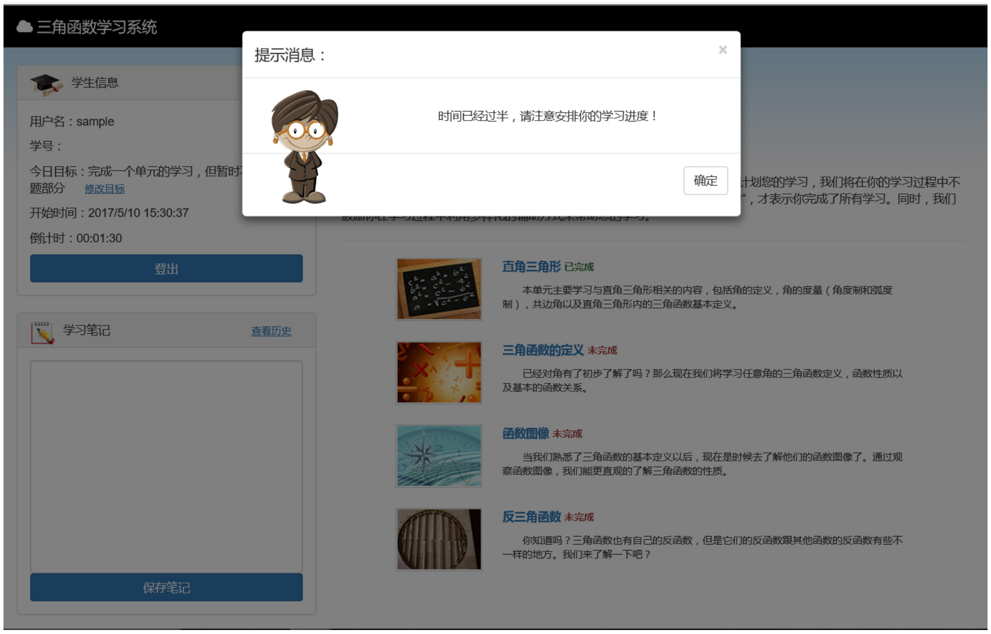

Figure 3.9: Time Alert in the System

Figure 3.10: Summarization Page before Log-out

3.3 Instruments

Questionnaires and pre- and post-tests were used to evaluate the effectiveness of the instructional system. Questionnaires and pre- and post-tests were all paper-based for better monitoring. The purpose of this study was to find out the relationship between the motivation, SRL strategy use, and academic performance for SRL learners. The instruments used are as follows:

Personal Data Questionnaire

All participants were required to fill out the personal data questionnaire. Questions pertained to the students' genders and ages.

The Motivational Strategies for Learning Questionnaire (MSLQ)

The MSLQ learning strategy scales (Pintrich et al., 1993) were used to determine if students differ in their motivation and self-regulation across the learning process and across the four groups. The original MSLQ contains 31 items about the motivation and 50 items about learning strategy use. The motivation items assess students' learning goals and value beliefs for a course, including self-efficacy and text anxiety in a course. The learning strategy items assess students' use of different cognitive and meta-cognitive strategies and management of different resources such as time and human assistance. All questions were answered by using a 7-point Likert scale from "very true of me" to "not at all true of me".

The MSLQ has been widely used in the literature, and research studies have shown that it is reliable and valid in assessing college student learning strategies and motivational orientations (Dabbagh & Kitsantas, 2005). Internal reliability coefficients for the MSLQ range from 0.52 to 0.80, and coefficient alphas are mostly above 0.70 (Pintrich et al., 1993). Survey questions were adapted to the online instructional system based on the original items. The survey questions were translated into Chinese and then were translated back into English by a student peer to ensure the validity of the instruments. The final version of the MSLQ questionnaire contained 21 items for learning motivation and 39 items for learning strategies (see Appendix D).

Pre- and Post-test (Trigonometry Functions)

In order to find out the effectiveness of the instructional system, pre-test and post-test of trigonometry functions were given to the participants before and after the learning sessions. The pre-test and post-test were designed based on the same instructional material and were evaluated by mathematics teachers to have the same levels of difficulty and reliability for testing students' knowledge about the learning content. Questions in the pre-test and post-test were different but with the same difficulty levels. Each test contained 20 questions covering most concepts taught in the system. The questions were designed similar to the practice problems in each module. The difficulty level differed from basic mathematical concept and definitions to comprehensive ones that required students to manipulate learned knowledge in different cases.

3.4 Data Analysis Method (ANOVA)

Three sets of two-way ANOVA were performed to investigate whether different treatment groups (MD, SI, and MDSI) had an impact on students' motivation, use of self-regulated learning strategies, and knowledge acquisition (trigonometry), controlling for gender differences.

The pre- and post-test scores of MSLQ for motivation and use of self-regulated learning strategies were collected and coded to evaluate the motivation of students and their use of self-regulated strategies. The pre- and post-test scores on trigonometry functions were also collected for academic performance evaluation. To answer the research questions, two-way ANOVA was conducted to examine the effect of gender and group membership (1) on the difference between pre- and post-test scores of MSLQ for motivation, (2) on the difference between pre- and post-test scores of MSLQ for use of self-regulated learning strategies, and (3) on the difference between pre- and post-test scores of trigonometry functions.

3.4.1 Effect of the Motivational Design

Research Question 1: Can motivational design promote motivation for SRL learners in mathematics?

Students' gender and group memberships were used as independent variables, and the difference between the pre- and post-test scores of MSLQ for motivation was the dependent variable for the two-way ANOVA test. Corresponding F statistic and p values were analyzed to determine the effect contributed by the treatment. Interaction between gender and group membership was considered for the data analysis. Post-hoc test was conducted to find out whether the treatment had a positive effect on the difference of students' motivation, controlling for the gender difference.

Test for H1: $(IV : GroupID, Gender; \quad DV : M_{MD} = postM_{MD} - preM_{MD})$

3.4.2 Effect of the SRL Intervention

Research Question 2: Can embedded SRL interventions promote the use of self-regulated learning strategies in online mathematics learning?

The two-way ANOVA was performed with gender and group membership as independent variables, and the difference between the pre- and post-test scores of MSLQ for self-regulated learning strategies as the dependent variable. The F statistic and p values were analyzed to determine the effect contributed by the treatment. Interaction between the gender and group membership was also considered in the data analysis. Post-hoc test was conducted to find out whether the treatment had positive effects on the difference of students' use of self-regulated learning strategies, controlling for the gender difference.

