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The Effects of Pedagogical Agents on Mathematics Anxiety and Mathematics Learning

Quan Wei
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THE EFFECTS OF PEDAGOGICAL AGENTS ON MATHEMATICS
ANXIETY AND MATHEMATICS LEARNING

by

Quan Wei

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Instructional Technology and Learning Sciences

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2010
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The purpose of this study was to investigate the impact of the mathematics anxiety treatment messages in a computer-based environment on ninth-grade students’ mathematics anxiety and mathematics learning. The study also examined whether the impact of the treatment messages would be differentiated by learner’s gender and by learner’s prior mathematics anxiety levels (High vs. Medium vs. Low). Participants were 161 ninth-grade students, who took a required introductory algebra class in a public high school neighboring Utah State University. The learning environment was integrated with a pedagogical agent (animated human-like character) as a tutor. This study employed a pretest and posttest experimental design. Participants’ mathematics anxiety was measured at the beginning and at the end of the intervention; participants’ mathematics learning was measured before and after each lesson (four lessons in total). The participants were randomly assigned to work with either an agent presenting mathematics anxiety treatment messages (TR) or an agent without presenting the treatment messages (NoTR). Because
of student attrition, only 128 students were included for data analysis.

The results suggested that mathematics anxiety treatment messages provided by a pedagogical agent had no impact on student mathematics anxiety and mathematics learning. Second, there were no main or interaction effects of the treatment messages and learners’ gender on mathematics anxiety and mathematics learning. Third, there were significant interaction effects between treatment messages and learner’s prior mathematics anxiety levels only on current mathematics anxiety ($p < .05$). High-anxious students in the TR condition decreased their anxiety more than those in the NoTR condition. Medium-anxious students in the TR condition increased their anxiety whereas those in the NoTR condition decreased their anxiety. Low-anxious students in the TR condition did not change their anxiety whereas those in the NoTR condition increased their anxiety.

(111 pages)
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Above all, I want to dedicate this dissertation to my dearest parents.

Quan Wei
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CHAPTER I
INTRODUCTION

Statement of the Problem

Affect and cognition have drawn attention from educators since 1960s (Krathwohl, Bloom, & Masia, 1964). Studies showed that “affect and cognition are integrally linked within an associative network of mental representations” (Forgas, 2001, p. 17) and affect plays an important role in learning. Similarly, affective factors in learning mathematics have been actively studied for about three decades. McLeod (1994) indicated that approximately 100 articles dealing with affective issues have been published in the Journal of Research in Mathematics Education since 1970s. One affective factor that received greater attention was mathematics anxiety. A meta-analysis study on mathematics anxiety conducted by Hembree (1990) indicated that there was a negative relationship between mathematics anxiety and mathematics performance. Thus, mathematics anxiety has been studied in order to help students learn mathematics more successfully and build positive attitudes towards mathematics in the long-term (Reyes, 1984).

Although it is not determined yet what factors make learners feel anxious when confronting mathematics, learners with higher mathematics anxiety show a strong tendency to avoid learning mathematics, hold negative attitudes towards mathematics, have weak self-confidence in doing mathematics, and receive lower grades in mathematics-related courses in general (Ashcraft, 2002; Hembree, 1990; Ma & Xu, 2004).
Also, there is a gender difference in mathematics anxiety. Girls display a higher level of mathematics anxiety than do boys (Ashcraft, 2002; Campbell & Evans, 1997).

A number of solutions have been suggested to help reduce mathematics anxiety, such as the provision of corrective feedback and experience of success, the use of systematic desensitization, relaxation training, counseling support group, instructional games, computer assisted instruction, and so on (Aksu & Saygi, 1988; Davidson & Levitov, 1993; Hannula, 2002; Hembree, 1990; Hendel & Davis, 1978; Williams, 1988). In traditional classroom settings, teachers may attempt to reduce mathematics anxiety of students by teaching them effective problem-solving strategies, providing corrective feedback, and encouraging students to sustain mathematics (Aksu & Saygi, 1988; Berman, 2003; Davidson & Levitov, 1993). In addition, clinical psychologists suggest helping students be aware of and positively cope with their fear of doing mathematics (Hackworth, 1992; Williams, 1988).

With the rapid development of technology, an inquiry is being held into how to simulate those suggested strategies to reduce mathematics anxiety in computer-based learning environments. Pedagogical agents (PA), animated lifelike characters on the screen, have received increasing attention among the researchers in technology-based learning (Elliott, Rickel, & Lester, 1999; Johnson, Rickel, & Lester, 2000; Rickel & Johnson, 1999). The agents are expected to facilitate learning through rendering social context to a computer-based learning environment (Johnson et al., 2000; Kim, 2004). The uniqueness of the PA might be their capability to interact with learners affectively (Elliott et al., 1999; Johnson et al., 2000; Kim & Baylor, 2006). The capability of affective interaction could be applied to simulate some of the anxiety treatment strategies that
teachers and clinical psychologists have used and thereby may contribute to reducing learners’ mathematics anxiety. However, rare studies have examined the effect of a PA in that regard. Therefore, this study investigated whether the anxiety treatment messages presented by a PA could help reduce mathematics anxiety of students and improve mathematics learning.

**Purpose and Research Questions**

The purpose of the study was to investigate, first, if the mathematics anxiety treatment messages presented by a PA have an impact on student mathematics anxiety and mathematics learning; second, if there is an interaction between the messages and student gender; third, if there is an interaction between the messages and student prior mathematics anxiety. The research questions were as follows:

1. What is the impact of anxiety treatment messages provided by a PA on mathematics anxiety?
2. Is there an interaction effect of anxiety treatment messages provided by a PA and learner’s gender on mathematics anxiety?
3. Is there an interaction effect of anxiety treatment messages provided by a PA and learner’s prior mathematics anxiety on mathematics anxiety?
4. What is the impact of anxiety treatment messages provided by a PA on mathematics learning?
5. Is there an interaction effect of anxiety treatment messages provided by a PA and learner’s gender on mathematics learning?
6. Is there an interaction effect of anxiety treatment messages provided by a PA and learner’s prior mathematics anxiety on mathematics learning?

**Hypotheses**

**Hypothesis 1:** It was expected that participants who received anxiety treatment messages provided by a PA would lower their anxiety more than those who did not receive anxiety treatment messages provided by a PA.

**Hypothesis 2:** It was expected that female participants who received anxiety treatment messages provided by a PA would lower their anxiety more than those who did not receive the messages, whereas the treatment messages would have less impact on mathematics anxiety of male participants.

**Hypothesis 3:** It was expected that high-anxious participants who received anxiety treatment messages provided by a PA would lower their mathematics anxiety more than those who did not receive the messages, whereas the treatment messages would have less impact on mathematics anxiety of medium- and low-anxious participants.

**Hypothesis 4:** It was expected that participants who received anxiety treatment messages provided by a PA would increase their mathematics learning more than those who did not receive the messages.

**Hypothesis 5:** It was expected that female participants who received anxiety treatment messages provided by a PA would increase their mathematics learning more than those who did not receive the messages, whereas the treatment messages would have less impact on mathematics learning of male participants.
Hypothesis 6: It was expected that high-anxious participants who received anxiety treatment messages provided by a PA would increase their mathematics learning more than those who did not receive the messages, whereas the treatment messages would have less impact on mathematics learning of medium- and low-anxious participants.

Significance of the Study

Previous studies on treating mathematics anxiety were conducted either in clinical or classroom settings. A cognitive-behavioral therapy is known as one of the most efficacious treatments for mathematics anxiety (Foss & Hadfield, 1993; Zettle, 2003). The focus of this study was to investigate the effect of a PA’s mathematics anxiety treatment messages that were developed to simulate the cognitive-behavioral therapy for high school students. Therefore, this study has two main contributions. First, this study tested if a PA’s treatment messages in the virtual world would be as effective as the treatment in clinical and classroom settings. The study, therefore, will produce new understanding of how advanced technology could contribute to reducing teenage students’ mathematics anxiety. Furthermore, this approach, if shown effective, is much more scalable than the conventional expensive cognitive-behavioral therapy. Second, individual difference has been drawing attention from educators and intervention designers. The study may provide implications for designing effective computer-based treatments for diverse learners learning mathematics -- diverse in gender and mathematics-anxiety levels.
Definition of Terms

Mathematics Anxiety

Mathematics anxiety has been generally defined as unpleasant feelings of tension or fear that interfere with mathematics problem solving or other mathematics related activities (Ashcraft, 2002; Cemen, 1987; Ma & Xu, 2004; Tobias, 1993). For the purpose of this study, it was operationalized as student self-reported unpleasant feelings of tension or fear experienced when involved in mathematics learning related activities and mathematics learning processes. The Learning Mathematics Anxiety scale, a subscale of the Revised Mathematics Anxiety Rating Scale (RMARS) that assesses the anxiety about the activity or process of learning mathematics, was used in this study to measure student mathematics anxiety (operational definition).

Mathematics Learning

According to the Learning Principle of the National Council of the Teachers of Mathematics (NCTM), “Students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge” (NCTM, 2000, p.11). In this study, mathematics learning was focused on applying students’ understanding to problem-solving skill acquisition and operationalized as participants’ achievements from mathematics pretest to posttest covering the four topic areas of introductory algebra, signed number arithmetic, combining like terms and distribution, factoring, and graphing the linear equations using slope and y-intercept.
CHAPTER II
LITERATURE REVIEW

In human society, the process of learning is largely achieved by a person or a group of people assisting an individual to learn. A teacher teaches a student by providing instruction and demonstration, a master guides an apprentice to develop a skill, a coach teaches a player playing techniques, students work together to solve a problem. All these learning activities show that learning occurs in the social context. The teacher, master, coach, and each student act as the facilitating agent for learning. Learning includes both social and cognitive aspects (Salomon & Perkins, 1998).

Affect is an inseparable factor in intelligence development from Piaget’s points of view (DeVries, 1997). Affect plays an important role in learning in general as it also does in learning mathematics. Some students enjoy learning mathematics, but many dislike doing mathematics. It is not uncommon to hear someone saying “I can’t do math,” “I hate math,” and “I don’t want to take a math course any more.” The affective aspect in learning mathematics has always been a concern in mathematics education. Mathematics anxiety, as one of the affective reactions to learning mathematics, has been received a large amount of attention from educators during 1980s and 1990s. Research on mathematics anxiety consistently demonstrates that the low-anxious students outperform their highly-anxious peers in mathematics (Hembree, 1999). Although the cause of mathematics anxiety still cannot be identified clearly, the consequences of being anxious reported low achievement in math, avoidance of taking mathematics courses, pursuing mathematics as a college major, or even pursuing a mathematics-related career path.
Therefore, it is essential to help students overcome mathematics anxiety. Hackworth (1992) suggested some activities for reducing mathematics anxiety in classroom environments. These include structured mathematics instruction, good study techniques, positive messages, and successful problem solving experiences. Furthermore, clinical therapies based on cognitive-behavioral approach are suggested to be effective for reducing mathematics anxiety, such as systematic desensitization, anxiety management training, and discussion of negative feelings (Foss & Hadfield, 1993; Wadlington, Austin, & Bitner, 1992).

Since the classroom use of computers is highly recommended to teach mathematics (NCTM, 1995), techniques for reducing mathematics anxiety might be implemented in computer-based learning environments. Animated pedagogical agents, digital human-like characters on the screen, are used to simulate human roles and serve as a tutor, an expert, or a co-learner (Kim & Baylor, 2006). Studies demonstrated that students display deeper learning and higher motivation when interacting with animated pedagogical agents (Baylor, 2002; Moreno, Mayer, Spires, & Lester, 2001). Pedagogical agents might help reduce mathematics anxiety.

In the following sections, I first discuss the importance of social interaction and the role of affect in learning. Second, research in mathematics anxiety is reviewed. Lastly, use of animated pedagogical agents for increased engagement is introduced.

