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The Role of Learner Attributes and Affect Determining the Impact of Agent Presence

Yanghee Kim, Ph. D.

Department of Instructional Technology

Utah State University

2830 Old Main Hill

Logan, UT 84321

Tel (435) 797-2653

Fax (435) 797-2693

yanghee.kim@usu.edu

<http://www.create.usu.edu>

Abstract

This paper introduces two experimental studies that have examined the efficacy of agent presence in relation to learner attributes and affect. With 132 high-school females, Study I investigated the effects of learners' prior math attitudes (high vs. low) and prior math self-efficacy (high vs. low) on the changes in their attitudes and self-efficacy after working at a pedagogical-agent-based environment. The results indicated that the females with low-prior-math attitudes significantly increased their math attitudes after working at the environment, whereas the attitudes of females with high-prior-math attitudes were not significantly changed. The same trend was observed for their math self-efficacy. Study II investigated the interaction of learner gender, learner sociability (low-sociable vs. high-sociable), and agent presence (present vs. absent) on learners' math attitudes, math self-efficacy, and learning, with 180 male and female high-school students. The results showed that, for both male and female, low-sociable students had significantly more positive math attitudes after working with an agent than without an agent, whereas high-sociable students had significantly more positive math attitudes after working at the learning environment without an agent than with an agent. The same was true for math self-efficacy. The learners significantly increased their learning regardless of the conditions. The implications of the findings are discussed.

The Role of Learner Attributes and Affect Determining the Impact of Agent Presence

INTRODUCTION

Educational theorists and researchers often emphasize the importance of the social context of cognition and its applications to learning and instruction. Learning is a highly social activity. Interactions with teachers, peers, and instructional materials are considered crucial for the cognitive and affective development of learners. Social interaction among participants in learning is seen as the primary source of intellectual development (John-Steiner & Mahn, 2003). This emphasis on social cognition seems to demand reframing the conventional use of computers as cognitive tools (Jonassen, 1995; Lajoie, 2000) and suggests a new metaphor: computers as social cognitive tools (Kim & Baylor, 2006).

A pedagogical agent is an animated life-like character (Johnson, Rickel, & Lester, 2000) embedded in an instructional application. The presence of a pedagogical agent is often valued in terms of its potential to build social affective relations with a learner, supported by human/computer interaction research (Nass & Moon, 2000). It sounds natural to propose, then, that the efficacy of agent presence would be influenced by learner variations such as a learner's affective states and personal attributes. This paper introduces two experimental studies that have examined this proposition.

THEORETICAL BACKGROUND

Pedagogical Agents

In pedagogical-agent-based learning, a learner grasps instructional content while interacting with one or more life-like pedagogical agents. These agents may provide information and/or encouragement, share mental tasks, or collaborate with the learner. What makes pedagogical agents unique from conventional computer-based learning would be their ability to simulate real-world social relations (Bickmore, 2003; Dautenhahn, Bond, Canamero, & Edmonds, 2002).

In this sense, pedagogical agents may help overcome some constraints of and expand functionalities of conventional technology-based learning environments. Traditionally, computer-based learning (e.g., intelligent tutoring systems) was tailored to meet an individual's needs, supporting each learner independently when the environments were well designed (Aimeur & Frasson, 1996; J. R. Anderson, Corbett, Koedinger, & Pelletier, 1995; Gertner & VanLehn, 2000; Graesser, VanLehn, Rose, Jordan, & Harter, 2001). However, those learning environments might have limitations in simulating situated social interaction that is regarded as a significant influence on both learning and motivation (Lave & Wenger, 2001; Palinscar & Brown, 1984; Powell, Aeby, & Carpenter-Aeby, 2003; Vygotsky, Cole, John-Steiner, Scribner, & Souberman, 1978; Wertsch, Minick, & Arns, 1984). Pedagogical agents can be designed to support the social affective aspect of learning, playing well-defined instructional roles, following specified social conventions, and even responding to learners with apparent empathy (Hays-Roth & Doyle, 1998). Earlier, Reeves and Nass (1996) concluded, from more than ten years of studies, that people applied the same social rules and expectations to computers as they did to humans in the real world. The simulated social presence of pedagogical agents in a computing environment may provide a learner with a sense of companionship and have the learner perceive the environment as relevant and meaningful (Biswas, Schwartz, & Bransford, 2001).