Test for H2: $(IV : GroupID, Gender; \quad DV : M_{SI} = postM_{SI} - preM_{SI})$

3.4.3 Effect on Academic Outcome

Research Question 3: Can the use of motivational design and self-regulated learning intervention implemented in a computer-based learning environment foster knowledge acquisition

A two-way ANOVA was performed with gender and group membership as independent variables and the difference between the pre- and post-test scores on trigonometry functions as the dependent variable. The F statistic and p values were analyzed to determine the effect contributed by the treatment. Interaction between the gender and group membership was also considered in the data analysis. Post-hoc test was conducted to find out whether the treatment had positive effects on the difference of students' academic performance, controlling for the gender difference.

Test for H3: $(IV : GroupID, Gender; \quad DV : M_{trig.} = postM_{trig.} - preM_{trig.})$

Chapter 4

Results

4.1 Demographic Data Summary

Students participating in this study were randomly selected from Hechuan High School and Yucai Vocational School. Two hundred and thirty-six students were registered for the study and data from 183 were finally collected. Students withdrew from the study for various reasons: absence from pre- or post-tests; unavailable computer or Internet access; personal reasons for withdrawal; and incomplete questionnaires because of filling mistakes. The following tables show the total number of participants (see Table 4.1), and their average age is 16.20 (see Table 4.2), ranging from 15 to 18 years old.

There were 89 male and 94 female students in the sample. The table below (see Table 4.3) shows the gender information for each study group:

Table 4.1: Sample Age Information

	Gender		
Age	Male	Female	Total
15	8	8	16
16	55	61	116
17	25	24	49
18	1	1	2
Total	89	94	183

Table 4.2: Sample Age Statistics

Age			Statistic	Std. error
	Mean		16.20	.04
	95 % Confidence	Lower Bound	16.11	
	Interval for Mean	Upper Bound	16.29	
	Median		16.00	
	Variance		.36	
	Std. Deviation		.60	
	Minimum		15.00	
	Maximum		18.00	

Table 4.3: Gender Distribution in All Groups

	GroupID				
Gender	CT	MD	SI	MDSI	Total
male	19	26	23	21	89
female	19	21	23	31	94
Total	38	47	46	52	183

Table 4.4: Attrition Rate in the Study

GroupID	Number enrolled	Number completed	Attrition rate(%)
CT	59	38	35
MD	59	47	20
SI	59	46	22
MDSI	59	52	12

A total of 236 students were divided into 4 groups randomly, and the attrition rates are shown above (see Table 4.4). As shown in Table 4.4, the control group had the highest attrition rate -35% - compared with the MDSI group, which had the lowest - 12%; the MD and SI groups had similar attrition rates in the middle - 20% and 22%.

4.2 Data Analysis by Research Question

4.2.1 Effect of the Motivational Design

Research Question 1: Can motivational design promote motivation for SRL learners in Mathematics?

A two-way ANOVA was conducted that examined the effect of gender and dif-

Table 4.5: T-test for the Pre-Scores of MLSQ (Motivation) Between Two Schools

	School								
	Vocational High			Hechuan High					
	M	SD	n	M	SD	n	t	*p*	*df*
Pre-score of motivation	105.80	21.10	80	108.24	19.16	103	-.82	.41	181

Note: Equal variance is assumed.

ferent instructional design models on students' learning motivation. Pre- and post-tests of MSLQ relating to motivation were coded according to the 7-point Likert scale. Students' answers were coded from 1 to 7 if the survey question was positive to students learning motivation; otherwise, the answers were coded from 7 to 1. The difference between the total scores of pre- and post-tests of MSLQ (motivation) was calculated and was used as the dependent variable for the two-way ANOVA. In order to test the school effect on the result, t-test was conducted within two schools to compare the pre-scores of MLSQ (motivation). Results showed that there was no statistically significant difference between the pre-score of MLSQ (motivation) of the two schools ($t = -.82$, $df = 181$, $p = .41$) at the 0.05 level of significance (see Table 4.5).

Normality of dependent variables and homogeneity of variance were tested to meet the assumptions of the two-way ANOVA test (see Table 4.6). There was no statistically significant difference of variances between groups ($groupID * Gender$) ($F(7,175) = 1.08$, $p = .38$). Outliers were identified and replaced by the scores which satisfied the normality requirement and were closest to the outliers ($N = 9$).

Description of the data (see Table 4.7) showed that every treatment group had

Table 4.6: Levene's Test of Homogeneity for Difference of MLSQ (Motivation)

	F	df1	df2	*p*
Difference of motivation	1.08	7	175	.38

the mean of the difference of motivation scores different from those of the control group ($M_{CT} = .26, M_{MD} = 14.87, M_{SI} = 3.30$ and $M_{MDSI} = 16.56$).

According to the ANOVA test (Table 4.8), there was no statistically significant interaction between the effects of gender and instructional design models on students' motivation, $F(3,175) = 1.70$, $p = .17$, but there were statistically significant differences between treatment groups and the control group, $F(3,175) = 16.11$, $p < .001$.

According to the *p*-values and mean differences of the post-hoc test (see Table 4.9), sample groups: the motivational design group (MD), $M = 14.87$, and motivational design and SRL intervention group (MDSI), $M = 16.56$, with motivational design, showed significant improvement in motivation during the online learning compared with the control group, $M = .26$ ($M_{CT-MD} = -14.61, p < .001; M_{CT-MDSI} = -16.29, p < .001$). The group with SRL design only (SI), $M = 3.30$, showed some promotion in learning motivation but had no statistically significant results ($M_{CT-SI} = -3.04$, $p = .75$).

4.2.2 Effect of the SRL Intervention

Research Question 2: Can embedded SRL interventions promote the use of self-regulated learning strategies in online mathematics learning?

Table 4.7: Descriptive Information of the Mean of Motivation Difference Based on Group and Gender

Variable	Mean	Std. deviation	N
CT			
male	-4.63	12.23	19
female	5.16	14.45	19
Total	.26	14.11	38
MD			
male	13.92	16.69	26
female	16.05	14.23	21
Total	14.87	15.51	47
SI			
male	2.65	11.56	23
female	3.96	11.17	23
Total	3.30	11.26	46
MDSI			
male	18.67	16.91	21
female	15.13	11.90	31
Total	16.56	14.09	52

Note: CT=control group;
MD=treatment group with motivational design;
SI=treatment group with SRL intervention;
MDSI=treatment group with both motivational design and SRL intervention.

Table 4.8: Two-way ANOVA Test between the Differences of Motivation and Differences of Group & Gender With Interaction

Source	Sum of squares	df	Mean square	F	*p*
groupID	9146.06	3	3048.69	16.11	.00
gender	261.65	1	261.65	1.38	.24
groupID*gender	966.00	3	322.00	1.70	.17
Error	33116.07	175	189.23		

Note: $R^2 = .23$, Adjusted $R^2 = .20$

Table 4.9: Post-Hoc Test to Evaluate the Effect of the Motivational Design

Comparison	*Mean dif·*	Std. error	*p*	95% Confidence interval	
				Lower bound	Upper bound
CT vs MD	$-14{\cdot}61*$	3.00	.00	-22.39	-6.82
CT vs SI	$-3{\cdot}04$	3.02	.75	-10.86	4.78
CT vs MDSI	$-16{\cdot}29*$	2.94	.00	-23.91	-8.68
MD vs SI	$11{\cdot}57*$	2.85	.00	4.17	18.97
MD vs MDSI	$-1{\cdot}69$	2.77	.93	-8.87	5.50
SI vs MDSI	$-13{\cdot}25*$	2.78	.00	-20.48	-6.03

Note: Based on observed means.