**Social and Affective Aspect of Learning**

Intellectual development takes place in a social context. Scenarios range from a
student seeking help from a teacher, to a group of students working together to master problems. Piaget discussed that child development is in association with social factors (DeVries, 1997). Vygotsky considered social interaction as the most important component for intellectual and personal development (Wood, 1998). From a Vygotskian point of view, social interaction serves as a bridge between a learner’s existing knowledge and skills and the demands of tasks (Vygotsky, 1978).

The field of psychology has traditionally identified three distinct components of the human mind, affect (feeling), cognition (knowing), and conation (willing) (Forgas, 2001; Hilgard, 1980). More recently, researchers acknowledge that affect and cognition are closely related in human intellectual and social functioning. For example, when humans are in a positive mood, they view the world as more friendly and make positive judgments (e.g., Izard, 1964; Razran, 1940; Wehner & Izzrd, 1962; Wesman & Ricks, 1966). The positive or negative affect has differential persuasive power on influencing people’s attitudes toward a target (Petty, Desteno, & Rucker, 2001). As Piaget concludes, “affective states that have no cognitive elements are never seen, nor are behaviors found that are wholly cognitive” (Piaget, 1981, p. 5). Therefore, it is natural that mathematics learning is achieved through both a learner’s affect and cognition.

**Mathematics Anxiety**

Mathematics anxiety is generally defined as unpleasant feelings of tension or fear that interfere with mathematics performance (Ashcraft, 2002; Cemen, 1987; Ma & Xu, 2004). Mathematics anxiety has two components, emotional and cognitive (Liebert &
Morris, 1967). The emotional component includes nervousness, tension, dread, fear, and discomfort when doing math (Morris, Davis, & Hutchings, 1981). The cognitive component includes concerns of one’s performance, self-doubt, lack of confidence, and negative attitudes (Cemen, 1987; Morris et al., 1981). Learners who are anxious when confronting mathematics problems are known to experience rapid pulse, nervous stomach, heart palpitations, tension headaches, upset feelings, and sweaty palms (Adams, 2001; Cemen, 1987). The consequences of mathematics anxiety include lower mathematics achievement, the avoidance of taking mathematics courses, negative attitudes towards mathematics, and less self-confidence in doing mathematics (Frost, Hyde, & Fennema, 1994; Hembree, 1990).

The Yerkes-Dodson Law predicts the relationship between arousal (anxiety) and performance (Yerkes & Dodson, 1908). The law, represented as an inverted U-curve, indicates that both low and high levels of anxiety produce minimum performance and that a moderate level of anxiety results in maximum performance in a task (Yerkes &
Dodson, 1908). The shape of the curve varies according to the difficulty of the task. Difficult or complex cognitive tasks can be successfully performed when arousal (anxiety) is low whereas simple tasks can be successfully performed when arousal (anxiety) is high (Clark, 2008).

Mathematics Anxiety as a Process

Spielberger (1972) conceptualized anxiety as a state, a trait, and a process. He defined the state anxiety as the “unpleasant state or condition which is characterized by activation or arousal of the autonomic nervous system” (Spielberger, 1972, p. 482). The trait anxiety describes individual differences in anxiety rather than situational experiences. Anxiety as a process refers to “the sequence of cognitive, affective, and behavioral responses that occur as a reaction to some form of stress” (Spielberger, 1972, p. 484). Through Spielberger’s anxiety-as-process model, anxiety is considered as a result of a series of reactions to the psychological threat.

Based on Spielberger’s model, Cemen (1987) developed a mathematics-anxiety-as-process model, which explains how mathematics anxiety is generated and increases over time. In this model, prior to the mathematics anxiety reaction, there are two factors that make mathematics anxiety reaction occur: situational and dispositional factors (Cemen, 1987). Situational factors leading to mathematics anxiety include teacher influence in mathematics class, the way mathematics is taught, the nature of mathematics, negative experiences, parental encouragement, and past mathematic achievement. Dispositional factors relating to the personality of individuals include self-doubt in doing mathematics, the lack of confidence in doing mathematics, negative attitudes towards
doing mathematics, and gender difference in completing mathematics tasks (Cemen, 1987). When mathematics anxiety reaction is triggered, it may present as a nervous stomach, sweaty palms, a rapid heart beat, holding one’s breath, sucking a thumb, or dizziness (Adams, 2001; Cemen, 1987). After cognitive reappraisal, decisions are then made to cope with mathematics anxiety. This involves avoidance of mathematics-related courses, development of negative attitudes towards mathematics, lack of confidence in doing mathematics, and increase in anxiety (Ashcraft, 2002; Cemen, 1987; Hembree, 1990; Ma & Xu, 2004). According to this mathematics-anxiety-as-process model, no matter what factors caused mathematics anxiety, mathematics anxiety may be reduced if students are aware of and positively cope with their mathematics anxiety.

**Figure 2.** Mathematics-anxiety-as-process model.

**Previous Research on Mathematics Anxiety**

In a meta-analysis on mathematics anxiety, Hembree (1990) concluded that mathematics anxiety starts increasing during the junior high grades, reaches the vertex in 9th and 10th grades, and levels off through senior high school and college. He summarized that several variables correlated with mathematics anxiety, such as attitudinal constructs and mathematics performance. Also, there is a gender difference in mathematics anxiety.

**Variables correlated with mathematics anxiety.** Studies indicated that some
variables, such as attitudinal constructs and mathematics performance, correlate with mathematics anxiety (Hembree, 1990). These studies identified an inverse relationship between mathematics anxiety and attitudinal constructs (e.g., self-efficacy, attitudes, etc.), and an inverse relationship between mathematics anxiety and mathematics performance.

**Attitudinal constructs.** Attitudinal constructs included enjoyment of mathematics, self-confidence in mathematics, self-concept in mathematics, mathematics as a male domain, attitudes toward doing mathematics, self-efficacy about doing mathematics and student perceptions of others’ attitudes toward mathematics. In general, positive attitudes toward mathematics consistently relate to lower mathematics anxiety (Hembree, 1990). In other words, students with high mathematics anxiety usually have negative attitudes towards mathematics. A strong inverse relationship was found in the enjoyment of mathematics, self-concept, self-confidence (Hembree, 1990) and self-efficacy (Cooper & Robinson, 1991) in doing mathematics. Also, students with high mathematics anxiety viewed mathematics as a male domain and viewed their parents and teachers as somewhat negative towards mathematics.

**Mathematics performance.** A negative association between mathematics anxiety and mathematics performance was found in many studies. Learners with high mathematics anxiety, compared to those with low mathematics anxiety, receive lower scores in mathematics (Cates & Rhymer, 2003; Hembree, 1990; Ma, 1999).

**Gender difference in mathematics anxiety.** More females report higher mathematics anxiety than males (Ashcraft, 2002; Frost et al., 1994; Hembree, 1990). Osborne (2001) concluded that gender difference in mathematics anxiety partially explained gender difference in mathematics achievement based on the data drawn from
the senior cohort data file from the *High School and Beyond* study. The results indicated that males had lower levels of mathematics anxiety and achieved higher scores in mathematics than females.

**Treatments for mathematics anxiety. Psychological treatments.** Cognitive-behavioral therapy emphasizes the relationship between thoughts, behaviors, and emotions and aims to help clients positively cope with their worries (Dugas & Robichaud, 2007). Cognitive-behavioral therapies, such as cognitive restructuring, relaxation training, anxiety management training, situational exposure, and systematic desensitization, are effective methods for treating general anxiety disorder (Gould, Otto, Pollack, & Yap, 1997). Dugas and Robichaud developed a step by step cognitive-behavioral treatment for anxiety disorder: (1) help clients be aware of their anxiety, (2) develop a greater tolerance for uncertainty, and (3) encourage clients to approach problematic situations rather than avoid them (Dugas & Robichaud, 2007).

Foss and Hadfield (1993) designed a Mathematics Avoidance Clinic, in which they taught college students how to manage their mathematics anxiety through relaxation training, guided imagery, hands-on mathematics activities, etc. After attending the Mathematics Avoidance Clinic in three semesters, student mathematics anxiety was significantly reduced. Similarly, Zettle (2003) conducted research in comparing systematic desensitization, acceptance, and commitment therapy in the treatment of mathematics anxiety of college students. The purpose of both therapies was to train students to cope with their mathematics anxiety positively. The results indicated that both therapies were effective in reducing mathematics anxiety. In a meta-analysis of 151 studies, Hembree (1990) found that the more effective treatment for reducing math
anxiety uses systematic desensitization along with relaxation training. The treatments, such as restructuring beliefs and enhancing self-confidence in mathematics, have a moderate effect on reducing math anxiety.

**Classroom interventions.** Students appear to benefit from corrective feedback and highly structured mathematics courses. Aksu and Saygi (1988) tested the effect of corrective feedback on mathematics anxiety of sixth grade Turkish students. The results indicated that corrective feedback on quiz papers had a significant positive influence on mathematics anxiety. Norwood (1994) also found that high mathematics anxious students are more comfortable in highly structured mathematics courses.

Preis and Biggs (2001) argued that poor teaching can be one possible source of mathematics anxiety. “Learners with math fears need instructors who are patient and encouraging. They need instructors who can help them gain self-confidence in doing mathematics and who can help them come to believe that they are capable of learning mathematics” (Preis & Biggs, 2001, p. 8). Other anxiety reducing strategies included accommodating various learning styles, making mathematics relevant, providing positive mathematics experiences and classroom atmosphere, modeling problem solving and logical thinking in instruction, using instructional games that require original thinking, building confidence (Williams, 1988), and using computer assisted instruction.

**Animated Pedagogical Agents**

Animated pedagogical agent technology has been recognized as an approach for making computer-based learning more interactive (Clarebout, Elen, Johnson, & Shaw,
2002; Lester, Voerman, Towns, & Callaway, 1999; Lester, Zettlemoyer, Gregoire, & Bares, 1999; Shaw, Ganeshan, Johnson, & Millar, 1999). In order to master complex tasks in actual classroom environments, students need teachers who can provide hands-on practice as well as demonstrate concepts, teach problem-solving skills, and answer questions. If the task is highly complicated, the students may also need teammates to collaborate. Occasionally, such teachers and teammates are not available. In computer-based learning, animated pedagogical agents can be used to simulate such face-to-face interaction and play the roles of the teachers and teammates, to guide through learning (Johnson & Rickel, 1997; Lester, Zettlemoyer, et al., 1999; Shaw et al., 1999).

**Background of Animated Pedagogical Agents**

According to Johnson and colleagues (2000), animated pedagogical agents were built upon two previous research areas: knowledge-based learning environments and animated interface agents. Knowledge-based learning environments are computerized learning environments which intend to provide personalized training to adapt to an individual’s needs by using artificial intelligence (Alshawi, Goulding, & Faraj, 2006; Forcheri & Molfino, 1991; Johnson et al., 2000). Animated interface agents are characters that interact with an individual in a virtual environment. The design and implementation of an agent are based on natural face-to-face interaction in the real world, using both verbal and nonverbal communication techniques (Johnson et al., 2000; Laurel, 1997). To communicate with the learner, agents may use pointing gestures (Lester, Zettlemoyer, et al., 1999; Rickel & Johnson, 1999), locomotion, eye-gaze (Lester, Voerman, et al., 1999; Lester, Zettlemoyer, et al., 1999), and facial expressions (Johnson et al., 2000). These
non-verbal features of the animated pedagogical agents can broaden the bandwidth of human-computer interaction (Johnson et al., 2000).

**Benefits of Animated Pedagogical Agents**

Interacting with animated pedagogical agents in the computer-based learning environment seems to promote student learning and increase student engagement and motivation (Lester et al., 2001; Moreno et al., 2001). The benefits of animated pedagogical agents include enhanced information presentation, increased sense of ease and comfort, increased motivation, and enhanced learning.