Along the line, it has been desired to equip a pedagogical agent with personas. To build social relations, a pedagogical agent should have human-like personas to be natural and believable (Bates, 1992; Lester, Voerman, Towns, & Callaway, 1999; Ortony, 2002). A pedagogical agent is frequently designed to represent a human instructional role, such as *expert* (Johnson et al., 2000), *tutor* (Graesser, Moreno, & Marineau, 2003), *mentor* (Baylor & Kim, 2005), and *virtual peer* or *learning companion* (Chan & Baskin, 1990; Dillenbourg & Self, 1992; Goodman, Soller, Linton, & Gaimari, 1998; Hietala & Niemirepo, 1998;

Kim, 2003; Uresti, 2000). A pedagogical agent designed as a virtual peer adopts a peer metaphor, where the agent who acts as a co-learning peer learns *with* the learner.

The positive impact of pedagogical agents on cognitive and/or motivational outcomes has been supported by some empirical studies. Atkinson (2002) reported that students who received worked-example instruction from animated pedagogical agents reported lower levels of perceived difficulty than did students in the control group who received textual information without the agents and also outperformed the counterparts in both near- and far-transfer tests. Moreno and colleagues showed that students with pedagogical agents produced significantly more correct solutions on difficult transfer problems and rated their interests in the material significantly greater than students without pedagogical agents (Moreno, Mayer, Spires, & Lester, 2001). These authors concluded that students might build a positive personal relationship that promoted their interest and learning. Kim and colleagues found that male and female college students showed significantly greater interest and self-efficacy in the task after working with an agent who expressed empathy than did students who worked with a non-empathetic agent (Kim, Baylor, & Shen, 2007). Ryokai and colleagues showed that children who played with the pedagogical agent *Sam* designed as a virtual peer listened to *Sam*'s stories carefully and mimicked *Sam*'s linguistic styles (Ryokai, Vaucelle, & Cassell, 2003). In her review study, Gulz (2004) summarizes the benefits of pedagogical agents: 1) increased motivation, 2) increased sense of ease and comfort in a learning environment, 3) stimulation of essential learning behavior, 4) increased smoothness of information and communication processes, 5) the fulfillment of a need for personal relationships in learning, and 6) gains in terms of memory, understanding and problem solving.

Difference in Learner Characteristics

Learners differ in their cognition and affect when learning (Ackerman, Kyllonen, & Roberts, 1999). The concept of individual difference has interested educational researchers

over time since the late 50s and early 60s. Cronbach (1957) suggested that there existed the interaction between aptitude and treatment (ATI), meaning that two treatments might produce different possible payoff functions given learners with varying aptitudes. His idea led to a surge of empirical studies on aptitude-treatment interaction, the results of which have supported the individuals' varying reactions to the same treatment, which influenced the effectiveness of the treatment. More recently, aptitude has been extended to include other learner characteristics such as prior knowledge, cognitive styles, learning preferences, task-related attitudes, and so on (Hyona, 2002; Larsen & Diener, 1987; Nilsson & Mayer, 2002; Triantafillou, Pomportsis, Demetriadis, & Georgiadou, 2004).