The error term is Mean Square (Error) = 189.24

*. The mean difference is significant at the .05 level.

Table 4.10: T-test for the Pre-Scores of MLSQ (SRL) Between the Two Schools

	School								
	Vocational High			Hechuan High					
	M	SD	n	M	SD	n	t	*p*	*df*
Pre-score of SRL	174.54	41.87	80	179.04	33.88	103	-.78	.44	149.78

Note: Equal variance is not assumed.

A two-way ANOVA was conducted to examine the effect of gender and different instructional design models on students' SRL strategy use. Similar to the previous research question coding method, pre- and post-tests of MSLQ relating to SRL strategy were coded according to the 7-point Likert scale. Students' answers were coded from 1 to 7 if the survey question showed a positive correlation to SRL strategy use; otherwise, the answers were coded from 7 to 1. The differences between the total scores of pre- and post-tests of MSLQ (SRL) were calculated and were used as the dependent variable for the two-way ANOVA. In order to test the school effect on the result, t-test was conducted within the two schools to compare the pre-scores of MLSQ (SRL). Results showed that there was no statistically significant difference of the pre-scores of MLSQ (SRL) between the two schools ($t = -.78$, $df = 149.78$, $p = .44$) at the 0.05 level of significance (see Table 4.10).

Normality of dependent variables and homogeneity of variance were tested to meet the assumptions of the two-way ANOVA test (see Table 4.11). There was no statistically significant difference of variances between groups ($groupID * Gender$) ($F(7,175) = 1.20$, $p = .31$). Outliers were identified and replaced by the scores which satisfied the normality requirement and were closest to the outliers ($N = 7$).

Table 4.11: Levene's Test of Homogeneity for Difference of MLSQ (SRL)

	F	df1	df2	p
Difference of SRL skills	1.20	7	175	.31

The data (see Table 4.12) showed that every treatment group had the mean of the differences of SRL scores different from that of the control group ($M_{CT} = .24$, $M_{MD} = 6.64$, $M_{SI} = 22.11$ and $M_{MDSI} = 24.87$).

According to the ANOVA test (see Table 4.13), there was no statistically significant interaction between the effects of gender and instructional design models on students' SRL strategy use, $F(3,175) = 1.55$, $p = .20$. There were statistically significant differences between the treatment group and the control group in aspects of SRL skills, $F(3,175) = 11.63$, $p < .001$.

According to the p-values and mean differences of the post-hoc test (see Table 4.14), sample groups: the SRL intervention group (SI), $M = 22.11$,and motivational design and SRL intervention group (MDSI), $M = 24.87$, with motivational design, showed significant improvement in use of SRL strategies during the online learning process compared with the control group, $M = .24$ ($M_{CT-SI} = -21.87$, $p < .001$; $M_{CT-MDSI} = -24.63$, $p < .001$). The group with motivational design only (MD), $M = 6.64$, showed some improvement in SRL strategy use but had no statistically significant results ($M_{CT-MD} = -6.40$, $p = .60$).

Table 4.12: Descriptive Information of the Mean of SRL Difference Based on Group and Gender

Variable	Mean	Std. deviation	N
CT			
male	-5.68	22.87	19
female	6.16	24.83	19
Total	.24	24.29	38
MD			
male	6.15	28.59	26
female	7.24	24.06	21
Total	6.64	26.39	47
SI			
male	25.87	23.81	23
female	18.35	22.24	23
Total	22.11	23.10	46
MDSI			
male	29.10	22.83	21
female	22.00	18.85	31
Total	24.87	20.63	52

Note: CT=control group;

MD=treatment group with motivational design;

SI=treatment group with SRL intervention;

MDSI=treatment group with both motivational design and SRL intervention.

Table 4.13: Two-way ANOVA Test Between the Differences of SRL and Differences of Group & Gender With Interaction

Source	Sum of squares	df	Mean square	F	*p*
groupID	19335.59	3	6445.20	11.63	.00
gender	7.98	1	7.98	.01	.91
groupID*gender	2570.87	3	856.96	1.55	.20
Error	96953.46	175	189.23		

Note: $R^2 = .18$, Adjusted $R^2 = .15$

Table 4.14: Post-Hoc Test to Evaluate the Effect of the SRL Intervention

				95% Confidence interval	
Comparison	$Mean\ dif\cdot$	Std. error	p	Lower bound	Upper bound
CT vs MD	$-6{\cdot}40$	5.14	.60	-19.72	6.92
CT vs SI	$-21{\cdot}87{*}$	5.16	.00	-35.26	-8.49
CT vs MDSI	$-24{\cdot}63{*}$	5.02	.00	-37.66	-11.60
MD vs SI	$-15{\cdot}47{*}$	4.88	.01	-28.13	-2.81
MD vs MDSI	$-18{\cdot}23{*}$	4.74	.00	-30.52	-5.94
SI vs MDSI	$-2{\cdot}76$	4.76	.9	-15.11	9.60

Note: Based on observed means.

The error term is Mean Square(Error) = 554.02

*. The mean difference is significant at the .05 level.

Table 4.15: T-test for the Pre-test Scores (Academic) Between Two Schools

	School								
	Vocational High			Hechuan High					
	M	SD	n	M	SD	n	t	*p*	*df*
Pre-test (academic)	6.76	3.51	80	6.01	2.72	103	1.63	.10	181

Note: Equal variance is assumed.

4.2.3 Effect on the Academic Achievement

Research Question 3: Can the use of motivational design and self-regulated learning intervention implemented in a computer-based learning environment foster knowledge acquisition?

A two-way ANOVA was conducted to examine the effect of gender and different instructional design models on students' knowledge acquisition. The differences between the total scores of pre- and post-tests of trigonometry were calculated and were used as the dependent variable for the two-way ANOVA. In order to test the school effect on the results, a t-test was conducted within the two schools to compare the scores of pre-tests (academic). Results showed that there was no statistically significant difference of the pre-test scores between the two schools ($t = 1.63$, $df = 181$, $p = .10$) at the 0.05 level of significance (see Table 4.15).

