The role of student gender for determining the impact of a pedagogical agent

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**Theoretical frameworks**

Gender difference in classrooms and educational computing has interested educational researchers. Females seem to depend on the quality of relationship and commonality of experience as they try to access another person’s idea or knowledge (Belenky, Clinchy, Goldberger, & Tarule, 1986; Herzig, 2002). From a series of classroom observation studies, Sandler and colleagues (1996) reported that females’ participation in class was more affected by teacher behavior than that of males. Females are more likely to form a more closed and tight social network than boys and that such a network significantly influences their academic pursuit (Riegle-Crumb, Farkas, & Muller, 2006). Similarly, in educational computing, females are more sensitive than males to help messages presented by the system (Arroyo, Murray, Woolf, & Beal, 2003) and perform better with highly interactive hints than with non-interactive and low-intrusive hints (Arroyo, Beck, Woolf, Beal, & Schultz, 2000). Females prefer instructional programs to be more like learning tools helping them through direct and frequent verbal feedback (Cooper & Weaver, 2003). One of the difficulties females have with learning from many instructional programs is that generally warrior-like characters in such programs do not appeal to them (Littleton, Light, Joiner, Messer, & Barnes, 1998). This lack of identification with the programs seems to cause the females to experience computer anxiety, lack of interest in the subject, and poor performance. Females might be more successful in computer-based learning if instructional programs could afford verbal encouragement, caring, and social relations. With the advance of interface technology, it is possible to simulate such social cues in a computer-based learning environment.
Pedagogical agents (PAs) are animated life-like characters (Johnson, Rickel, & Lester, 2000) embedded in computer-based learning. A trend in human/computer interaction research indicates that computer users do not merely use computers to perform tasks but also expect computers to be social actors (Nass, Steuer, & Tauber, 1994). Being human-like, a PA simulates such human instructional roles as expert, tutor, mentor, or peer and, consequently, provides social context at computer-based learning (Kim & Baylor, 2006). The positive impact of pedagogical agents has been empirically supported on learners’ cognitive and/or motivational outcomes (Atkinson, 2002; Graesser, Moreno, & Marineau, 2003; Kim, 2004; Lester, Towns, & FitzGerald, 1999; Moreno, Mayer, Spires, & Lester, 2001; Ryokai, Vaucelle, & Cassell, 2003). Yet, it is unknown that learner/agent relations mirror gender difference in real life, influencing males’ and females’ affect and learning differently.

**Purposes**

This study examined how male and female teenage students reacted differently to the presence of a PA. The study first examined, in classroom experiments, if learner gender would be a determining factor for the effectiveness of a pedagogical agent on learner attitudes and learning. Next, in-depth interviews inquired into the two groups of students’ perspectives of their agent’s role for their learning and affect.

**Classroom experiments**

The experiments had two research questions: Q1) will females’ mathematics attitudes be more positive than males’? Q2) will females increase their learning more than males?

**Participants**
Participants were 120 9th-grade students enrolled in required introductory algebra in two inner-city high schools in a mountain-west state in the United States. Sixty-four students were male and 56 female. The average age of the students was 15.93 (SD = .87).

**Intervention: Pedagogical-agent-based algebra**

The intervention was computer-based algebra integrated with pedagogical agents. Two lessons were implemented on two consecutive days, each lesson taking one class hour (Lesson 1: Combining like terms and Lesson 2: Graphing linear equations). Each lesson consisted of two phases (Review and Problem Practice), where the learners were able to review individually what they had learned from their teacher and practiced solving problems on the topics. Designed as a peer helper, a pedagogical agent presented not only content-related information and feedback but also encouragement and persuasion to help build learners’ positive mathematics attitudes. To control for the confounding effect by agent gender or ethnicity, one of four pedagogical agents (Caucasian male and female and non-Caucasian male and female) was randomly assigned to each student by the system. The intervention was self-contained, within which the students completed all the tasks: entering demographic data, performing the learning task, and taking pre and posttests.

**Measurements**

**Mathematics attitudes**

Mathematics attitudes in the study were defined as learners’ overall evaluative response to learning mathematics, following Petty, Desteno, and Rucker’s (2001) definition. Pre and posttest questionnaires were derived from the Mathematics Attitude Survey (Ethington & Wolfe, 1988) and the Attitudes Toward Mathematics Inventory

(Tapia & Marsh, 2004). The items were scaled from 1 (*Strongly disagree*) to 7 (*Strongly agree*). The pretest (5 items) measured learners’ general attitudes toward learning mathematics and was used as a covariate in the analysis. Item reliability evaluated with coefficient $\alpha$ was .80. The posttest questionnaire with 7 items measured learners’ general attitudes toward learning mathematics (GA, same as the pretest, 5 items) and learners’ attitudes toward learning mathematics specifically in the pedagogical-agent-based environment (SA, 2 items). Item reliability evaluated with coefficient $\alpha$ was .84. For analysis, the mean scores were calculated. Appendix A presents the attitudes measures.

**Learning**

Learning outcomes were measured with a pretest and an immediate posttest. Prior to the lesson, a pretest with 10 open-ended problems in the topic area was implemented; at the end of the learning task, the students were asked to solve another set of 10 parallel problems. The pre and posttests were integrated into the learning environment, without agent presence. To examine the increase from pretest to posttest, the mean scores were calculated and used in the analysis.