The concept of individual difference fundamentally posits that different types of learners might benefit from different instructional approaches. In a Snow & Lohman's (1984) study, the provision of structured guidance was beneficial to students with low ability more than to their high-ability counterparts. After receiving structured guidance, low-ability students became more positive about their ability and about the learning experiences. Arroyo and colleagues found that concrete hints were more effective for low-ability students, whereas highly symbolic hints were more effective for high-ability students (Arroyo, Beck, Woolf, Beal, & Schultz, 2000). Sonnenwald and Li (2003) found that students with a competitive learning style perceived a collaborative learning system more positively, whereas students with an individualistic style perceived the system more negatively. In pedagogical-agent-based learning, Hietala and Niemirepo (1998) showed that the level of learner academic competency determined a learner's choice of an agent as the collaborating partner.

In classrooms, even experienced teachers might be limited in tailoring instruction for each student, due to the lack of resources. Computer-based tutoring may afford some degree of flexibility in that regard. Adaptive e-learning is characterized by identifying and accommodating individual variations among learners. Russell (1997) states that "individual

differences in learning styles dictate that technology will facilitate learning for some, but will probably inhibit learning for others, while the remainder experience no significant difference (p. 44).” Similarly, the effectiveness of pedagogical agents should not be exceptional and should be influenced by individual differences. The designers of educational systems, therefore, need to be aware of individual differences that would affect motivation and learning and endeavor to address learners’ different cognitive and affective styles and preferences (Hills, 2003).

Conventionally, tutoring systems have addressed individual difference to some degree through individualized guidance, but their focus remained mainly on learner cognition. Individual difference, however, can be characterized in multiple dimensions, especially including learner affective characteristics like attitudes toward the task, self-efficacy beliefs in the task, personalities, or emotions (Gagne, Wager, & Rojas, 1981; Jonassen & Grabowski, 1993; Merrill, 2002). In particular, such affective characteristics as task-specific attitudes (McInerney & Van Etten, 2002; Shaw & Marlow, 1999) and self-efficacy beliefs (Badura, 1997; Britner & Pajares, 2001) are considered influential for learner engagement and successful learning experience. Nonetheless, not many tutoring systems have paid attention to learner differences in those affective characteristics.

As mentioned earlier, the role of life-like pedagogical agents in instructional systems is valued in terms of building social relations with a learner through affective interchanges (Bickmore, 2003; Dautenhahn et al., 2002). It would be meaningful to examine the impact of the social presence of a pedagogical agent in relation to learner attributes and affect. This paper introduces two experiments that have examined how different levels of learner attributes and affect would interact with the presence of a pedagogical agent to influence learners’ affect and cognition in learning. Study 1 focused on the differing levels of task-specific attitudes and self-efficacy to examine their impact on the changes in learner attitude and self-efficacy after learners’ working at a pedagogical-agent-based learning

environment. Study 2 focused on learner gender and learner sociability to examine their interaction with agent presence on learner attitudes, self-efficacy, and learning. Detailed descriptions follow.

STUDY 1

Females' lack of interest in learning STEM (science, technology, engineering, and math) has concerned educators in the USA. In an effort to address this concern, a pedagogical-agent-based learning environment (called MathGirls) was created to investigate the efficacy of a pedagogical agent on persuading high-school females to increase their positive attitudes toward and self-efficacy beliefs in learning math. In the framework of individual difference, the author conjectured that the females' strong or weak task-specific attitudes and self-efficacy might result in differential impacts of the pedagogical agent. Hence, this experiment examined how the levels of prior math attitudes and prior math self-efficacy would influence the efficacy of agent persuasion at MathGirls. There were two research questions: 1) *Will the levels (high vs. low) of learner prior attitudes influence their attitudes changes after working with a pedagogical agent?* 2) *Will the levels (high vs. low) of learner prior self-efficacy influence their self-efficacy changes after working with a pedagogical agent?*

Participants

Participants were 132 female 9th graders taking required introductory algebra in two high schools located in a mountain-west state of the USA. The ethnic compositions of the participants as self-reported were Caucasian (58.3%), Hispanic (22.8%), African-American (3.9%), Asian (3.3%), and others (11.7%). The average age was 15.51 ($SD = 1.14$).