**Enhanced information presentation: verbal and non-verbal.** In human conversation, various forms of non-verbal behavior (e.g., gesture, eye-blinking, mod, facial expression, etc.) are produced simultaneously with speech. These non-verbal behaviors are usually consistent with the meaning being conveyed. Pedagogical agents in computer-based learning environment simulate human-to-human communication and have the capability of presenting information in both verbal and non-verbal format.

Pedagogical agents can transmit non-verbal information when talking or responding to learners by nodding, gazing, gesturing, or making facial expressions. These non-verbal cues allow learners to communicate with their agent as they would with a human being. COSMO (Lester, Voerman, et al., 1999), a 3-D animated agent equipped with gesture, locomotion, gaze, and speech features, inhabited a computer-based learning environment to help students learn internet packet routing. An informal focus group that used COSMO reported clear explanation by using both verbal and non-verbal cues (Lester, Voerman, et al., 1999).
Cassell and Thorisson (1999) investigated whether envelope feedback, i.e., nonverbal behaviors related to the process of conversation such as gaze, gesture, eye-blinking and head movements, plays a bigger role in interaction than content-related feedback and emotional feedback (such as smile and puzzlement). They concluded that participants rated the agent that gave envelope feedback more helpful, lifelike, and more smooth in its interaction style (Cassell & Thorisson, 1999).

Lusk and Atkinson (2007) examined the impact of animated pedagogical agents with different levels of embodiment on students’ learning. Participants were randomly assigned into three groups: fully embodied agent with speech and nonverbal forms of communication (locomotion, gesture, and gaze), minimally embodied agent only with speech, and voice-only conditions. Participants who studied with fully embodied agents provided more conceptually accurate solutions to transfer problems than their counterparts in the voice-only condition.

**Increased sense of ease and comfort.** The presence of the pedagogical agents in a computer-based learning environment can have a positive effect on students’ perception of learning tasks and learning environment (Lester et al., 2001). Middle school students worked at a computer-based lesson, *Design-A-Plant*, in which they interacted with a pedagogical agent to design plants that would survive only in a certain environment. The students rated the agent highly in terms of helpfulness, believability, and entertainment value. Mulken, Andre, and Muller (1998) reported that the presence of an agent in a technical presentation positively influenced participants’ perception of the learning experience. Participants who used an agent evaluated the technical presentation as significantly less difficult, more interesting, and more entertaining than those who did not
used an agent. Similarly, Moundridou and Virvou (2002) found that students who worked with an agent rated the tutoring system more enjoyable and easier to use than those who worked at a no-agent version.

**Increased motivation.** Agent’s presence seems to make a learning environment more social and hence increase motivation and engagement (Lester et al., 2001; Moreno et al., 2001; Moundridou & Virvou, 2002). Robertson, Cross, Macleod, and Wiemer-Hastings (2004) studied 60 primary school children, where half of the group wrote a story using the agent version of an intelligent tutoring system – *StoryStation* and the other half wrote a story using the no-agent version. Children who used the agent version indicated more strongly that they wanted to use the system again than did children used the no-agent version. Similarly, Moreno, Mayer, and Lester (2000) found that students who designed a plant with the assistance of an agent showed significantly higher motivation to continue learning and significantly higher interest in the material than those who designed a plant without an agent. Ryokai, Vaucelle, and Cassell (2003) examined the impact of an embodied conversational agent, Sam, on engaging pre-school girls in collaborative storytelling. Children who played with Sam were more engaged in collaborative storytelling and talked more about storytelling after the activity, compared to children who played with a human peer.

**Enhanced learning.** Findings from research on the effect of animated pedagogical agents on learning achievement are not consistent. Some studies showed that pedagogical agents do not contribute to student learning. For instance, pedagogical agents have not been shown to influence memory, problem solving, or understanding (e.g., Moundridou & Virvou, 2002; Mulken et al., 1998). Mulken and colleagues (1998)
performed a study with 30 adult participants, where 15 participants worked with an agent and the other 15 participants worked without an agent. They found that use of pedagogical agents did not have an impact on comprehension and recall when learning either technical or non-technical information. Moundridou and Virvou (2002) investigated use of a pedagogical agent on the learning of 48 college students. The students were randomly assigned to the agent group and the non-agent group. They concluded that the presence or absence of the animated agents did not affect the learning outcomes.

Other studies show that use of pedagogical agents has a positive impact on near and far knowledge transfer (e.g., Atkinson, 2002; Moreno et al., 2000; Moreno et al., 2001) and retention (e.g., Dunsworth & Atkinson, 2007). Atkinson (2002) conducted a study on helping undergraduate students solve word problems using a computer program. 50 undergraduate students were randomly assigned to one of five conditions: voice plus agent, text plus agent, voice only, text only, or control. Students in the voice-plus-agent condition outperformed their counterparts in the control condition on both near and far transfers. Similarly, Dunsworth and Atkinson (2007) examined the impact of pedagogical agents on learning the human cardiovascular system. 51 undergraduate students were randomly assigned to one of the three conditions: on-screen text, narration, or narration plus agent. Students in narration-plus-agent condition performed better on retention questions than those in on-screen-text and narration conditions.

**Gender Difference**

Robertson and colleagues (2004) found that the presence of an animated
pedagogical agent positively impacts student interaction with the computer-based story writing program, *StoryStation*. Sixty primary school students were randomly assigned to either use a version of *StoryStation* with the agent or an equivalent version without the agent. The results indicated that girls tend to interact more with the agent version, while boys tend to interact more with the non-agent version. Burleson and Picard (2007) also investigated the effect of types of agent’s support (affect support vs. task support), on students who were 11-13 years old. The results revealed that girls who received affect support responded more positively than girls who received task support whereas boys who received task support responded more positively than boys who received affect support.

**Summary**

Mathematics anxiety is a complex and long-standing problem in mathematics learning. People who suffer from mathematics anxiety usually doubt their ability of doing mathematics, avoid taking mathematics courses, and limit their career choices to areas that do not require mathematics skills. Many studies have been done in both traditional classroom settings and clinical practice to find methods for treating mathematics anxiety. The efficacious way of reducing mathematics anxiety is either using cognitive-behavioral therapy that helps students cope with their mathematics anxiety or providing students with corrective feedback, problem-solving strategies, and highly structured learning activities in classroom teaching. An animated pedagogical agent with its social affordance can be used to simulate some effective anxiety treatment strategies in computer-based
learning. However, few studies have been done to examine the impact of animated pedagogical agents on reducing mathematics anxiety. This study, therefore, investigated the impact of the anxiety treatment messages presented by a pedagogical agent in computer-based mathematics learning on reducing mathematics anxiety and improving mathematics learning. Given the literature, it was anticipated that the anxiety treatment messages would have positive impact on students’ mathematics anxiety and mathematics learning. Moreover, female students and high-anxious students would benefit more from the treatment messages.
CHAPTER III

METHODS

This study investigated the effect of the mathematics treatment messages in a pedagogical-agent-based environment on mathematics anxiety and mathematics learning. The study also examined whether the impact of the mathematics anxiety treatment messages would be differentiated by the learner’s gender and by the learner’s prior anxiety levels. A randomized pretest and posttest experimental design was employed. This chapter describes the research methodology including participants, research design, materials, data collection and instrumentation, procedure, and data analysis.

Participants

The participants were 161 9th grade students enrolled in a “Algebra I” class in a high school located in a mountain-west state of the USA. According to state policy, students who did not pass algebra in junior high or middle schools must take this course in the ninth grade, regardless of their interest. The participants were recruited from six classes. A Parent Permission/Youth Assent letter (see appendix H) was sent to each student and their parent(s) to obtain permission for participating in the study. Among 161 students who participated in this study, only 128 participants were included in the final data analyses because 33 students did not complete one or more lessons due to tardiness or absence from school. Of all the 128 participants who completed all aspects of the study, the average age was 15.91 (SD = .96). The compositions of student ethnicity, which were
self-reported, were: Caucasian (59.4%), Hispanic (26.6%), African American (3.0%), Asian (1.6%), and Others (9.4%). Of the 128 students, 58 (45.3%) were male students and 70 (54.7%) were female.

The required sample size was estimated by using a power level of .90 and a medium effect size of .50 at $\alpha$-level .05 based on Cohen’s guideline (1988). The G*power, which is a general power analysis program, was used to calculate the minimum required sample size. The calculated minimum sample size was 36 for testing the hypothesis 1 and 4 (with 18 subjects in each cell, 2 cells in total), 52 for testing the hypothesis 2 and 5 (with 13 subjects in each cell, 4 cells in total), and 66 for testing the hypothesis 3 and 6 (with 11 subjects in each cell, 6 cells in total). In this study, 128 students participated and ranging from 60 to 68 in each cell for testing the hypothesis 1 and 4, 27 to 41 in each cell for testing the hypothesis 2 and 5, and 12 to 44 in each cell for testing the hypothesis 3 and 6. Therefore, there were enough participants to conduct this study.

**Research Design**

The research questions of the study were answered in a quantitative framework using a pretest and posttest experimental design. The students were randomly assigned to two experimental conditions: the presence of treatment messages group (TR condition) ($N = 60$) and the absence of treatment messages group (NoTR condition) ($N = 68$).

Figure 3 shows the intervention design structure for reducing mathematics anxiety in this study. The researcher developed a pedagogical agent providing learners with mathematics anxiety treatment messages and content-related messages. The mathematics
anxiety treatment messages presented by a PA were developed according to the Dugas and Robichaud’s cognitive-behavioral therapy (see page 14), with the three steps of (1) increasing students’ awareness of their mathematics anxiety, (2) developing tolerance for uncertainty in doing mathematics, and (3) encouraging students to do mathematics rather than avoid it. The content-related messages presented by a PA included information presentation and corrective feedback. Information presentation helped students review the mathematics concepts. Corrective feedback guided students through a right way to solve the problems.

Figure 3. Intervention design structure for reducing mathematics anxiety
Independent Variables

The independent variables included mathematics anxiety treatment messages (presence vs. absence), student gender (male vs. female), and student’s prior mathematics anxiety levels (low vs. medium vs. high).

The presence / absence of mathematics anxiety treatment messages. Mathematics anxiety treatment messages, which were modified from Dugas and Robichaud’s (2007) techniques for treating anxiety disorder to fit to mathematics learning anxiety, were used to help mathematics anxious students be aware of and positively cope with their anxiety when doing mathematics. In this study, two levels of mathematics anxiety treatment messages were implemented. One was the presence of treatment messages, and the other one was the absence of treatment messages. In the presence of

Figure 4. The example of mathematics anxiety treatment messages.
treatment messages condition (TR), besides providing students with the content-related messages, the PA presented students with treatment messages as well (as shown in Figure 4); while in the absence of treatment messages condition (NoTR), the PA only provided students with content-related messages.

Student gender. Student gender was identified by self-report. Students were asked to indicate their gender at login to the environment.

Student prior mathematics anxiety levels. Student mathematics anxiety was measured at the beginning of the study, using Learning Mathematics Anxiety survey, which relates to the anxiety about the activity or process of learning mathematics (Plake & Parker, 1982). The details about this instrument are presented in the following section, Dependent Variables. Students’ prior mathematics anxiety was categorized into three levels: low, medium, and high. According to the distribution of their scores of mathematics anxiety ($M = 28.97, SD = 10.59$), the scores that were less than one standard deviation below the mean were set as low ($N = 25$); the scores that were greater than one standard deviation above the mean were set as high ($N = 24$); and the scores that were in between one standard deviation below and above the mean were set as medium ($N = 79$).

Dependent Variables

The dependent variables in this study included student mathematics anxiety and mathematics learning.