Normality of dependent variables and homogeneity of variance were tested to meet the assumptions of the two-way ANOVA test (see Table 4.16). There was no statistically significant difference of variances between groups ($groupID * Gender$) ($F(7, 175) = 1.05$, $p = .40$). Outliers were identified and replaced by the scores

Table 4.16: Levene's Test of Homogeneity for Difference of Academic Tests

	F	df1	df2	*p*
Difference of acad. tests	1.05	7	175	.40

which satisfied the normality requirement and were closest to the outliers ($N = 1$).

The data (see Table 4.17) showed that every treatment group had the mean of the differences of academic scores different from that of control group ($M_{CT} = 6.53$, $M_{MD} = 10.96$, $M_{SI} = 8.50$ and $M_{MDSI} = 13.13$).

According to the ANOVA test (see Table 4.18), there was no statistically significant interaction between the effects of gender and instructional design models on students' motivation, $F(3,175) = 2.02$, $p = .11$, but there were statistically significant differences between the treatment groups and the control group, $F(3,175) = 46.49$, $p < .001$ (see Table 4.18).

According to the p-values and mean differences of the post-hoc test (see Table 4.19), experimental groups: MD, M=10.96; SI, M=8.50; MDSI, M= 13.13(see Table 4.17), showed significant improvements in knowledge acquisition during the online learning process compared with the control group, $M = 6.53$ ($M_{CT-MD} = -4.43$, $p < .001$; $M_{CT-SI} = -1.97$, $p = .01$; $M_{CT-MDSI} = -6.61$, $p < .001$). However, the MD group showed statistically significant improvements in academic gain over the SI group ($M_{MD-SI} = 2.46$, $p < .001$), while the MDSI group with both motivational design and SRL intervention had the best academic gain ($M_{MD-MDSI} = -2.18$, $p < .001$; $M_{SI-MDSI} = -4.63$, $p < .001$). The post-hoc test showed that

Table 4.17: Descriptive Information of the Mean of Academic Tests Difference (Pre-score and Post-score) Based on Group and Gender

Variable	Mean	Std. deviation	N
CT			
male	5.89	3.00	19
female	7.16	2.63	19
Total	6.53	2.85	38
MD			
male	9.92	3.01	26
female	12.24	2.43	21
Total	10.96	2.97	47
SI			
male	8.04	3.15	23
female	8.96	3.27	23
Total	8.50	3.21	46
MDSI			
male	13.43	2.82	21
female	12.93	2.35	31
Total	13.13	2.54	52

Note: CT=control group;

MD=treatment group with motivational design;

SI=treatment group with SRL intervention;

MDSI=treatment group with both motivational design and SRL intervention.

Table 4.18: Two-way ANOVA Test between the Difference of Academic tests and Group & Gender With Interaction

Source	Sum of squares	df	Mean square	F	p
groupID	1122.92	3	374.31	46.49	.00
gender	44.63 1	44.63	5.54	.02	
groupID*gender	48.66	3	16.22	2.02	.11
Error	1408.90	175	8.05		

Note: $R^2 = .46$, Adjusted $R^2 = .44$

Table 4.19: Post-Hoc Test to Evaluate the Effect on Academic Achievement

				95% Confidence interval	
Comparison	$Mean\ dif\cdot$	Std. error	p	Lower bound	Upper bound
CT vs MD	$-4\cdot43*$	.62	.00	-6.04	-2.83
CT vs SI	$-1\cdot97*$	.62	.01	-3.59	-.36
CT vs MDSI	$-6\cdot61*$	.61	.00	-8.18	-5.04
MD vs SI	$2\cdot46*$	.59	.00	.93	3.98
MD vs MDSI	$-2\cdot18*$	.57	.00	-3.66	-.70
SI vs MDSI	$-4\cdot63*$	.57	.00	-6.12	-3.14

Note: Based on observed means.

The error term is Mean Square(Error) = 8.05

*. The mean difference is significant at the .05 level.

using the motivational design and SRL intervention together would have a statistically significant positive effect on students' academic achievement compared with the other three groups.

Chapter 5

Discussion

5.1 Findings by Research Question

Research Question 1: Can motivational design promote motivation for SRL learners in mathematics?

H1: students participating in the online course with the ARCS design model show enhanced learning motivation in terms of self-efficacy, learning interest, and task value expectation compared with students not using the ARCS designed online course.

Previous research has shown that the ARCS motivational design is effective in promoting students' learning motivation (Keller & Suzuki, 2004). This study adopted the ARCS model in designing the instructional aspects of content arrangement, task difficulty level identification, and multimedia technology application. As students' motivation is affected by various factors, this study aimed to promote students' learning motivation in terms of self-efficacy, feeling of community, and learning interest (intrinsic interest and extrinsic interest).

ANOVA test results have shown that students in all treatment groups had statistical improvement in learning motivation compared with the control group. Students in both MD and MDSI treatment groups showed statistically significant improvement in learning motivation. However, students in treatment groups showed improvement in different motivational factors compared with the control group. The table below is a conclusion of the motivational improvement in different treatment groups. By comparing the difference of the mean scores of each item in MSLQ (motivation) between each treatment group and the control group, top 5 items with highest score-difference in each treatment group are listed below (see Table 5.1):

Table 5.1: Improvement of Learning Motivation in Treatment Groups

Treatment group	Motivational improvement	Difference to CT
MD	1. Understanding the subject matter of this course is very important to me.	0.068
	2. When I have the opportunity in this class, I choose course assignments that I can learn from even if they don't guarantee a good grade.	0.059
	3. The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.	0.046
	4. Understanding the subject matter of this course is very important to me.	0.042
	5. If I study in appropriate ways, then I will be able to learn the material in this course.	0.036

Table 5.1 Continued

Treatment group	Motivational improvement	Difference to CT
SI	1. I'm certain I can master the skills being taught in this class.	0.064
	2. If I try hard enough, then I will understand the course material.	0.052
	3. Considering the difficulty of this course and my skills, I think I will do well in this class.	0.051
	4. When I have the opportunity in this class, I choose course assignments that I can learn from even if they don't guarantee a good grade.	0.031
	5. I'm certain I can understand the most difficulty material presented in the readings for this course.	0.028
MDSI	1. If I don't understand the course material, it is because I didn't try hard enough.	0.083
	2. The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.	0.076
	3. I think the course material in this class is useful for me to learn.	0.064

Table 5.1 Continued

Treatment group	Motivational improvement	Difference to CT
	4. Considering the difficulty of this course and my skills, I think I will do well in this class. (self-efficacy)	0.054
	5. If I study in appropriate ways, then I will be able to learn the material in this course.	0.041