Intervention

The intervention *MathGirls* was a pedagogical-agent-based learning environment delivered via the web. In Mathgirls, the high-school females practiced algebra problem-solving individually for themselves after taking conventional lessons from their teachers.

The primary role of a pedagogical agent was to proactively persuade the females to increase their positive attitudes and self-efficacy in learning math while the agent guided the students through the learning tasks. Figure 1 presents a screenshot of the learning environment.

Curriculum

“Fundamentals in Algebra” was the curriculum. Following the Principles and Standards of the National Council of the Teachers of Mathematics (NCTM, 2000), the curriculum content dealt with fundamentals in two areas of introductory algebra, each area providing one-class-hour lesson. Lesson I covered combining like terms and the applications of distributive property; Lesson II covered graphing linear equations. Each lesson took one-class period and included four to five subsections that consisted of Reviews and Problem-Solving Practice.

Agent and message design

The agent was developed using the 3D agent design tool Poser 6 (<http://www.e-frontier.com>). Given that human voice carries affective information beyond the message, the agent voice was pre-recorded by a voice actor. The agent image and voice were integrated within Mimic Pro for lip synchronization. Facial expressions, blinking, and head movements were added to make the agent look natural. Then the 3D animated agent was rendered in Poser to produce AVI files, which were later batch-compressed to be cast via the web.

Agent scripts included three types: informational, motivational, and persuasive. The informational message was content-related, including reviews -- the brief overviews of what the students had learned from their teachers -- and feedback on their performances. When a student made a mistake, the agent provided error-specific explanations to guide her to the right problem-solving path, which helped construct knowledge step by step. The motivational message was words of praise or encouragement. When a student had the

correct answer, the agent said “Good job” or “Great, I’m proud of you”; when the student had a wrong answer, the agent said “Everybody makes mistakes” or “You’re getting there. One more thing you need to consider is...” The persuasive message was statements about the benefits or advantages of learning math and pursuing careers in STEM. At the beginning of each section, the agent proactively presented the persuasive message, without a learner’s request, to positively influence the females’ attitudes toward and self-efficacy in learning math.

Variables and Measures

Math attitudes

Fishbein and Ajzen (1975) defined an attitude as “ a learned predisposition to respond in a consistently favorable or unfavorable manner with respect to a given object (p. 6). In this study, math attitudes referred to the degree of learners’ favorableness toward learning math (L. W. Anderson & Bourke, 2000). A questionnaire of 10 items was derived from the Mathematics Attitude Survey (Ethington & Wolfe, 1988) and Attitudes Toward Mathematics Inventory (Tapia & Marsh, 2004), with the items scaled from 1 (*Strongly disagree*) to 7 (*Strongly agree*): 1) *I like math*, 2) *I enjoy learning math in class*, 3) *I want to take another math course*, 4) *I would like to participate or I do participate in extra math activities after school*, 5) *I think math is an important subject for me to study*, 6) *I think math is useful in everyday life*, 7) *I think only smart students can do math*, 8) *I hate math*, 9) *Doing math assignments always makes me nervous*, and 10) *I would not take a math class if I had a choice*. Learners’ math attitudes were measured before and after the intervention. The mean scores of the items were calculated. Given the pretest math attitudes, the learners were divided into three levels -- of high, mid, and low -- by their mean scores. For statistical contrast, a total of 75 females in the high- and low-attitudes groups were included in the analysis. Item reliability evaluated with Coefficient α was .87 in the pretest and .79 in the posttest.