**Design and Analysis**

A factorial design was used, in which student gender had two levels. To analyze mathematics attitudes having two sub-categories (GA/SA), a one-way MANCOVA was conducted, with a pretest set as a covariate. To analyze learning, a one-way repeated ANOVA was conducted. The significance level was set at $\alpha < .05$.

**Results**

*Mathematics attitudes*
The one-way MANCOVA revealed a significant main effect of student gender on mathematics attitudes, Wilks’ Lambda = .95, $F(2, 116) = 3.32, p < .05$, Partial $\eta^2 = .05$. Given the overall significance, a univariate analysis was further conducted to examine the contribution of each subcategory (GA and SA) to the overall significance. The results indicated a significant main effect of student gender on SA (students’ attitudes toward learning mathematics specifically at the agent-based learning), $F(1, 117) = 5.45, p < .05$, $\eta^2 = .04$. Females ($M = 8.53, SD = .37$) showed significantly more positive attitudes toward learning mathematics in the agent-based environment than did males ($M = 7.34, SD = .35$).

Learning outcomes

The one-way repeated ANOVA revealed a significant main effect of the within-subject factor, time, $F(1, 67) = 57.63, p < .001$, $\eta^2 = .45$. The learners overall significantly improved their algebra problem-solving skills from pretest ($M = 7.19, SD = .41$) to posttest ($M = 9.69, SD = .43$). There was no main effect of student gender.

In-Depth Interviews

The experiment revealed a significant difference between males’ and females’ attitudes toward the agent-based learning environment. To understand the gender difference, in-depth interviews with 23 students (9 Caucasian males and 15 girls including 8 Caucasians and 7 Hispanics) were conducted at their high school after the intervention. The interviews, each taking 20 to 30 minutes, used a loosely structured interview protocol listing a set of main questions such as what they liked or disliked about the program as well as how they perceived and interacted with the pedagogical agent. The interview data was analyzed following general guidelines of thematic analysis.
(Ezzy, 2002), to identify major commonalities and differences between males and females. A qualitative data analysis program, Atlas-ti, was used to check the stability and consistency across codes and categories.

**Gendered Pattern of Relationship Building and Its Consequences in Learning**

Males and females developed a very different relationship with their agent throughout the learning process. Even though both groups initially understood that the agent was a man-made computer program, females gradually, yet clearly developed a more human-like relationship with their agent. They paid attention to various aspects of the agent (e.g., facial expressions, its hair style, the tone of speech) and treated the agent as if it were their companion. Perla reported her pedagogical agent “helpful” and “really nice always” because “it’s just, ah… like human thing that someone is telling you compliments.” Janet also compared her agent to “the person next to you [who] would help you with whatever the problem you need.” The fact that female students’ relationship with their agent resembles a real person-to-person one was most evident when some females took the agent’s negative feedback very seriously (as if it came from their close friends) and experienced a high level of stress from such feedback. They found their agent was “not friendly” but “mean” and “rude,” and it made them “feeling bad,” “stupid” and even “hurt.” In contrast, males clearly expressed that the agent was a “fake person” far different from a “real person.” They called their agent as “a little computer thing” and “don’t really think that like computers are supposed to be your friend.” They did not see their agent as an entity, with which they could interact or
communicate. Instead, they tended to focus on their learning objective and treated their agent as a mere tool or instrument helping them solve a given problem.

Another clear gender difference emerged about the quality and effectiveness of the agents’ explanations. Overall, both males and females liked the immediate and individualized feedback by the agent. Yet, the males perceived that the agent’s explanations were sometimes redundant and insufficient or not specific enough other times. Only two males out of nine reported a positive aspect of their agent’s explanations. The two students confessed that they had felt “annoyed” listening to some unsolicited or unwanted explanation from their agent. In contrast, the females expressed a highly positive view about the quality and relevance of their agent’s explanations. They found that their agent presented “clear and very specific” explanations: it “explained every little parts of it.” The females’ emotional and social connection with their agent seemed to set off a positive context for the subsequent learning process. Since they enjoyed companionship with the agent, they were more willing to stay on and listen to the agent giving lengthy explanations. They rarely exhibited those actions frequently taken by the males (e.g., skipping a beginning explanation part, tuning off the agent’s intervention talk, jumping into a problem).

Discussion

In the experiment, females showed significantly more positive attitudes toward learning mathematics in the agent-based learning than did males. This suggested that these two groups of students should have qualitatively different experiences with their agent that changed their task-specific attitudes throughout the learning process. The interviews supported this conjecture, revealing a clear gender difference between males’
and females’ responses to their agent. The males consistently maintained their initial view of the agent as a tool/object and refused to engage in any extended interaction with it beyond their perceived need. In contrast, the females tended to immerse themselves in the interaction process and exhibited social responses similar to those in real-life context. The development of positive and pleasant companionship with their agent provided females with some advantages. It effectively engaged the females’ attention and patience throughout the task, so that they could benefit from the entire design of the learning environment. It also reduced the chance of experiencing negative emotions frequently reported by the males. This study provides a new insight that advanced technology can be effectively utilized in order to address inequity concerns in mathematics education. Many scholars in mathematics education have attributed the inequity issues to the socio-cultural context of school mathematics unfavorable for females and ethnic-minorities. This study found that pedagogical agent technology actually provided an affable learning environment that would support the positive learning experiences of those students.

References


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