Mathematics anxiety. Mathematics anxiety is defined as the unpleasant feelings of tension or fear about mathematics learning related activities and mathematics learning process. The 98-item Mathematics Anxiety Rating Scale (MARS) was developed by
Richardson and Suinn (1972) to assess mathematics anxiety. Later, Plake and Parker (1982) developed a revised version of MARS (RMARS) specifically targeting secondary school students. The RMARS\(^1\) is highly related to the MARS with the estimated correlation at .97, and yields a coefficient alpha reliability estimated at .98 (Plake & Parker, 1982). RMARS has two subscales: Learning Mathematics Anxiety, which relates to the anxiety about the activity or process of learning math, and Mathematics Evaluation Anxiety, which relates to the anxiety about the evaluation of mathematics learning. In this study, the subscale for Learning Mathematics Anxiety was used to assess students’ anxiety during mathematics learning activities and implemented before and after the intervention. This subscale, as shown in Appendix A, consisted of 16 items using 5-point Likert scale with response choices ranging from 1 being “not at all” to 5 being “very much.” In this study, the researcher conducted a test of internal consistency using Coefficient alpha to test the reliability of this instrument. The reliability of the items was \(\alpha = .91\).

**Mathematics learning.** The assessments of student mathematics learning (see Appendix B), which were administered as pre and posttests, were developed in collaboration with high-school mathematics teachers when developing the curriculum content for the learning environment, *MathGirls*. The items used a short-answer format, where students typed in their answers. For each question in the pretest, there was a parallel question in the posttest, which assessed the same knowledge with different items. The Pearson correlation between pretest and posttest was \(r = .79\), which indicated a high

\(^1\) The 24-item RMARS has been broadly used by researchers. It includes the 16-item Learning Mathematics Anxiety Scale and the 8-item Mathematics Evaluation Anxiety Scale.
correlation. The students’ posttest on learning was unlikely to be affected by their experience with the pretest.

Materials

Learning Environments

This study used a modified version of an agent-based introductory algebra learning environment, MathGirls, as the instructional material. MathGirls was developed by the CREATE research team under the direction of Dr. Yanghee Kim, Utah State University, and funded by the National Science Foundation (GSE - 05226343). The instructional material was developed as a web-based format and delivered via the web. MathGirls covers four areas of fundamental algebra as the curriculum content that have been developed in collaboration with high school teachers, following the Principles and Standards of the National Council of the Teachers of Mathematics (NCTM, 2000). Each area took one-class hour. Lesson 1 covered signed number arithmetic; Lesson 2 dealt with combining like terms and distribution; Lesson 3 covered factoring; and Lesson 4 dealt with graphing linear equations using slope and y-intercept. Each lesson consists of four to five subsections.

MathGirls consists of three phases.

- Review phase: As seen in Figure 5, at the beginning of every subsection of each lesson, participants were given a brief review of mathematics concepts that they have learned from their teacher in the classroom.
• Problem practice phase: After a brief review, participants practiced solving problems with the assistance of a PA. The PA provided adaptive corrective feedback based on participants’ performances. Figure 6 shows the example when student answer is correct, and Figure 7 shows the example when student answer is wrong.

• Test phase: At the beginning and the end of each lesson, participants were given a short quiz to test their knowledge about the math concepts before and after they interacted with the PA (see Figure 8).
Figure 6. An example screenshot of the problem practice when student answer is correct.

Figure 7. An example screenshot of the problem practice when student answer is wrong.
Anxiety Treatment

Based on Dugas and Robichaud’s (2007) cognitive-behavioral therapy for generalized anxiety disorder, a series of mathematics anxiety treatment messages were developed and incorporated into MathGirls (see appendix C). These treatment messages were used to help students be aware of and positively cope with their anxiety when doing mathematics. Intermittently in the lesson, the PA asked a student “Ok, how confident do you feel about multiplying numbers now? Feeling anxious when solving math problems is a common sense among us. Do you have such thought like ‘some people can do math, but not me’, ‘I don’t like math and it is not useful’, ‘my mind goes completely blank, I feel stupid’, or ‘I can’t remember how to do even the simplest things?’” If a student’s answer is yes, the PA replied “Stop telling yourself that you are stupid and that you can’t do math.
Your thought is the one that counts. If you tell yourself that you can’t do math, then you really can’t do math. It is not because you don’t have the ability to do it. It is because you won’t put forth the effort necessary to do it. Since you can’t do it anyway, why try it? With the time and practice, you will find that you are no longer afraid of doing math.” If a student’s answer is no, the PA encouraged the student to keep confident and doing good work. Figure 9 shows an example of interface screen that the PA provided student with mathematics anxiety treatment messages.

![An example screenshot of an interface providing mathematics anxiety treatment messages.](image)

Figure 9. An example screenshot of an interface that providing mathematics anxiety treatment messages.
Procedure

This study was implemented in four consecutive days in a computer lab of the participating school with collaboration from mathematics teachers, one lesson a day. The school has a 60-minute-class hour. Each of the intervention lessons took an average of 50 minutes, with individual variations. The overall procedures were as follows:

- The researcher gave a brief introduction to the purpose of this study and told students how to use the instructional materials, MathGirls. Then, students were asked to put on the headset to avoid distraction from each other’s work.
- Students accessed the web site and input their demographic information to log onto MathGirls. The system randomly assigned students to one of the experimental conditions: the presence of treatment messages (TR) or the absence of treatment messages (NoTR).
- Students took pretests (mathematics anxiety rating scale only on the first day and mathematics quiz in every lesson).
- Students performed the learning task and listened to the agent’s content-related and mathematics anxiety treatment messages, which took an average of 35 minutes.
- Students took posttests (mathematics anxiety rating scale only on the last day and mathematics quiz in every lesson).
Data Analysis

This study employed a randomized pretest posttest experimental design. All the participants were randomly assigned to one of the two conditions by system programming: the presence of the treatment messages provided by the PA (TR), and the absence of the treatment messages (NoTR). The independent variables included the use of mathematics anxiety treatment messages (presence vs. absence), student gender (male vs. female), and student’s prior mathematics anxiety levels (low vs. medium vs. high).

Data analysis for this study was divided into three steps.

In the first step, preliminary data analyses were conducted. First, the pretest mean scores of mathematics anxiety and mathematics learning for two experimental conditions were provided to test the randomization success. Second, several tests were conducted to assess violations of the assumptions for statistical procedures. Since this study used a repeated measures analysis of variance (ANOVA) method to answer research questions, the following three assumptions were tested in order to receive unbiased and reliable F-values: the normality of the dependent variables, the homogeneity of variance, and the homogeneity of covariance. Descriptive statistics for the dependent variables (mathematics anxiety and mathematics learning) in each condition were provided. In the third step, the primary analyses were conducted as follows to address all six hypotheses of research questions. Data from 128 participants (60 in TR condition, 68 in NoTR) were analyzed to answer research questions.

Hypothesis 1: Participants in the TR condition would lower their mathematics anxiety more than those in the NoTR condition. To test this hypothesis, a repeated
measures analysis of variance (ANOVA) was conducted to test the two-way interaction effect between time and condition. The within-groups variable was time, which was defined as time 1 for student pretest and time 2 for student posttest on mathematics anxiety. The between-groups variable was condition, which was defined as mathematics anxiety treatment messages (condition: presence vs. absence). The dependent variable was student scores on mathematics anxiety tests. The statistical significant level was set at $\alpha < .05$.

**Hypothesis 2:** Female participants in the TR condition would lower their mathematics anxiety more than those in the NoTR condition, whereas the treatment messages would have less impact on mathematics anxiety of male participants. To test this hypothesis, a repeated measures ANOVA was performed to test the three-way interaction effect between time, condition, and student gender. The within-groups variable was time, which was defined as time 1 for student pretest and time 2 for student posttest on mathematics anxiety. The between-groups variables were mathematics anxiety treatment messages (condition: presence vs. absence) and student gender (male vs. female). The dependent variable was student scores on mathematics anxiety tests. The statistical significant level was set at $\alpha < .05$.

**Hypothesis 3:** High-anxious participants in the TR condition would lower their mathematics anxiety more than those in the NoTR condition, whereas the treatment messages would have less impact on mathematics anxiety of medium- and low-anxious participants. To test this hypothesis, a repeated measures ANOVA was performed to test the three-way interaction effect between time, condition, and student prior mathematics anxiety levels. The within-groups variable was time, which was defined as time 1 for
student pretest and time 2 for student posttest on mathematics anxiety. The between-
groups variables were mathematics anxiety treatment messages (condition: presence vs. absence) and student prior mathematics anxiety levels (high vs. medium vs. low). The dependent variable was student scores on mathematics anxiety tests. The statistical significant level was set at $\alpha < .05$.

**Hypothesis 4:** Participants in the TR condition would increase their mathematics learning more than those in the NoTR condition. To test this hypothesis, a repeated measures ANOVA was conducted to test the two-way interaction effect between time and condition. The within-groups variable was time, which was defined as time 1 for student pretest and time 2 for student posttest on mathematics learning. The between-groups variable was mathematics anxiety treatment messages (condition: presence vs. absence). The dependent variable was student scores on mathematics learning tests. The statistical significant level was set at $\alpha < .05$.

**Hypothesis 5:** Female participants in the TR condition would increase their mathematics learning more than those in the NoTR condition, whereas the treatment messages would have less impact on mathematics learning of male participants. To test this hypothesis, a repeated measures ANOVA was performed to test the three-way interaction effect between time, condition, and student gender. The within-groups variable was time, which was defined as time 1 for student pretest and time 2 for student posttest on mathematics learning. The between-groups variables were mathematics anxiety treatment messages (condition: presence vs. absence) and student gender (male vs. female). The dependent variable was student scores on mathematics learning tests. The statistical significant level was set at $\alpha < .05$. 
**Hypothesis 6:** High-anxious participants in the TR condition would increase their mathematics learning more than those in the NoTR condition, whereas the treatment messages would have less impact on mathematics learning of medium- and low-anxious participants. To test this hypothesis, a repeated measures ANOVA was performed to test the three-way interaction effect between time, condition, and student prior mathematics anxiety levels. The within-groups variable was time, which was defined as time 1 for student pretest and time 2 for student posttest on mathematics learning. The between-groups variables were mathematics anxiety treatment messages (condition: presence vs. absence) and student prior mathematics anxiety levels (high vs. medium vs. low). The dependent variable was student score on mathematics learning tests. The statistical significant level was set at $\alpha < .05$. 
CHAPTER IV
RESULTS

This study investigated the main effect of the PA’s mathematics anxiety treatment messages, the interaction effect of treatment messages and student gender, and the interaction effect of treatment messages and student’s prior mathematics anxiety on mathematics anxiety and mathematics learning, with ninth-grade students taking required introductory algebra. To test the research hypotheses, repeated measures ANOVAs were conducted using SPSS 15.0 software (2007). For the purpose of displaying the research results, this chapter consists of three sections. The first section presents preliminary data analyses that have examined whether the assumptions of statistical procedures were met. The second section presents descriptive statistics for dependent variables. The third section presents the results of primary data analyses for each research hypothesis.

Preliminary Data Analysis

This section reports the test of randomization success and the tests of assumptions of repeated measures ANOVA.

Randomization Success

Participants were randomly assigned to one of the two experimental conditions by the system: the presence of the PA’s treatment messages (TR) and the absence of the PA’s treatment messages (NoTR). The first student who logged onto the system was assigned
to one experimental condition (e.g., TR), the second student who logged onto the system was assigned to the other experimental condition (e.g., NoTR), and this alternation continued until all students logged onto the system. This meant that each participant had an equal opportunity of being in each experimental condition.

In order to verify the randomization success statistically, two one-way analyses of variance (ANOVAs) were performed to investigate the difference between two experimental conditions regarding participants’ prior mathematics anxiety and mathematics learning. There was no significant difference between two experimental conditions on participants’ prior mathematics anxiety, $F (1, 126) = .36, p = .55$. Also, there was no significant difference between two experimental conditions on participants’ prior mathematics learning, $F (1, 126) = .03, p = .86$. The results indicated that participants’ prior mathematics anxiety and prior mathematics learning were not different from each other between two experimental conditions. Table 1 presents the mean scores and standard deviations for participants’ pretest of mathematics anxiety and mathematics learning for each condition.