Students in all treatment groups showed significant improvement in self-efficacy compared with the control group. Several factors can be considered as reasons for the improvement of self-efficacy for students in this study according to the related instructional design. First of all, the information relating to real-life application of trigonometry functions helped students connect the learning material with their real lives. Except for preparing for exams, students had a better understanding of how the trigonometry functions can be used in real life, especially in their future career lives. Thus, they better perceived the importance of learning trigonometry functions. Secondly, the design of the learning materials considered the knowledge gaps that might inhibit students from learning more difficult concepts. Extra information was provided through hyperlinks for students if they have difficulty understanding current mathematical concepts. Previous research has shown that it is easier for students to learn new concepts if they make connections between what they have already learned and the new concepts (Mayer, 2005). Students could use the hyperlinks to review the concepts that might be familiar to them and were important for learning of new concepts. Thirdly, the practice problem settings were designed to build self-confidence in students during the learning progress. The practice problems were arranged by their difficulty level from easy through medium to hard ones. The easy ones tested students' basic understanding of mathematical concepts; medium ones tested their skills at applying the theories and concepts to mathematical problems; while the hard ones required more complicated manipulation of the theories and concepts. Detailed step-by-step hints and links to related course material were also provided for students to build up their confidence in solving such questions. Lastly, knowledge visualization supported by multimedia technologies provided students with interactive learning experience for online learning. Through the interaction between students and graphs, students found the learning more interesting and meaningful compared to the traditional instructions from teachers in classroom, which was frequently expressed by students in interviews in the first stage of study. The animations were designed to help students obtain visual impressions about the graphs of trigonometry functions and set up comparisons between graphs of different functions, which is difficult to present by traditional teaching methods.

Another interesting finding from the study is that the students in the SI group also showed some improvement in learning motivation. The relationship between the SRL skills and motivation has been discussed in previous research. Data showed that, with SRL intervention, students also showed better self-efficacy as they deemed study skills also to be important for their success in an online course, which is coincident with the research fact that SRL skills and motivation are interdependent, and they are positively related to each other (Zimmerman, 1990).

Overall, the ARCS design model applied in this study resulted in statistically significant positive effects on students' learning motivation in aspects of self-efficacy and learning interest. The research results support the hypothesis that students with the ARCS design model have enhanced motivation compared with students in the control group.

Research Question 2: Can embedded SRL interventions promote the use of self-regulated learning strategy in online mathematics learning?

H2: students participating in the online course with SRL intervention show improved SRL strategies use compared with students without SRL intervention.

The results of this study showed positive effects on students' use of SRL strategies when learning trigonometry functions online compared with the control group. Students in SI and MDSI groups displayed statistically significant improvement in use of SRL strategies, while students in MD group showed some, but not statistically sigfnificant improvement. Interestingly, students in different treatment groups showed improvement in different SRL skills as shown by the research data. The following table lists about the top 5 items in MSLQ (SRL) where students in each treatment group reported improvement in SRL skills compared with those in the control group (see Table 5.2).

Table 5.2: Improvement of SRL Skills in Treatment Groups

Treatment group	SRL skills	Difference to CT
MD	1. Even if I have trouble learning the material in this class, I try to do the work on my own, without help from anyone.	0.059

Table 5.2 Continued

Treatment group	SRL skills	Difference to CT
	2. Even when course materials are dull and uninteresting, I manage to keep working until I finish.	0.049
	3. I make simple charts, diagrams, or tales to help me organize course material.	0.043
	4. When I study for this course, I go over my class notes and make an outline of important concepts.	0.041
	5. I often feel so lazy or bored when I study for this class that I quit before I finish what I planned to do.	0.036
SI	1. Even if I have trouble learning the material in this class, I try to do the work on my own, without help from anyone.	0.063
	2. I treat the course material as a starting point and try to develop my own ideas about it.	0.054
	3. I find it hard to stick to a study schedule.	0.053
	4. When studying for this course, I read my class notes and the course readings over and over again.	0.046

Table 5.2 Continued

Treatment group	SRL skills	Difference to CT
	5. When I study for this course, I go over my class notes and make an outline of important concepts.	0.045
MDSI	1. I find it hard to stick to a study schedule.	0.073
	2. Even when course materials are dull and uninteresting, I manage to keep working until I finish.	0.065
	3. I try to change the way I study in order to fit the course requirements and the teaching style.	0.053
	4. When I study for this class, I set goals for myself in order to direct my activities in each study period.	0.052
	5. When I study for this course, I go over my class notes and make an outline of important concepts.	0.043

The SRL intervention used in this study includes IMPROVE meta-cognitive questions, time management support and note-taking support. According to the research data, even without SRL intervention, students in the MD group still showed some extent of improvement in use of SRL strategies. However, because of the Wechat application used in the motivational design, where students could ask for help from teachers and peer students through the Internet in real time, students in the MD group reported highest improvement in help seeking strategy. Motivated students tend to be more self-regulated (Zimmerman, 1990), thus students in the MD group showed some other improvement in SRL skills, such as goal setting, self-monitoring, inference, etc.

Students in the SI and MDSI groups with SRL intervention all reported improvement of their time management skills. Students in these groups paid more attention to their learning time and tended to monitor time management during online learning. The results evidenced that determining learning time, counting down time used, and prompting time alert were effective in assisting student awareness of their time management. IMPROVE meta-cognitive questions used in the SI and MDSI systems also effectively promoted students' use of SRL strategies, as students in these groups tended more to make inferences based on previous knowledge in order to understand new concepts. They reported they were more active in making comparisons between concepts, note reviewing, knowledge elaboration, prior knowledge activation, and summarization.

Students in the MDSI group reported the highest improvement through use of SRL strategies. And their improvement involved additional SRL strategies. They not only paid attention to their learning time, but they also managed their time better. They also showed higher levels of SRL strategy use with respect to prior knowledge activation, re-reading, information searching, memorization, inferences, and self-monitoring. They were highly motivated and active in their online learning. It is coincident with the research findings that using both motivational design and SRL intervention in instructional design can have a better effect on students' learning experience (Dresel & Haugwitz, 2008).

As a conclusion, the hypothesis that students in the groups with SRL intervention showed better improvement in use of SRL strategies is supported by the data collected in this study. Using motivational design and SRL intervention together in instructional design to help students better self-regulate their learning through the internet is recommended.

Research Question 3: Can the use of motivational design and self-regulated learning intervention implemented in a computer-based learning environment foster knowledge acquisition?

H3: Students participating in the online course with either the ARCS design model, the SRL intervention, or both show better academic achievements by the end of the experiment compared with those without either of the two features. Students studying through the online course with both the ARCS design model and SRL intervention have the highest academic gain compared with other students.