Math self-efficacy

Self-efficacy beliefs are defined as an individual's judgment about his or her competency in performing a particular task (Bandura, 1986, 1997; Weiner, 1992). The direction of self-efficacy is best captured by "*I can vs. I can't*" (Weiner, 1992) or "*How sure are you ~?*" (Bandura & Schunk, 1981; Pajares, 1996). In this study, math self-efficacy referred to learners' beliefs about their competency in learning math. A questionnaire of six items was developed according to Bandura's guidelines (2001), with the items scaled from 1 (*Strongly disagree*) to 7 (*Strongly agree*): 1) *I am confident in learning math*, 2) *I can concentrate on the topic in math class*, 3) *I feel confident when I participate in math-class discussions*, 4) *I can remember math-related topics presented in class and textbooks very well*, 5) *I can finish math assignments by deadlines in general*, and 6) *I can achieve high grades in math*. Learners' math self-efficacy were measured before and after the intervention. Given the pretest math self-efficacy, the learners were divided into three levels - of high, mid, and low -- by their mean scores. For contrast, a total of 77 females in the high- and low-self-efficacy groups were included in the analysis. Item reliability evaluated with Coefficient α was .83 in the pretest and .88 in the posttest.

Procedures

The experiment was conducted as regular class work for two consecutive days in a media center at the school. After a brief introduction to the environment, the participants first logged on to the web-based MathGirls by entering demographic information, then took pretests on the first day, performed the tasks for two days, and took posttests on the second day. The learners worked at their own pace, taking approximately 40 minutes for each lesson, with individual variations. The agent proactively presented informational, motivational, and persuasive messages without the learner's request in order to ensure that all the participants received the same amount of information.

Design and Analysis

A factorial design was employed with group membership (high vs. low in prior attitudes and in prior self-efficacy). To analyze, a one-way repeated ANOVA was conducted, respectively for attitudes change and for self-efficacy change. The significant level was set at $\alpha < .05$.

Results

Math attitudes

The repeated ANOVA, with 75 females with high vs. low prior attitudes, resulted in the significant main effect for prior math attitudes on the females' changes in their math attitudes, [$F(1, 73) = 7.37, p < .01, \eta^2 = .09$]. Learners with low prior math attitudes significantly improved their math attitudes after listening to the agent's persuasive messages, whereas learners with high prior math attitudes did not show this improvement.

Math self-efficacy

The repeated ANOVA, with 77 females with high vs. low prior self-efficacy, indicated the significant main effect for prior math self-efficacy on the females' changes in their math self-efficacy, [$F(1, 75) = 15.17, p < .001, \eta^2 = .17$]. Learners with low prior math self-efficacy significantly improved their math self-efficacy after working with a pedagogical agent, whereas learners with high prior math self-efficacy did not show this improvement. Table 1 summarizes the findings.

STUDY 2

Research in computer-mediated communication identifies that differences in social and personal attributes of participants influence the patterns of their participation. Students who are shy and less sociable in the classroom become more active participants in computer-mediated interactions (Warschauer, Shetzer, & Meloni, 2000) than do students who are active in the classroom. Male students are more dominant participants than the female counterparts

(Herring, 1992; Nelson, 2000). Hence, such learner attributes like sociability and gender would, consistently, be factors to influence a learner's interaction with a pedagogical agent. Study 2 examined this expectation, with the question: *Will learner gender, learner sociability, and agent presence interact to influence learners' math attitudes, math self-efficacy beliefs, and learning?*

Participants

Participants were 180 male and female high-school students taking required introductory algebra in two high schools located in a mountain-west state of the USA. The study was implemented as a mandatory class activity. The ethnic compositions (self reported) of the participants were Caucasian (61.2%), Hispanic (22.4%), Asian (4.3%), African-American (3.5%), and others (8.6%). The average age of the participants was 15.52 ($SD = 1.14$).