Table 1

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Mathematics Anxiety M</th>
<th>SD</th>
<th>n</th>
<th>Mathematics Learning M</th>
<th>SD</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>29.57</td>
<td>11.00</td>
<td>60</td>
<td>16.93</td>
<td>5.46</td>
<td>60</td>
</tr>
<tr>
<td>No Treatment</td>
<td>28.44</td>
<td>10.27</td>
<td>68</td>
<td>16.76</td>
<td>5.47</td>
<td>68</td>
</tr>
<tr>
<td>Total</td>
<td>28.97</td>
<td>10.59</td>
<td>128</td>
<td>16.84</td>
<td>5.45</td>
<td>128</td>
</tr>
</tbody>
</table>

*Note.* The possible score range for mathematics anxiety is 16-80. The possible score range for mathematics learning is 0-29.
Demographic Information of Drop-outs

In this study, 33 students were not included in data analysis due to their tardiness or absence from school. The average age of these 33 students was 15.70 (SD = 1.08). The compositions of student ethnicity were: Caucasian (48.5%), Hispanic (27.3%), African-American (3.0%), Asian (3.0%), and Others (18.2%). Of the 33 students, 18 (54.5%) students were male and 15 (45.5%) students were female. The Chi-square analyses indicated that there was no association between student gender and whether or not they finished the study (\( \chi^2 = .90, p = .34 \)) and no association between student ethnicity and whether or not they finished the study (\( \chi^2 = 2.67, p = .61 \)). Therefore, the researcher concluded that 33 students who did not complete this study were demographically similar to the participants who completed this study.

Tests of the Assumptions of Repeated Measures ANOVA

Normality. Normality assumption in repeated measures ANOVA requires that the dependent variables should be normally distributed around the mean for each treatment level. The Kolmogorov-Smirnov (K-S) test was performed for pretests and posttests of mathematics anxiety and mathematics learning. The Q-Q plot was provided (see Appendix D, E, F, & G). The K-S test indicated that (1) the distribution of prior mathematics anxiety for the TR condition was normal, \( D (60) = .11, p = .08 \), and that of the NoTR condition was non-normal, \( D (68) = .12, p < .05 \); (2) the distribution of post-mathematics-anxiety for the TR condition, \( D (60) = .15, p < .05 \), and the NoTR condition, \( D (68) = .18, p < .05 \), were both non-normal; (3) the distribution of prior mathematics learning for the TR condition, \( D (60) = .09, p = .20 \), and the NTR condition, \( D (68) = .11 \),
$p = .06$, were both normal; 4) the distribution of post-mathematics-learning for the TR condition was normal, $D(60) = .11, p = .08$, and that of NTR condition was non-normal, $D(68) = .15, p < .05$. Although the dependent variables were not normally distributed around the mean at some treatment levels, the repeated measures ANOVA is not very sensitive to non-normal distribution. So violation of this assumption is rarely a cause for concern (Cohen, 2001).

**Homogeneity of variance.** Homogeneity of variance refers to the variances of the groups are the same (Field, 2005). Levene’s statistic on the mathematics anxiety pretest ($p = .69$), mathematics anxiety posttest ($p = .18$), mathematics learning pretest ($p = .86$), and mathematics learning posttest ($p = .83$) were not significant. Therefore, this assumption was satisfied.

**Sphericity.** Sphericity refers to the equality of variances of the differences between treatment measures (Field, 2005). Since there were only two measures (pre and posttest), therefore, the sphericity can be ignored.

**Descriptive Statistics**

Descriptive statistics for the pretest and posttest of mathematics anxiety are shown in Table 2. The pretest and posttest scores of mathematics anxiety ranged from 16 to 80. The higher score indicated higher level of mathematics anxiety and lower score indicated lower level of mathematics anxiety.
Table 2

Means and Standard Deviation for pretest and posttest of mathematics anxiety

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Pretest</th>
<th></th>
<th>Posttest</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>N</td>
<td>M</td>
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<tr>
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<td>128</td>
<td>27.34</td>
</tr>
</tbody>
</table>

Note. The possible score range for math anxiety is 16-80.

Descriptive statistics for the pretest and posttest of mathematics learning are shown in Table 3. The pretest and posttest scores of mathematics learning ranged from 0 to 29. The higher score indicated higher achievement and lower score indicated lower achievement.

Table 3

Means and Standard Deviation for pretest and posttest of mathematics learning

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Pretest</th>
<th></th>
<th>Posttest</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>N</td>
<td>M</td>
</tr>
<tr>
<td>Treatment</td>
<td>16.93</td>
<td>5.46</td>
<td>60</td>
<td>20.68</td>
</tr>
<tr>
<td>No Treatment</td>
<td>16.76</td>
<td>5.47</td>
<td>68</td>
<td>20.34</td>
</tr>
<tr>
<td>Total</td>
<td>16.84</td>
<td>5.45</td>
<td>128</td>
<td>20.50</td>
</tr>
</tbody>
</table>

Note. The possible score range for math performance is 0-29.

Main Analysis: Hypothesis Testing

The Main Effects of Mathematics Anxiety Treatment Messages

To test the main effect of the treatment messages on mathematics anxiety (Hypothesis 1) and mathematics learning (Hypothesis 4), two repeated measures
Anovas were performed.

**The effect on mathematics anxiety.** Hypothesis 1 predicted that participants in the TR condition would decrease their mathematics anxiety more than those in the NoTR condition. A repeated measures ANOVA revealed that the effect of treatment messages on mathematics anxiety was not significant, $F = 1.18, p = .28, \eta^2 = .01$ (see Table 4). Both TR and NoTR group participants decreased their mathematics anxiety (see Table 2). Mean scores for the TR group decreased from 29.57 ($SD = 11.00$) to 28.75 ($SD = 12.20$) (the mean score difference was 0.82), and mean scores of the NoTR group decreased from 28.44 ($SD = 10.27$) to 26.10 ($SD = 10.63$) (the mean score difference was 2.34).

**Table 4**

<table>
<thead>
<tr>
<th>Source</th>
<th>$F$</th>
<th>$df$</th>
<th>$p$</th>
<th>$\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>5.06</td>
<td>1</td>
<td>.03*</td>
<td>.04</td>
</tr>
<tr>
<td>Time $\times$ Condition</td>
<td>1.18</td>
<td>1</td>
<td>.28</td>
<td>.01</td>
</tr>
</tbody>
</table>

* $p < .05$

**The effect on mathematics learning.** Hypothesis 4 predicted that participants in the TR condition would increase their learning more than those in the NoTR condition. A repeated measures ANOVA revealed that the effect of treatment messages on mathematics learning was not significant, $F = .08, p = .78, \eta^2 = .001$ (see Table 5). Both TR and NoTR group participants increased their mathematics learning (see Table 3). Mean scores for the TR group increased from 16.93 ($SD = 5.46$) to 20.68 ($SD = 5.72$) (the mean score difference was 3.75), and mean scores for the NoTR group increased from
Table 5

Main and Interaction Effect on Mathematics Learning for a Repeated Measures ANOVA

<table>
<thead>
<tr>
<th>Source</th>
<th>F</th>
<th>df</th>
<th>P</th>
<th>η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>130.56</td>
<td>1</td>
<td>.000*</td>
<td>.51</td>
</tr>
<tr>
<td>Time × Condition</td>
<td>.08</td>
<td>1</td>
<td>.78</td>
<td>.001</td>
</tr>
</tbody>
</table>

*p < .001

The Interaction Effects of the Treatment Messages and Student Gender

To test the interaction effect of the treatment messages and student gender on mathematics anxiety (Hypothesis 2) and mathematics learning (Hypothesis 5), two 3-way repeated measures ANOVAs were conducted, with time, condition, and student gender as factors.

The interaction effect on mathematics anxiety. Hypothesis 2 predicted that female participants in the TR condition would decrease their anxiety more than those in the NoTR condition, whereas treatment messages would have less impact on mathematics anxiety of male participants. The descriptive statistics for this analysis are presented in Table 6.

A repeated measures ANOVA revealed that the interaction effect of time, condition, and student gender was not significant, $F = 0.05, p = .82, \eta^2 = .00$ (see Table 7). This indicated that the treatment messages did not affect male and female participants differently on their mathematics anxiety over time. Female participants in both TR and NoTR conditions decreased their mathematics anxiety (see Table 6). Mean scores for the
TR group decreased from 29.55 ($SD = 9.83$) to 28.66 ($SD = 11.10$) (the mean score difference was 0.89), and mean scores for the NoTR group decreased from 29.15 ($SD = 10.79$) to 26.49 ($SD = 10.59$) (the mean score difference was 2.66). Male participants in both TR and NoTR conditions decreased their mathematics anxiety as well (see Table 6). Mean scores for the TR group decreased from 29.58 ($SD = 12.16$) to 28.84 ($SD = 13.32$) (the mean score difference was 0.74), and mean scores for the NoTR group decreased from 27.37 ($SD = 9.52$) to 25.52 ($SD = 10.86$) (the mean score difference was 1.85).

Table 6

Means and Standard Deviation on Mathematics Anxiety for Female and Male Students in Each Condition

<table>
<thead>
<tr>
<th>Gender</th>
<th>Condition</th>
<th>Time 1 (Pretest)</th>
<th>Time 2 (Posttest)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
<td>Female</td>
<td>Treatment</td>
<td>29.55</td>
<td>9.83</td>
</tr>
<tr>
<td></td>
<td>No Treatment</td>
<td>29.15</td>
<td>10.79</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>29.35</td>
<td>10.31</td>
</tr>
<tr>
<td>Male</td>
<td>Treatment</td>
<td>29.58</td>
<td>12.16</td>
</tr>
<tr>
<td></td>
<td>No Treatment</td>
<td>27.37</td>
<td>9.52</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>28.48</td>
<td>10.84</td>
</tr>
</tbody>
</table>

Table 7

Main and Interaction Effects on Mathematics Anxiety for a Repeated Measures ANOVA

<table>
<thead>
<tr>
<th>Source</th>
<th>$F$</th>
<th>$df$</th>
<th>$p$</th>
<th>$\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>4.63</td>
<td>1</td>
<td>.03*</td>
<td>.04</td>
</tr>
<tr>
<td>Time $\times$ Condition</td>
<td>1.01</td>
<td>1</td>
<td>.32</td>
<td>.01</td>
</tr>
<tr>
<td>Time $\times$ gender</td>
<td>0.11</td>
<td>1</td>
<td>.74</td>
<td>.001</td>
</tr>
<tr>
<td>Time $\times$ Condition $\times$ Student gender</td>
<td>0.05</td>
<td>1</td>
<td>.82</td>
<td>.00</td>
</tr>
</tbody>
</table>

* $p < .05$
**The interaction effect on mathematics learning.** Hypothesis 5 predicted that female participants in the TR condition would increase their mathematics learning more than those in the NoTR condition, whereas treatment messages would have less impact on mathematics learning of male participants. The descriptive statistics for this analysis are presented in Table 8.

Table 8

*Means and Standard Deviation of Mathematics Learning for Female and Male Students in Each Condition*

<table>
<thead>
<tr>
<th>Gender</th>
<th>Condition</th>
<th>Time 1 (Pretest)</th>
<th>Time 2 (Posttest)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Female</td>
<td>Treatment</td>
<td>16.52</td>
<td>5.21</td>
</tr>
<tr>
<td></td>
<td>No Treatment</td>
<td>16.05</td>
<td>5.53</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>16.29</td>
<td>5.37</td>
</tr>
<tr>
<td>Male</td>
<td>Treatment</td>
<td>17.32</td>
<td>5.74</td>
</tr>
<tr>
<td></td>
<td>No Treatment</td>
<td>17.85</td>
<td>5.30</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>17.59</td>
<td>5.52</td>
</tr>
</tbody>
</table>

A repeated measures ANOVA revealed that the interaction effect of time, condition, and student gender was not significant, $F = 2.28$, $p = .13$, $\eta^2 = .02$ (see Table 9). This indicated that treatment messages did not affect male and female students’ mathematics learning differently over time. Female participants in both TR and NoTR conditions increased their learning (see Table 8). Mean scores for the TR group increased from 16.52 ($SD = 5.21$) to 19.66 ($SD = 5.70$) (the mean score difference was 3.14), and mean scores for the NoTR group increased from 16.05 ($SD = 5.53$) to 19.93 ($SD = 5.88$) (the mean score difference was 3.88). Male participants in both TR and NoTR conditions
increased their learning as well (see Table 8). Mean scores for the TR group increased from 17.32 ($SD = 5.74$) to 21.65 ($SD = 5.67$) (the mean score difference was 4.33), and mean scores for the NoTR group increased from 17.85 ($SD = 5.30$) to 20.96 ($SD = 5.75$) (the mean score difference was 3.11).