The results of the study showed that both motivational design and SRL intervention had positive effects on students' academic achievement. Compared with the control group, students in all treatment groups demonstrated statistically significant academic improvement in trigonometry functions. The MD group showed statistically significant improvement in academic gain over the SI group, while the MDSI group with both motivational design and SRL intervention had the best academic gain. The post-hoc analysis showed that using motivational design and SRL intervention together would have a statistically significant positive effect on students' academic achievement compared with the other three groups. According to the research data, in learning trigonometry function, motivation played a more important role in enhancing students' academic achievement than SRL skills (see Table 4.9). Previous research has shown that motivation is positively related to academic achievement (Kim et al., 2014). And motivation has been demonstrated to be an important factor in preventing students from giving up and withdrawing from online mathematics learning (Smith et al., 2014). On the other hand, self-regulated learning can be used not only to explain the differences of students' achievement but also can help to improve students' achievement (Schunk, 2005). Therefore, it is suggested that motivational design and SRL intervention should be introduced at the same time in the online instructional design in order to help students attain better academic achievement, which has been statistically shown in this study (see Table 4.19).

The hypothesis that students with either ARCS motivational design or SRL intervention have better academic achievements than students in the control group, and students with both motivational design and SRL intervention end up with the best academic gains is supported by the results of this study.

5.2 Limitations of Study

The computer design technique employed in this study is limited so that the functionality of the website is constrained in the following aspects.

It has been previously discussed that current math online learning systems have problems with math symbols and notations, as there are many unique math terms that are hard to present on HTML files (Smith & Ferguson, 2005). The system designed for this study still cannot solve the notation problem well, even though the HTML files used in this study have embedded LaTeX math symbols to better present appropriate math diagrams, symbols, and notations. However, the math terms entered by students were not well designed when students tried to take notes in the system.

Adaptive scaffolding of SRL skills has been addressed by previous research, which has shown that adaptive scaffolding is effective in enhancing students' SRL skills (Azevedo et al., 2011). A complex algorithm is required in order to provide adaptive scaffolding for students to learn online, and it is hard to apply such an algorithm to the current system in this study. Providing adaptive feedback to students learning online can be more effective in promoting students' learning motivation. Research shows that providing students with timely, explicit feedback for their performance enhances students' self-efficacy during online learning (Bangert, 2004).

Lastly, the practice problem session was limited by the question-variation and hints-functionality design. Problem-solving skill is one important technique that students need to learn in mathematics. In interviews, math teachers suggested more practice problems to ensure students master the knowledge in the course. However, current instructional system could only have a limited number of problems for students to practice.

The validity of the research was limited by the format of the self-reported questionnaire and by the research time allowed by the schools. It is hard to control the students' attitudes towards completing the questionnaires in the current situation, which is a major problem when collecting data through self-reporting (Winne & Jamieson-Noel, 2002). It happened in the process of data collection that some students missed pages of the questionnaire and some students checked answers in symmetric orders. These types of data were considered invalid in the research, so such sets of data were not included in the data analysis. The limited time for students to learn trigonometry functions online also threatened to determine the validity of the research results. SRL skills are habits that can be taught to students over a period of time. However, because holidays and exam dates had been set for the semester, it was hard to find enough time for students to participate in the study. Even though the learning material was edited and adapted to the limited research time, two weeks might not have been sufficient for students to pick up new habits. As this study tried to inform instructional designers and educators how to design effective instructional methods for online math learning which could be generalized to a larger population and other math topics, it is also recommended that more students in other schools to be enrolled in the study for better research validity.

Conducting the research in Chinese schools limited somewhat the generalizability of the research findings. Generally speaking, there are several distinctive characteristics of the Chinese students in the two schools I have investigated. Under the testing-oriented education pattern in China, schools usually put pressure on students to succeed with fully scheduled daily curricula and intensive homework assignments. In these circumstances, most students take for granted that the schools and teachers will take care of arranging their studies, and they have limited time to plan self-study. Secondly, most students never think about reasons for learning. There is only one purpose of learning for those students, which is the college entrance examination. They lack intrinsic motivation, which is defined as internal reinforcement for self-determination and self-regulation of actions (Brophy, 2011), to learn. Based on the teachers' comments, these students usually use as little time as possible for learning. Lastly, basic trigonometry is introduced to Chinese students in junior middle schools, so most of the students participating in this study already had some knowledge of trigonometry. They might have had different expectations for the online course than those who have no knowledge about trigonometry.

5.3 Recommendation for Future Study

Due to the autonomous nature of online learning, motivation and self-regulation are very important habits for success in the online learning environment (Artino & Stephens, 2009). However, motivation is affected by various factors, such as personal interest, self-efficacy, learning environment setting, and task values perceived by students. Meanwhile, SRL skills are quite context dependent: different topics may require different SRL skills. Effectiveness of SRL strategies is also affected by learning material and personal characteristics. Hence, there are few recommendations for future study that aims to promote students' learning motivation and SRL skills for online math learning.

Based on the instructional system developed and tested in this study, several aspects can be recommended for future system design. The ARCS model is still recommended for instructional design to enhance students' learning motivation. Grounded in expectancy-value theory, reinforcement theory, and cognitive evaluation theory, the ARCS model assists a designer in identifying and solving specific motivational problems associated with appealing of instruction (Keller, 2010). The ARCS model provides instructional designers with criteria for how to pay attention to maintaining students' learning motivation. Future designers will need nevertheless to solve the math symbol and notation problems. Note-taking features in the current instructional system were effective in reminding students to take notes while learning, but without good math symbol input methods, the function of note-taking features is still limited. Secondly, the application of Wechat to create a sense of community worked well in the study, but if the online chatting system can be embedded in the instructional system, it will be more convenient for students to communicate with others during learning. Thirdly, it is highly recommended that a practice problem management system be produced. A database of practice problems can be set up in the back stage, and randomly selected problems can be shown to students each time they log into the system, which can provide more opportunity for students to self-evaluate their learning outcomes. Practice problems can also be expanded into more categorical formats such as filling in blanks and open-ended questions, but not limited to multiple choice questions. The hint feature can also be designed as adaptive feedback according to students' answers. Lastly, a log trace feature can be embedded in the system to help teachers and researchers keep track of students' answers and hypertext behaviors in the learning progress.

It is also useful to explore additional SRL strategies that are appropriate for online math learning. Math learning is different from other topics, such as literature and language learning, where memorization plays an important role in learning. Math learning requires not only memorizing related concepts, definitions and theories, but also developing the skills for analyzing those math terms and applying them in appropriate ways and situations. Interviews and surveys can be used to find out additional useful SRL strategies for online math learning and make appropriate interventions in future instructional design to assist students in self-regulating their learning activities.

The IMPROVE method is still recommended to enhance students' SRL skills. The meta-cognitive questions used in this study had helpful effects on how students regulated their ideas during learning, but lack of monitoring the completion of those questions affected the strength of the research design. More advanced monitoring techniques are needed to ensure the quality of students' work on those questions.