Independent Variables

There were three independent variables of learner sociability, learner gender, and agent presence. Merriam-Webster Dictionary defines *sociable* as "inclined by nature to companionship with others." Learner sociability in this study was defined as learners' willingness to engage in activities with other people. It was measured with a questionnaire with 5 items scaled from 1 (*Strongly disagree*) to 7 (*Strongly agree*), prior to the learning tasks: 1) *I like to hang around people in general*, 2) *Where there is a party, I try to go if possible*, 3) *In class, I like to learn by working with others*, 4) *I usually do better when I am learning alone*, and 5) *When learning, I would like to get help from others*. The item 4 was coded reversely. The item reliability was evaluated as Coefficient $\alpha = .79$. Given the mean scores (24.8) and median (25), students who acquired the scores between 0 and 22 were categorized to low-sociable and students between 29-35 to high-sociable. Students between 23-28 were dropped to contrast the high- and low-sociable groups. A total of 116 students

(64 boys and 52 girls) identified as either high-sociable or low-sociable were included in the analysis. Those students were randomly assigned either to Agent-presence or to No-agent. In the agent-presence condition, a pedagogical agent was present on screen and proactively provided the three types of messages used in Study 1. In the no-agent condition, students performed the learning task, reading the same messages presented as on-screen texts.

Intervention and Measures

Study 2 used the same learning environment, MathGirls, and the same measures for math attitudes and math self-efficacy used in Study 1. The implementation procedures were consistent.

Learning was measured by pre- and post-tests, each having 10 open-ended problems representing the topics covered in the lessons. Each question was counted for one point, and the system graded for the correct answers. The pretest was used as a covariate in the analysis, to control for learners' prior knowledge.

Design and Analysis

The study employed a $2 \times 2 \times 2$ factorial design, in which the variables included learner gender (male vs. female), learner sociability (high vs. low), and agent presence (agent-present vs. no-agent). To analyze data, a three-way ANCOVA was conducted, respectively for math attitudes, for math self-efficacy, and for learning, with a pretest set as a covariate. The significant level was set at $\alpha < .05$.

Results

Math attitudes

There were significant 2-way interaction effects of learner sociability and agent presence on math attitudes [$F(1, 107) = 4.43, p < .05, \eta^2 = .04$]. For both male and female, low-sociable students showed more positive attitudes toward learning math after working

with an agent ($M = 48.71$, $SD = 1.29$) but less positive attitudes after working without an agent ($M = 45.72$, $SD = 1.21$), whereas high-sociable students showed the opposite trend, i.e., more positive attitudes after working without an agent ($M = 48.13$, $SD = 2.88$) but less positive attitudes after working with an agent ($M = 41.74$, $SD = 2.93$).

Math self-efficacy

A consistent trend was observed for math self-efficacy. There were significant 2-way interaction effects of learner sociability and agent presence on math self-efficacy [$F(1, 107) = 6.78$, $p < .01$, $\eta^2 = .06$]. For both male and female, low-sociable students showed higher self-efficacy in learning math after working with an agent ($M = 29.92$, $SD = 1.05$) but lower self-efficacy after working without an agent ($M = 28.25$, $SD = .99$), whereas high-sociable students showed higher self-efficacy after working without an agent ($M = 31.32$, $SD = 2.38$) but lower self-efficacy after working with an agent ($M = 24.48$, $SD = 2.40$).

Learning

There were no significant main or interaction effects of learner gender, learner sociability, and agent presence for learning. Regardless of the conditions, however, the students significantly increased their learning from pre- to post-test [$F(1, 108) = 31.47$, $p < .001$]. Table 2 summarizes the findings of Study II.

DISCUSSION

As reflected in this special issue, researchers in pedagogical agents have attempted to find a way to promote building social relations between a learner and an agent. It is desired that this social relations would contribute to addressing the learner's affective challenges in learning, improving their positive attitudes toward the learning task and, subsequently, promoting the learner to sustain the task and demonstrate greater engagement. At the same time, learners are different in their cognition and affect. Learners' varying affective states may exert influence on the social relations between a learner and an agent and, consequently, the effectiveness of agent presence in a learning environment. The

application of pedagogical agents might be efficacious when it accounts for learner differences.