Table 9

**Main and Interaction Effects on Mathematics Learning for a Repeated Measures ANOVA**

<table>
<thead>
<tr>
<th>Source</th>
<th>$F$</th>
<th>$df$</th>
<th>$p$</th>
<th>$\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>124.75</td>
<td>1</td>
<td>.00*</td>
<td>.50</td>
</tr>
<tr>
<td>Time $\times$ Condition</td>
<td>0.13</td>
<td>1</td>
<td>.72</td>
<td>.001</td>
</tr>
<tr>
<td>Time $\times$ gender</td>
<td>0.10</td>
<td>1</td>
<td>.75</td>
<td>.001</td>
</tr>
<tr>
<td>Time $\times$ Condition $\times$ Student gender</td>
<td>2.28</td>
<td>1</td>
<td>.13</td>
<td>.02</td>
</tr>
</tbody>
</table>

* $p < .001$

**The Interaction Effect of the Treatment Messages and Student’s Prior Mathematics Anxiety Levels**

To test the interaction effect of the treatment messages and prior mathematics anxiety on mathematics anxiety (Hypothesis 3) and mathematics learning (Hypothesis 6), two 3-way repeated measures ANOVAs were conducted, with time, condition, and prior anxiety levels as factors.

**The interaction effect on mathematics anxiety.** Hypothesis 3 predicted that high-anxious participants in the TR condition would decrease their anxiety more than those in the NoTR condition, whereas treatment messages would have less impact on mathematics anxiety of medium- and low-anxious students. The descriptive statistics for this analysis are presented in Table 10.
Table 10

Means and Standard Deviation of Mathematics Anxiety for High-, Medium-, and Low-anxious Students in Each Condition

<table>
<thead>
<tr>
<th>Anxious Levels</th>
<th>Condition</th>
<th>Time 1 (Pretest)</th>
<th>Time 2 (Posttest)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>High</td>
<td>Treatment</td>
<td>46.92</td>
<td>5.37</td>
</tr>
<tr>
<td></td>
<td>No Treatment</td>
<td>44.67</td>
<td>6.39</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>45.80</td>
<td>5.88</td>
</tr>
<tr>
<td>Medium</td>
<td>Treatment</td>
<td>28.29</td>
<td>5.67</td>
</tr>
<tr>
<td></td>
<td>No Treatment</td>
<td>27.27</td>
<td>6.25</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>27.78</td>
<td>5.96</td>
</tr>
<tr>
<td>Low</td>
<td>Treatment</td>
<td>17.00</td>
<td>0.82</td>
</tr>
<tr>
<td></td>
<td>No Treatment</td>
<td>16.50</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>16.75</td>
<td>0.81</td>
</tr>
</tbody>
</table>

A repeated measures ANOVA revealed that the interaction effect of time, condition, and prior anxiety was significant, $F = 3.56, p < .05, \eta^2 = .06$ (see Table 11). Further analyses, three one-way repeated measures ANOVAs, revealed that the effect of treatment messages was significant for medium-anxious students ($F = 7.19, p < .01, \eta^2 = .09$), whereas the effect of treatment messages was not significant for high- ($F = 0.41, p = .53, \eta^2 = .02$) and low-anxious students ($F = 1.98, p = .17, \eta^2 = .08$). High-anxious participants in both TR and NoTR conditions decreased their mathematics anxiety (see Table 10). Mean scores for the TR group decreased from 46.92 ($SD = 5.37$) to 40.75 ($SD = 10.87$) (the mean score difference was 6.17), and Mean scores for the NoTR group decreased from 44.67 ($SD = 6.39$) to 41.17 ($SD = 9.43$) (the mean score difference was 3.5). For medium-anxious participants, those in the TR condition increased their anxiety from 28.29 ($SD = 5.67$) to 29.03 ($SD = 10.67$) (the mean score difference was 0.74) whereas those in the NoTR condition decreased their anxiety from 27.27 ($SD = 6.25$) to
23.70 (SD = 7.39) (the mean score difference was 3.57) (see Figure 10). For low-anxious participants, those in the TR condition showed the consistent level of anxiety from 17.00 (SD = 0.82) to 16.92 (SD = 2.22) (the mean score difference was 0.08) whereas those in the NoTR condition increased their anxiety from 16.50 (0.80) to 19.83 (8.52) (the mean score difference was 3.33) (see Figure 10).

Table 11

<table>
<thead>
<tr>
<th>Source</th>
<th>F</th>
<th>df</th>
<th>p</th>
<th>η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>3.93</td>
<td>1</td>
<td>.05*</td>
<td>.03</td>
</tr>
<tr>
<td>Time × Condition</td>
<td>0.14</td>
<td>1</td>
<td>.71</td>
<td>.001</td>
</tr>
<tr>
<td>Time × Prior anxiety levels</td>
<td>4.46</td>
<td>2</td>
<td>.02*</td>
<td>.07</td>
</tr>
<tr>
<td>Time × Condition × Prior anxiety levels</td>
<td>3.56</td>
<td>2</td>
<td>.03*</td>
<td>.06</td>
</tr>
</tbody>
</table>

*p < .05

In addition, as seen in Table 11, there was a significant two-way interaction effect between time and student’s prior anxiety, $F = 4.46, p < .05, \eta^2 = .07$. Regardless of the treatment, high-anxious students decreased their anxiety more than medium-anxious students whereas low-anxious students increased their anxiety after the intervention (see Figure 11). High-anxious students decreased their anxiety from pretest ($M = 45.80, SD = 5.88$) to posttest ($M = 40.96, SD = 10.15$) (the mean score difference was 4.84); medium-anxious students decreased their anxiety from pretest ($M = 27.78, SD = 5.96$) to posttest ($M = 26.37, SD = 9.03$) (the mean score difference was 1.41); and low-anxious students increased their anxiety from pretest ($M = 16.75, SD = 0.81$) to posttest ($M = 18.38, SD = 5.37$) (the mean score difference was 1.63). This indicated that the PA-based learning
Figure 10. Interaction effect between time and condition.
environment affected high-, medium-, and low-anxious students’ anxiety differently.

**Figure 11.** Interaction effect between time and prior anxiety.

**The interaction effect on mathematics learning.** Hypothesis 6 predicted that high-anxious participants in the TR condition would increase their learning more than those in the NoTR condition, whereas treatment messages have less impact on mathematics learning of medium- and low-anxious participants. The descriptive statistics for this analysis are presented in Table 12.

A repeated-measures ANOVA revealed that the interaction effect of time, condition, and student’s prior anxiety on learning was not significant, $F = 0.59$, $p = .56$, $\eta^2 = .01$ (see Table 13). This indicated that the treatment messages did not affect the learning of high-, medium-, and low-anxious students differently over time. High-anxious students in both TR and NoTR conditions increased their learning. Mean scores for the TR group increased from 16.58 ($SD = 4.64$) to 19.58 ($SD = 4.72$) (the mean score
Table 12

Means and Standard Deviation of Mathematics Learning for High-, Medium-, and Low-anxious Students in Each Condition

<table>
<thead>
<tr>
<th>Anxious Levels</th>
<th>Condition</th>
<th>Time 1 (Pretest)</th>
<th>Time 2 (Posttest)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>High</td>
<td>Treatment</td>
<td>16.58</td>
<td>4.64</td>
</tr>
<tr>
<td></td>
<td>No Treatment</td>
<td>17.08</td>
<td>4.96</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>16.83</td>
<td>4.80</td>
</tr>
<tr>
<td>Medium</td>
<td>Treatment</td>
<td>17.71</td>
<td>5.73</td>
</tr>
<tr>
<td></td>
<td>No Treatment</td>
<td>16.27</td>
<td>6.07</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>16.99</td>
<td>5.90</td>
</tr>
<tr>
<td>Low</td>
<td>Treatment</td>
<td>15.15</td>
<td>5.32</td>
</tr>
<tr>
<td></td>
<td>No Treatment</td>
<td>18.25</td>
<td>3.22</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>16.70</td>
<td>4.27</td>
</tr>
</tbody>
</table>

difference was 3.0), and mean scores for the NoTR group increased from 17.08 (SD = 4.96) to 18.50 (SD = 6.38) (the mean score difference was 1.42). Medium-anxious students in both TR and NoTR conditions increased their learning. Mean scores for the TR group increased from 17.71 (SD = 5.73) to 21.69 (SD = 5.96) (the mean score difference was 3.98), and mean scores for the NoTR group increased from 16.27 (SD = 6.07) to 20.23 (SD = 6.16) (the mean score difference was 3.96). Low-anxious students in both TR and NoTR conditions increased their learning. Mean scores for the TR group increased from 15.15 (SD = 5.32) to 19.00 (SD = 5.72) (the mean score difference was 3.85), and mean scores for the NoTR group increased from 18.25 (SD = 3.22) to 22.58 (SD = 2.68) (the mean score difference was 4.33).
Table 13

*Main and Interaction Effects on Mathematics Learning for a Repeated Measures ANOVA*

<table>
<thead>
<tr>
<th>Source</th>
<th>F</th>
<th>Df</th>
<th>p</th>
<th>$\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>86.41</td>
<td>1</td>
<td>.000*</td>
<td>.42</td>
</tr>
<tr>
<td>Time $\times$ Condition</td>
<td>0.25</td>
<td>1</td>
<td>.62</td>
<td>.002</td>
</tr>
<tr>
<td>Time $\times$ Prior anxiety levels</td>
<td>2.42</td>
<td>2</td>
<td>.09</td>
<td>.04</td>
</tr>
<tr>
<td>Time $\times$ Condition $\times$ Prior anxiety levels</td>
<td>0.59</td>
<td>2</td>
<td>.56</td>
<td>.01</td>
</tr>
</tbody>
</table>

* $p < .001$
CHAPTER V
DISCUSSION

Introduction

Prior studies indicated that a PA can function as a social cognitive tool to scaffold learner’s affect through social interaction with a learner (Kim, Xu, & Wei, 2007). Cognitive-behavioral therapies that help people be aware of and positively cope with their fear of doing mathematics have been suggested as an effective way of treating mathematics anxiety in clinical settings (Hackworth, 1992; Williams, 1988).

In this study, a cognitive-behavioral approach was integrated into the messages that were provided by a PA to reduce high-school students’ mathematics anxiety in computer-based learning environment. First, it was expected that, by simulating the role of a teacher trying to reduce students’ mathematics anxiety, a PA would help learners be aware of and positively deal with their anxiety when doing mathematics. Also, gender difference exists in motivation to work with an agent. Girls tend to interact more frequently with an agent than boys (Robertson et al., 2004) and hold more positive attitudes about working with agents (Kim, Wei, Xu, & Ko, 2007). Therefore, it was expected that the impact of treatment messages provided by a PA on male and female students would vary. Further, because the treatment messages were delivered consistently to all the students in the treatment condition, it was expected that the impact of treatment messages provided by a PA on high-, medium-, and low-anxious students would be different. High-anxious students were expected to benefit from the treatment messages
more than medium- and low-anxious students.