Finally, with respect to research design and data collection methods, it is recommended that the time of students' use of the instructional system be extended for better research results. Except for the self-reported data collected in this study, other data collection methods, such as the think-aloud method and observation, can also be used to gain various types of data to triangulate the research results. Furthermore, the long term effect on students' learning motivation and SRL skills through the ARCS motivational design and IMPROVE method is also valuable research topic, because learning motivation and SRL skills are important for students in other areas of learning as well.

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Appendix A

Azevedo et al.'s model of SRL (Greene et al., 2010)

Micro-level processes	Description	Student example
macro-level process: planning		
Planning	Stating two or more sub-goals simultaneously or stating a sub-goal and combining it with a time requirement.	"First I'll look around to see the structure of environment and then I'll go to specific sections of the circulatory system"

Sub-goal	Learner articulates a specific sub-goal that is relevant to the experiment provided overall goal. Must verbalize the goal immediately before taking action.	"I'm looking for something that's going to discuss how things move through the system"
Recycle goal in working memory	Restating the goal (e.g., question or parts of a question) in working memory	"Describe the location and function of the major valves in the heart"
Macro-level process: monitoring		
Content evaluation	Monitoring content relative to goals. Learner states content is or is not useful toward reaching the goal.	"I'm reading through the info but it's not specific enough for what I'm looking for"
Expectation of adequacy of content	Expecting that a certain type of representation will prove either adequate or inadequate given the current goal	"...the video will probably give me the info I need to answer this question" or "I don't think this section on blood pressure will answer my question"

Feeling of knowing	Learner is aware of having read something in the past and having some understanding of it, but not being able to recall it on demand or learner states this is. Information not seen before	"I recognize that from the pretest." or "artherosclerosis – I never heard that word before."
Judgment of learning	Learner makes a statement that they understand what they've read or becomes aware that they don't know. or understand everything they read	"I get it" or "I don't know this stuff, it's difficult for me"
Monitor progress toward goals	Assessing whether previously-set goal has been met.	"Those were our goals, we accomplished them"
Monitor use of strategies	Participant comments on how useful a strategy was	"Yeah, drawing it really helped me understand how blood flow throughout the heart"
Time monitoring	Participant refers to the number of minutes remaining	"I only have 3 min left"

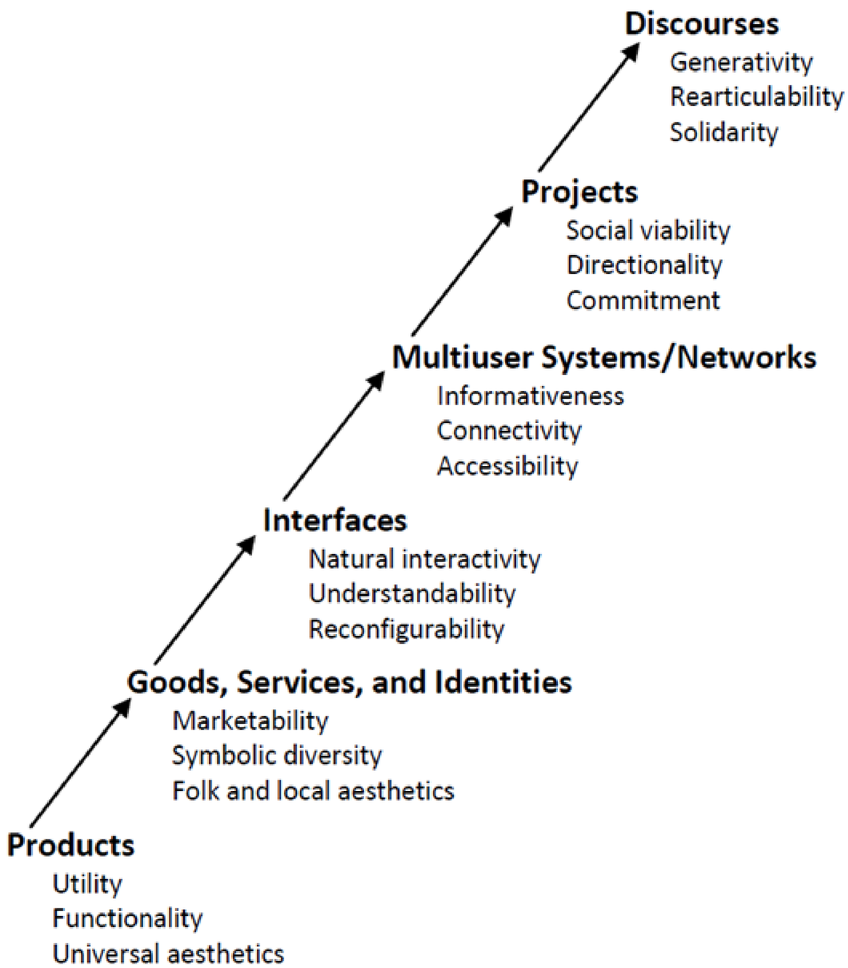
Task difficulty	Learner indicates the task is hard or easy.	“This is harder than reading a book.”
Macro-level process: strategy use		
Control video	Using pause, start, rewind, or other controls in the digital animation	Clicking pause during the video
Coordinating informational sources	Coordinating multiple representations, e.g., drawing and notes.	“I’m going to put that [text] with the diagram”
Draw	Making a drawing or diagram to assist in learning	“I’m trying to imitate the diagram as best as possible”
Inferences	Making inferences based on what was read, seen, or heard in the hypermedia environment	[Learner sees the diagram of the heart] and states “so the blood..through the .then goes from the atrium to the ventricle. And then.”
Knowledge elaboration	Elaborating on what was just read, seen, or heard with prior knowledge	[after inspecting a picture of the major valves of the heart] the learner states “so that’s how the systemic and pulmonary systems work together”

Memorization	Learner tries to memorize text, diagram, etc.	"I'm going to try to memorize this picture"
Prior knowledge Activation	Searching memory for relevant prior knowledge either before beginning performance of a task or during task performance	"It's hard for me to understand, but I vaguely remember learning about the role of blood in high school"
Read notes	Reviewing learner's notes.	"Carry blood away. Arteries-away."
Re-reading	Re-reading or revisiting a section of the hypermedia environment	"I'm reading this again."
Search	Searching the hypermedia environment with or without the Encarta search feature	"I'm going to type blood pressure in the search box"
Selecting a new informational source	The selection and use of various cognitive strategies for memory, learning, reasoning, problem solving, and thinking. May include selecting a new representation, coordinating multiple representations, etc.	[Learner reads about location valves] then switches to watching the video to see their location

Summarization	Summarizing what was just read, inspected, or heard in the hypermedia environment	“This says that white blood cells are involved in destroying foreign bodies”
Taking notes	Copying text from the hypermedia environment	“I’m going to write that under heart”
Macro-level process: task difficulty and demands		
Help seeking behavior	Learner seeks assistance regarding either the adequateness of their answer or their instructional behavior	“Do you want me to give you a more detailed answer?”
Macro-level process: interest		
Interest statement	Learner has a certain level of interest in the task or in the content domain of the task	“Interesting”, “This stuff is interesting”

Appendix B

Krippendorff's Trajectory of Artifacts


Discourses
Generativity
Rearticulability
Solidarity
Projects
Social viability
Directionality
Commitment
Multiuser Systems/Networks
Informativeness
Connectivity
Accessibility
Interfaces
Natural interactivity
Understandability
Reconfigurability
Goods, Services, and Identities
Marketability
Symbolic diversity
Folk and local aesthetics
Products
Utility
Functionality
Universal aesthetics

Appendix C

Interview Questions

C.1 Questions for Math teachers

Instructional system:

- How can we improve the instructional system?