Following this line of thought, the author conducted two experiments that examined the impact of an animated pedagogical agent in relation to the concept of individual difference. The two experiments revealed that individuals' affect and personal attributes determined the impact of a pedagogical agent on their task-specific attitudes and self-efficacy beliefs. First, Study 1 showed that females with low-attitudes benefited from the agent-based learning environment, improving their positive attitudes toward math learning after working with a pedagogical agent. Females with low-self-efficacy showed the consistent pattern. This finding is somewhat unique, supporting that a pedagogical agent would be a viable tool for the high-school females with less positive attitudes toward and weak self-efficacy in learning math. The study proves that well-designed messages of an agent can exercise persuasive power to facilitate the females' aspirations in math learning. In contrast, this benefit was not shown for learners with high-math attitudes and learners with high-self-efficacy. An interpretation might be that the high-attitude females and the high-self-efficacy females have already reached a sufficient level and may not need additional help to increase.

Second, Study II found that, regardless of learner gender, less-social students showed significantly more positive attitudes toward and higher self-efficacy in learning math with an agent than did the high-social counterparts. Analogous to what was observed in computer-mediated communication, the low-social students might engage in interactions with the agent more seriously and feel more positive after working with the agent. In contrast, the high-social students who typically get along easily with human partners might perceive the agent as artificial, probably due to the agent's limited interactivity compared to humans. Further in-depth research on this conjecture needs to be done.

Third, the participants across the conditions in Study II significantly improved their math skills after working at MathGirls. On one hand, the environment might be sufficiently robust to help the learners perform better in spite of their personal variations. On the other hand, the value of agent presence might be reckoned in terms of learner affect more than learner cognition (i.e., learning), as indicated in some earlier studies (Dehn & van Mulken, 2000; Gulz & Haake, 2006).

There were limitations in the studies. First, the interactions between a learner and an agent were limited, in that the agent initiated their interactions by presenting the messages proactively. Second, the lesson flow was sequential in a lock step, where the learners were not able to go back to the previous stage. Those were contrived to control for confounding factors. Also, the two-day exposure to the agent in both studies might not be sufficient, especially when the inquiries were about affective changes. Future research is invited to overcome the limitations and confirm the current findings.

To conclude, the uniqueness of the two studies might be the examination of agent impact in relation to learner characteristics, unlike the majority of agent research having paid more attention to agent properties, such as modality (Atkinson, 2002; Craig, Gholson, & Driscoll, 2002), emotional expressiveness (Kim et al., 2007; Lester et al., 1997), and demographic embodiment (Cowell & Stanney, 2005; Kim & Baylor, 2006). The findings of the experiments in general support the application of a pedagogical agent as a viable solution to create socially affable context in technology-based learning, at least for some learners.

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Table 1

A Summary of Findings from Study I

Measures	Findings
Math attitudes	<ol style="list-style-type: none"><li data-bbox="507 414 1380 470">1. The high-school females with low-prior-math attitudes significantly improved their math attitudes after working with a pedagogical agent.<li data-bbox="507 470 1380 526">2. The high-school females with high-prior-math attitudes made no significant changes.
Math self-efficacy	<ol style="list-style-type: none"><li data-bbox="507 571 1332 660">1. The high-school females with low-prior-self-efficacy significantly improved their math self-efficacy after working with a pedagogical agent.<li data-bbox="507 660 1332 716">2. The high-school females with high-prior-self-efficacy made no significant changes.

Table 2

A Summary of Findings from Study II

Measures	Findings
Math attitudes	<ol style="list-style-type: none">1. For both male and female, low-sociable students showed higher math attitudes after working with a pedagogical agent than without an agent.2. For both male and female, high-sociable students showed higher math attitudes after working without an agent than with an agent.
Math self-efficacy	<ol style="list-style-type: none">1. For both male and female, low-sociable students showed higher math self-efficacy after working with a pedagogical agent than without an agent.2. For both male and female, high-sociable students showed higher math self-efficacy after working without an agent than with an agent.
Learning	<ol style="list-style-type: none">1. There were no differences for learning, across the conditions2. All the students who worked at MathGirls increased their learning significantly.

Figure 1. The Learning Environment with a Pedagogical Agent.