In this chapter, the findings of the study are discussed in terms of the three expectations: (1) the effects of mathematics anxiety treatment messages, (2) the interaction effects of treatment messages and student gender, and (3) the interaction effects of treatment messages and student prior mathematics anxiety. Following that, the implications and limitation of this study and recommendations for future research are discussed.

Discussion

The Effects of Mathematics Anxiety Treatment Messages

The effect on mathematics anxiety. The treatment messages provided by a PA did not contribute to decreasing students’ mathematics anxiety, which failed to support Hypothesis 1. This might be because the treatment messages were not individualized but uniform to every student. Helping students be aware of and positively cope with their mathematics anxiety has been considered as an effective method for treating mathematics anxiety in counseling settings (Foss & Hadfield, 1993; Zettle, 2003), where treatments are tailored to a patient’s needs. In this study, the mathematics anxiety treatment messages provided by a PA employed the awareness building and coping strategies, without tailoring to individual learners.

Additionally, the results indicated that participants in both TR and NoTR conditions decreased their mathematics anxiety after the intervention. It is plausible that the mathematics anxiety of the TR group decreased, but questionable why the NoTR
group’s anxiety also decreased. Reasons might include: (1) students received content-related corrective feedback during the task that guided them through a right way of doing the problems, and (2) the intervention, MathGirls, was a highly structured algebra learning environment, in which students went through the review, problem practice, and tests step by step. This stepwise structure might help ease the students and thereby reduce students’ mathematics anxiety (Aksu & Saygi, 1988; Norwood, 1994), even without the anxiety treatment messages.

**The effect on mathematics learning.** The treatment messages provided by a PA did not contribute to increasing students’ mathematics learning. This result failed to support the hypothesis 4 that participants in the TR condition would increase their learning more than those in the NoTR condition. Rather, participants in both TR and NoTR conditions increased their learning after the intervention. The content-related corrective feedback provided by a PA that guided students to solving problems correctly in both TR and NoTR condition may contribute to this result.

To summarize, the treatment messages provided by a PA did not have an impact on students’ mathematics anxiety and mathematics learning. Both TR and NoTR groups decreased their mathematics anxiety and increased their mathematics learning. This result, at least, suggests that a PA-based environment could be used as a tool to care for students’ affect (Kim et al., 2007) and promote their learning (Moreno et al., 2001).

**The Interaction Effects of Treatment Messages and Student Gender**

**The interaction effect on mathematics anxiety.** There was no significant
interaction effect of treatment messages and student gender on mathematic anxiety over time. This result failed to support the Hypothesis 2 that female participants in the TR condition would decrease their anxiety more than those in the NoTR condition whereas treatment messages would have less impact on mathematics anxiety of male participants. The result was different from a previous study that reported girls responded more positively to the PA that provided affect support than the PA that provided task support (Burleson & Picard, 2007). In this study, female students in NoTR condition decreased their mathematics anxiety more (mean decrease of 2.66) than those in TR conditions (mean decrease of 0.89). Male students had the same pattern that the NoTR group (mean decrease of 1.85) decreased their anxiety more than TR group (mean decrease of 0.74). It could be inferred that the PA-based environment itself may be sufficient for reducing students’ mathematics anxiety; adding the treatment messages may be redundant or unnecessary.

**The interaction effect on mathematics learning.** There was no significant interaction effect of treatment messages and student gender on mathematics learning over time. This result failed to support the Hypothesis 5 that female participants in the TR condition would increase their learning more than those in the NoTR condition whereas treatment messages would have less impact on mathematics learning of male participants. Rather, female students in the NoTR condition increased their mathematics learning more (mean increase of 3.88) than those in the TR condition (mean increase of 3.14) whereas male students in the TR condition increased their learning more (mean increase of 4.33) than those in the NoTR condition (mean increase of 3.11).
The interaction effect on mathematics anxiety. There was a significant interaction effect of treatment messages and student prior mathematics anxiety on mathematics anxiety over time. Further analysis revealed that the effect of the treatment messages provided by a PA was significant for medium-anxious students whereas the effect of the treatment messages provided by a PA was not significant for high- and low-anxious students. High-anxious students in the TR condition decreased their anxiety (mean decrease of 6.17) more than high-anxious students in the NoTR condition (mean decrease of 3.50); medium-anxious students in the TR condition slightly increased their anxiety (mean increase of 0.74) whereas medium-anxious students in the NoTR condition (mean decrease of 3.57) decreased their anxiety; and low-anxious students in the TR condition remained their anxiety unchanged whereas low-anxious students in the NoTR condition increased their anxiety (mean increase of 3.33). This result supported part of Hypothesis 3, which stated that high-anxious students in the TR condition would decrease their anxiety more than high-anxious students in the NoTR condition. However, this result might be caused, in part, by the statistical phenomenon, regression toward the mean, which refers to high- and low-anxious students’ tendency to move closer to the center of the distribution on posttest of anxiety. The mean scores of mathematics anxiety pretest for TR condition (46.92) was higher than that for NoTR condition (44.67), so the TR group might have stronger regression to the mean than the NoTR group, which lead to more decrease in anxiety for the TR group than for the NoTR group. This result may suggest that treatment messages would have less impact on mathematics anxiety of
medium-anxious students. For medium-anxious students, the PA-based environment itself might be sufficient to reduce their feelings of fear of doing mathematics. Telling them to cope with their anxiety (integrated in the treatment messages) may have served as a reminder of their worries of doing mathematics and increased their anxiety when doing the task.

**The interaction effect on mathematics learning.** There was no significant interaction effect of treatment messages and student prior mathematics anxiety on mathematics learning over time. This result failed to support Hypothesis 6 that high-anxious participants in the TR condition would increase their learning more than high-anxious participants in the NoTR condition whereas treatment messages would have less impact on mathematics learning of medium- and low-anxious participants. Instead, high-anxious students in both TR and NoTR conditions increased their learning after the intervention.

**Implications**

The previous research showed that a PA could have positive impact on student’s affect (Kim et al., 2007) and that the cognitive-behavioral therapies were effective methods for treating mathematics anxiety in clinical settings (Foss & Hadfield, 1993; Hembree, 1990; Zettle, 2003). Instead of a human therapist, this study used a PA to deliver the cognitive-behavioral therapies, which integrated the PA research and the clinical research. The findings of the study support the effectiveness of the PA-based environment on decreasing learners’ mathematics anxiety and increasing their learning.
However, the anxiety treatment messages did not have an effect on reducing students’ mathematics anxiety. Rather the messages affected the students with high, medium, and low anxiety differently. This finding has important implications for the design and development of an affective PA. That is, design a PA to present affective support (e.g., treatment messages) adaptively to meet individuals’ affective needs. In real life, clinical psychologists are not always available, and treating mathematics anxiety is a time-consuming process. Learners with mathematics anxiety would benefit from a PA if it can provide an appropriate amount of treatment messages tailored to individual’s needs. The findings also implied that teachers should understand the individual differences in treating anxiety and adjust their strategies to help anxious students in classroom settings.

Limitation

This study has several limitations. First, the study did not include a control condition. The results of this study indicated that the participants’ mathematics anxiety decreased, and their mathematics learning increased, regardless of the presence or absence of the treatment messages, student gender, and student prior mathematics anxiety. It is difficult to argue that agent presence would contribute to this impact because there was no control condition without the presence of an agent. Future research might investigate the impact of the treatment messages provided by a PA, compared to a group that receives the same messages in text.

Second, although the treatment messages were developed by the researcher based on cognitive-behavioral therapies, the way of delivering the treatment messages was
limited. The study presented a list of feelings, from which the participants chose one as their feeling that they encountered during the task. The messages should be more helpful if they are designed to accommodate the broader range of the participants’ feelings. That is, a participant can type in his/her feelings, and the PA can provide a treatment message accordingly.

Third, the generalization of this study results is limited. This study was restricted to a sample of ninth-grade students who took Algebra I course in a high school located in the western U.S. About 40% of the students in the sample were minorities. Therefore, the extent to which the findings apply to other subjects, schools, or locations remains to be seen.

Lastly, the duration of the implementations was one week, which was rather short to examine the changes in a psychological construct.

**Recommendations for Future Research**

Given the limitations of the study, future research is recommended to better understand the impact of a PA’s treatment messages. First, the study did not include a control group without the intervention or without the PA’s presence. Therefore, it is somewhat difficult to attribute the anxiety reduction and learning increase after the intervention to the benefit of the PA-based environment overall or to the benefit of the PA’s presence. Future research should clarify this issue with a more sophisticated design.

Second, future research should use advanced technology to design a more sophisticated learning environment so that students can type in their thoughts during
problem solving. Thus, researcher can vary the amount of treatment messages according to the individuals’ anxiety levels.

Lastly, a week-long intervention is short to examine the changes in anxiety. Also, this study did not examine a three-way interaction of treatment messages, student gender, and prior anxiety. Therefore, future research might replicate the study in a longer term and examine the three way interaction.
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Appendix A

Mathematics Anxiety Rating Scale
Mathematics Anxiety Rating Scale

The items in the questionnaire refer to things and experiences that may cause tension or apprehension. For each item, place a check (√) in the circle under the column that describes how much you would be made anxious by it. Work quickly, but be sure to think about each item.

<table>
<thead>
<tr>
<th>Item</th>
<th>Not at all</th>
<th>A little</th>
<th>A fair amount</th>
<th>Much</th>
<th>Very much</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watching a teacher work an algebraic equation on the blackboard.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buying a math textbook.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading and interpreting graphs or charts.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signing up for a course in Statistics.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Listening to another student explain a math formula.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking into a math class.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Looking through the pages on a math text.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starting a new chapter in a math book.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking on campus and thinking about a math course.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Picking up a math textbook to begin working on a homework assignment.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading the word “statistics”.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working on an abstract mathematical problem, such as: “if x =</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>outstanding bills, and y = total income, calculate how much you</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>have left for recreational expenditures.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading a formula in chemistry.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Listening to a lecture in a math class.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Having to use the tables in the back of a math book.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Being told how to interpret probability statements.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix B

Math Performance Test
Lesson 1
Pretest

1. $3 - 11 + 8 + 1 - 0 = \phantom{0}$

2. $-2 \times 2 \times 1 \times -9 = \phantom{0}$

3. $-20 \div 4 \div 5 = \phantom{0}$

4. $-50 \div -25 = \phantom{0}$

5. $(10 \div 5)^3 \div -2 = \phantom{0}$

6. $8 \div 1 \div 1 \times (2) - 3 = \phantom{0}$
Lesson 1
Posttest

1. \(2 - 10 + 8 + 1 - 1 = \) ___________

2. \(2 \times 3 \times 2 \times (-3) = \) ___________

3. \(10 \div (-5) \div (-2) = \) ___________

4. \(100 \div 25 \div 2 = \) ___________

5. \( (4 \div 2)^3 \div (-2) = \) ___________

6. \(- (9 \div 3)^2 \times 7 = \) ___________
Lesson 2
Pretest

Simplify the expressions

1. \(4a + 7a = \) ____________________________

2. \(13x - 9x + 7x - 5x = \) ______________________

3. \(5(x+3) = \) _____________________________

4. \(3(x-7) + x = \) __________________________

5. \(3(a+2) - 2(a-5) = \) _____________________

6. \((a+7)(a-3) = \) __________________________
Lesson 2
Posttest

Simplify the expressions

1. \(8ab^2 - 3ab^2 = \) ________________

2. \(9p + 2q - 3q - 3p = \) _____________

3. \(-3(x-3) = \) _________________

4. \(5x + 2(x - 1) = \) _________________

5. \(2(x - y) + 3(a + y) = \) ________________

6. \((-x+7) (-x + 2) = \) _________________
1. Find all positive factors of 27.