Trigonometry functions instruction online:

- What are the difficulties in your opinion when students learn trigonometry functions online?
- How can we help students with those difficulties?
- What kind of multimedia technology will help students learn trigonometry functions online?
- How can we help students to better regulate their learning over the Internet?
- How can human tutors help students learn trigonometry functions online?

Learning math online:

- What are the advantages and disadvantages of learning math online in your opinion?
- Provide comments on current online math instructional systems/software.

Motivation:

- What are the factors that can affect the motivation of students to learn online?

C.2 Questions for Students

noindent*Instructional system:*

- How can we improve the instructional system?

Trigonometry functions instruction online:

- What are the difficulties you have when learning trigonometry functions online?
- What do you expect from the instructional system to help with those difficulties?
- What kind of multimedia technology will help you learn trigonometry functions online?
- If given the general learning goal, what would you like to do to learn trigonometry functions online?

- How can human tutors help you learn trigonometry functions online better?

Learning math online:

- What are the advantages and disadvantages of learning math online in your opinion?
- Provide comments on current online math instructional systems/software.

Motivation:

- What are the factors that may motivate you to learn in an online environment?

Appendix D

Instruments

D.1 MSLQ(Motivation)

The following questions ask about your motivation for and attitudes about this class. Remember there are no right or wrong answers, just answer as accurately as possible. Use the scale below to answer the questions. If you think the statement is very true of you, circle 7; if a statement is not at all true of you, circle 1. If the statement is more or less true of you, find the number between 1 and 7 that best describes you.

1	2	3	4	5	6	7
Not at all true of me						Very true of me

1. In a class like this, I prefer course material that really challenges me so I can learn new things.

2. If I study in appropriate ways, then I will be able to learn the material in this course.

3. I think I will be able to use what I learn in this course in other courses.

4. I believe I will receive an excellent grade in this class.

5. I'm certain I can understand the most difficulty material presented in the readings for this course.

6. It is my own fault if I don't lean the material in this course.

7. It is important for me to learn the course material in this class.

8. I'm confident I can understand the basic concepts taught in this course.

9. If I can, I want to get better grades in this class than most of the other students.

10. In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn.

11. I am very interested in the content area of this course.

12. If I try hard enough, then I will understand the course material.

13. I'm confident I can do an excellent job on the assignments and tests in this course.

14. The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.

15. I think the course material in this class is useful for me to learn.

16. When I have the opportunity in this class, I choose course assignments that I can learn from even if they don't guarantee a good grade.
17. If I don't understand the course material, it is because I didn't try hard enough.
18. Understanding the subject matter of this course is very important to me.
19. I'm certain I can master the skills being taught in this class.
20. I want to do well in this class because it is important to show my ability to my family, friends, employer, or others.
21. Considering the difficulty of this course and my skills, I think I will do well in this class.

D.2 MSLQ(SRL)

The following questions ask about your learning strategies and study skills for this class. Again, there are no right or wrong answers. Answer the questions about how you study in this class as accurately as possible. Use the same scale to answer the remaining questions. If you think the statement is very true of you, circle 7; if a statement is not at all true of you, circle 1. If the statement is more or less true of you, find the number between 1 and 7 that best describes you.

1	2	3	4	5	6	7
Not at all true of me						Very true of me

1. When I study the material for this course, I outline the material to help me organize my thoughts.

2. During class time I often miss important points because I'm thinking of other things.

3. I usually study in a place where I can concentrate on my course work.

4. When reading for this course, I make up questions to help focus my reading.

5. I often feel so lazy or bored when I study for this class that I quit before I finish what I planned to do.

6. I often find myself questioning things I hear or read in this course to decide if I find them convincing.
7. When I study for this class, I practice saying the material to myself over and over.
8. Even if I have trouble learning the material in this class, I try to do the work on my own, without help from anyone.
9. When I become confused about something I'm reading for this class, I go back and try to figure it out.
10. When I study for this course, I go through the readings and my class notes and try to find the most important ideas.
11. I make good use of my study time for this course.
12. If course readings are difficult to understand, I change the way I read the material.
13. When studying for this course, I read my class notes and the course readings over and over again.
14. When a theory, interpretation, or conclusion is presented in class or in the readings, I try to decide if there is good supporting evidence.
15. I work hard to do well in this class even if I don't like what we are doing.
16. I make simple charts, diagrams, or tales to help me organize course material.

17. I treat the course material as a starting point and try to develop my own ideas about it.
18. I find it hard to stick to a study schedule.
19. When I study for this class, I pull together information from different sources, such as lectures, readings, and discussion.
20. Before I study new course material thoroughly, I often skim it to see how it is organized.
21. I ask myself questions to make sure I understand the material I have been studying in this class.
22. I try to change the way I study in order to fit the course requirements and the teaching style.
23. I often find that I have been reading for this class but don't know what it was all about.
24. I ask the instructor to clarify concepts I don't understand well.
25. I memorize key words to remind me of important concepts in this class.
26. When course work is difficult, I either give up or only study the easy parts.
27. I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying for this course.
28. I try to relate ideas in this subject to those in other courses whenever possible.

29. When I study for this course, I go over my class notes and make an outline of important concepts.
30. When reading for this class, I try to relate the material to what I already know.
31. I have a regular place set aside for studying.
32. I try to play around with ideas of my own related to what I am learning in this course.
33. When I study for this course, I write brief summaries of the main ideas from t he readings and my class notes.
34. When I can't understand the material in this course, I ask another student in this class for help.
35. Whenever I read or hear an assertion or conclusion in this class, I think about possible alternatives.
36. I make lists of important items for this course and memorize the lists.
37. Even when course materials are dull and uninteresting, I manage to keep working until I finish.
38. When studying for this course I try to determine which concepts I don't understand well.
39. When I study for this class, I set goals for myself in order to direct my activities in each study period.

D.3 Demographic Survey

1. What's your Gender?

    Male

    Female

2. Age:

    15-16

    16-17

    17-18

    18 and above

3. Which high school do you attend?

    Hechuan High school

    Yucai Vocational High school