2. Identify the prime number: 4, 15, 33, 13, 63

3. Find the prime factorization of 21.

4. Find the prime factorization of 18.

5. Find the greatest common factor of 12 and 16.

6. Find the greatest common factor of 35 and 49.
Lesson 3
Posttest

1. Find all positive factors of 35.

2. Identify the prime number: 14, 25, 65, 17, 81

3. Find the prime factorization of 35.

4. Find the prime factorization of 30.

5. Find the greatest common factor of 28 and 49.

6. Find the greatest common factor of 15 and 18.
Lesson 4
Pretest

1. Please graph (or point) the ordered pair (2, -5) on the coordinate plane.

2. Please graph (or point) the ordered pair (-3, 2) on the coordinate plane.

3. Evaluate the y-value for an x-value of 3 from the equation \( y = 2x \).

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

4. Graph (or point) the ordered pair you calculated for the question 3.

5. Evaluate the y-value for an x-value of -1 from the equation \( y = -3x \).

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1</td>
<td></td>
</tr>
</tbody>
</table>

6. Graph (or point) the ordered pair you calculated for the question 5.

7. Evaluate the y-value from the equation \( y = 2x + 2 \) to get the y-intercept.

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

8. Graph (or point) the y-intercept from the equation \( y = x - 4 \).

9. Graph the line that goes through the origin and has a slope of 1/3.

10. Graph a line using the y-intercept (b) and the slope (m). \( m = -1, b = 4 \).
Lesson 4
Posttest

1. Please graph (or point) the ordered pair (3, -2) on the coordinate plane.

2. Please graph (or point) the ordered pair (-1, 3) on the coordinate plane.

3. Evaluate the y-value for an x-value of 2 from the equation \( y = 4x \).

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

4. Graph (or point) the ordered pair you calculated for the question 3.

5. Evaluate the y-value for an x-value of -3 from the equation \( y = -2x \).

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3</td>
<td></td>
</tr>
</tbody>
</table>

6. Graph (or point) the ordered pair you calculated for the question 5.

7. Evaluate the y-value from the equation \( y = 3x + 4 \) to get the y-intercept.

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

8. Graph (or point) the y-intercept from the equation \( y = 2x - 6 \).

9. Graph the line that goes through point (-3, 2) and has a slope \( m = -2/3 \).

10. Graph the line that has a slope \( m = 2 \) and a y-intercept \( b = -2 \).
Appendix C
Scripts of Mathematics Anxiety Treatment Messages
When you solve math problems, what do you usually do? Please choose one of the following:
1. Looking for cheering up from teachers and your friends.
2. Rechecking your answers over because you are not sure whether you did them correctly.
3. Spending a long time in reading a math problem before solving it because you are not sure that the way you use to solve the problem was right.
4. You always feel confident.

If student choose 1:
Script:
Well, it is ok for you to ask cheering up from others who can help you on math. You might feel a little bit uncertain while solving the problem, but you are on the right track. With time and practice, that worry will go away.

If student choose 2:
Script:
Well, you may not feel confident about your work while solving the math problems. Everyone’s lives are filled with uncertainty. However, with time and practice, you will find that worry will go away.

If student choose 3:
Script:
Well, it is not surprising to hear that you are not a hundred percent sure about the method using for solving the problem. Don’t worry. With time and more practice, you will be confident about the way you use to solve the problem.

If student choose 4:
Script:
Great! Keep on good work

Ok, how confident do you feel now about multiplying numbers? Feeling anxious when solving math problems is a common sense among us. Do you have such thought like:
- Some people can do math, not me.
- I don’t like math and it is not useful
- My mind goes completely blank, I feel stupid
- I can’t remember how to do even the simplest things.

If students answer “yes”
Script:
Stop telling yourself that you are stupid and that you can’t do math. Stop telling yourself that you hate math and that it serves no useful purpose. What would you do if I called
you stupid, or if one of your friends called you stupid? Then why do it to yourself? Your thought is the one that counts. If you tell yourself that you can’t do math, then you really can’t do math. It is not because you don’t have the ability to do it. It is because you won’t put forth the effort necessary to do it. Since you can’t do it anyway, why try it? Tell yourself that math is useful and that you enjoy it.

If students answer “no”
Script:
Superb! Let’s keep doing good work with confidence.

Hey, how are we doing? Do you feel you don’t like solving the problems or solving problems is not useful to you?

If students answer “yes”
Script:
Our thoughts matter a lot. If we think that we don’t like doing math, then we actually can’t do well in math. It is not because of our ability but because of our attitudes. We should put forth the effort and tell ourselves that math is useful and we enjoy it.

If students answer “no”
Script:
Great! Keep staying in confidence and moving on.

As I mentioned before, feeling anxious when solving math problems is natural. Remember that even those who are good at math are somewhat anxious about math too. In math class, have you ever thought like “I don’t like doing math problems”, “I am not good at solving math problems”, or “When I try to solve math problems, it doesn’t work”?

If students answer “yes”
Script:
If you get frustrated with one particular math problem or a part of it, then simply move on to another one. Sometimes you will feel more anxious if you stay with the one that is causing you headaches. So I suggest moving on to another math problem. This helps ease the tension by providing a nice little breather. And the next problem or two may help jog your memory and assist with the problem one.

If students answer “no”
Script:
Great! We should keep positive thoughts and confidence.

Learning math is a common activity in your school life. You might want to avoid learning
math as much as you can because you are afraid of or feel anxious when solving math problems. Have you tried to avoid learning math or doing your homework because you always feel anxious when confronting with math?

If students answer “yes”
Script:
People usually tend to avoid the things that they fear. Like learning math, you might think you will feel less anxious if you don’t do math. But is the avoidance helpful for you to reduce your anxiety about doing math? Of course, the answer is “no”. You might become even more afraid of doing math over time. So if you want to reduce your math anxiety, it is best to face math, solving math problem repeatedly. With the time and practice, you will find that you are no longer afraid of doing math.

If students answer “no”
Script:
Great! Avoiding learning math is not helpful at all. You will be more confident about doing math if you keep doing math everyday.

Are you worried and wanna skip the problem? No way! To become confident, it is best to face solving math problem repeatedly. With the time and practice, you will find that you are no longer afraid of doing math.

If you have a difficulty with one particular question, don’t worry and just do your best, I believe that with time and practice, you will improve.

Let’s think about how anxious we feel when working on math problems. Remember that there is a strong relationship between the way we feel and what we actually do. Our feelings of being anxious about doing math will affect our actual problem-solving. So, to work on problems successfully, we should try to get rid of any worries. Alright?

Don’t get discouraged when you face a difficulty question. Our effort will pay off for sure.

Tell yourself that math is useful and that if others can do math, you sure can.

Alright, we are doing great. We will develop our math skill with time. Let’s be patient with this practice.

Even when we miss a problem, we will do better next. If we are negative about ourselves,
we will get anxious and is not helpful at all. Rather, just face the problems one by one with confidence. I believe with time and practice, you will find that you are no longer afraid of doing math.

I can see our progress over last three sections. Exciting, isn’t it? Even when we face a difficult math problem, let’s just try to tackle it. With time and practice, we will become more confident.

When you get frustrated with one particular problem or a part of it, keep moving on to another one. This helps ease the frustration. Take a deep breath, and the next problem or two may help jog your memory.

Good work! I had so much fun working with you. Keep in mind that improvement is always good, no matter how much or how little. Even if you do fail a math class, that’s not the worst thing in the world. Do you feel you learned something? Did you try your hardest to succeed? If the answers to these are “yes”, then that’s what truly matters!
Appendix D

Q-Q Plot of Pre-mathematics-anxiety
Appendix E

Q-Q Plot of Post-mathematics-anxiety
Normal Q-Q Plot of Post-mathematics-anxiety for TR Condition

Normal Q-Q Plot of Post-mathematics-anxiety for NTR Condition
Appendix F

Q-Q Plot of Pre-mathematics-learning
Appendix G

Q-Q Plot of Post-mathematics-learning
Appendix H

Parent/Youth Consent Form
PARENT/GUARDIAN PERMISSION/YOUTH ASSENT
Students’ Use of a Computer-based Algebra Lesson

Introduction/Purpose: Quan Wei is a Ph.D. student in the Department of Instructional Technology and Learning Science at Utah State University (USU). Professor Yanghee Kim is the principal investigator who has oversight of this study. Quan Wei is conducting research on the use of computers for math learning, and would like to ask your permission to have your student participate in computer-based algebra practice. The proposed study is aimed at investigating how computers can be helpful for math learning. Approximately 100 students will be involved in this research.

Procedures: The project will be implemented in regular math classes held in a computer lab. Students will be asked to do the following:
- students will be given a 5-minute introduction to the activity and how to use the interfaces.
- students will be asked to put on headsets so that students can concentrate on their own tasks.
- students will access the web site and input their demographic information to log onto the instructional module.
- students will answer a few questions about their math anxiety and take pretest on algebra.
- students will perform learning tasks.
- students will answer questions about their math anxiety again and take posttest on algebra.

Benefits: There may not be any direct benefit. However, students may have an opportunity to practice problem solving on algebra. In addition, the investigator may learn more about how to better design effective courseware for math teaching and learning.

Risks: There are no anticipated risks involved in this study.

Confidentiality: All information gathered from your student will be completely confidential. Information from this study will be compiled into a research paper. However, the identity of student will be coded with numeric ID number generated by system programming and will not be associated with any published results for the purpose of protecting privacy. The student’s information will be kept in a secured computer in the researcher’s university office. The researcher and the programmer will be the only persons with access to this information. The code will be stored separately from the data collected, also in a locked file cabinet in a university office. The code linking your student to this study will be destroyed one year after the study has been completed.

Costs: There are no costs to you, nor will there be any compensation for participation in this study.

Voluntary participation: Participation in the study is entirely voluntary. You may refuse to have your student participate or you may withdraw him/her at any time without any consequence. An alternate activity, solving paper-based math problems, will be provided by the teachers for those students who will not be involved in the research. Your student may also withdraw at anytime without consequence.

Copy of consent: You have been given two copies of this parent permission form. Please sign both copies, keep one for yourself, and return the second copy to the researcher.
PARENT/GUARDIAN PERMISSION/YOUTH ASSENT
Students’ Use of a Computer-based Algebra Lesson

Offer to answer questions: If you have additional questions about this study you may contact Quan Wei at (435) 797-2673. She will be happy to talk to you about the study.

IRB Approval Statement: The Institutional Review Board for the protection of human participants at USU has approved this research study. If you have any pertinent questions or concerns about your rights or a research-related injury, you may contact the IRB Administrator at (435) 797-0567. If you have a concern or complaint about the research and you would like to contact someone other than the research team, you may contact the IRB Administrator to obtain information or to offer input.

Investigator Statement: I certify that the research study has been explained to the parent/guardian by me, and that he/she understands the nature and purpose, the possible risks and benefits associated with taking part in this research study. Any questions that have been raised have been answered.

Yanghee Kim, Ph.D. (435) 797-2653

Quan Wei, Ph.D. student (435) 797-2673

Date 4/24/07

Signature of Parent: I understand that you are asking for my permission to allow my student to participate in this research. I understand the purpose, procedures, possible problems and benefits of the study and my student’s rights as a participant in the study. I have received a copy of this form. By signing below, I give permission for my student to participate.

Signature of Parent or Guardian Date

Youth Assent: I understand that my parent/guardian is aware of this research study and that permission has been given for me to participate. I understand that it is up to me to participate even if my parent says yes. If I do not want to be in this study, I do not have to and no one will be upset if I don’t want to participate or if I change my mind later and want to stop. I can ask any questions that I have about this study now or later. By signing below, I agree to participate.

Signature of Student Date
VITA

QUAN WEI

Home Address:

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Logan, UT 84341
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EDUCATIONAL BACKGROUND

2002-2010 Department of Instructional Technology, Utah State University, Logan, UT.
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1994-1999 Lab instructor, Department of Educational Technology, Shandong Teacher’s University, Jinan, Shandong, China.

PUBLICATIONS

Kim, Y., & Wei, Q. (in review). “The Impact of User Attributes and User Choice in an Agent-Based Environment.”


