Abstract

This study examined the impact of learners' attributes (gender and ethnicity) on their choice of a pedagogical agent and the impact of the attributes and choice on their perceptions of agent affability, task-specific attitudes, task-specific self-efficacy, and learning gains. Participants were 210 high-school male and female, Caucasian and Hispanic students who worked at computer-based algebra integrated with pedagogical agents. The results indicated, first, that students preferentially chose a same-gender agent and a same-ethnicity agent, supporting similarity-attraction theory. Second, males who chose an agent showed more positive attitudes toward working at the learning environment than did males who were assigned to an agent whereas females who were assigned to an agent showed more positive attitudes than did females who chose an agent. Third, Hispanic students showed more positive attitudes toward working at the learning environment than Caucasians. Fourth, females perceived the agent as significantly more affable than did males; Hispanics perceived the agent as significantly more affable than did Caucasians. Last, learner attributes and choice did not affect learning in the agent-based environment.

Keywords: *interactive learning environments; human-computer interface; multimedia/hypermedia systems; virtual reality; secondary education*

1. Introduction

With the advance of interface technology, animated digital characters have been increasingly used in applications and interested researchers from various disciplines, such as artificial intelligence (Johnson, Rickel, & Lester, 2000), human-computer interaction (Isbister & Nass, 2000), educational technology (Kim & Baylor, 2006; Moreno & Mayer, 2000) and social psychology (Blascovich, Loomis, Beall, Swinth, Hoyt, & Bailenson, 2002). The researchers have investigated the efficacy of the characters from the unique perspective of their disciplines. In the field of educational technology, on-screen characters are broadly identified as *pedagogical agents* that are defined as animated life-like characters embedded in computer-based learning environments (Johnson et al., 2000). Social interaction is considered critical for learning and intellectual development (Lave & Wenger, 2001; Palinscar & Brown, 1984; Powell, Aeby, & Carpenter-Aeby, 2003; Vygotsky, Cole, John-Steiner, Scribner, & Souberman, 1978; Wertsch, Minick, & Arns, 1984). The social presence of a pedagogical agent is likely to promote interactions between a learner and the agent (Kim & Baylor, 2007) and, therefore, augment the functionality of conventional computer-based tutoring systems (Kearsley, 1993; Kim, Baylor, & Shen, 2007). Interacting with an agent is likely to facilitate learner engagement in the learning task, resulting in enhanced performance.

It is well documented that human-computer interaction is comparable to human-to-human interaction (Johnson, Gardner, & Wiles, 2004; Reeves & Nass, 1996). That is to say, computer users seem to interact with their agent as if the agent were human. In classrooms, the personal attributes of a learner and others are often considered a determining factor for the efficacy of an instructional intervention. Also, learners' being able to choose in the learning process may engender a feeling of autonomy and empowerment, which enhances learners' motivation and performance. Grounded in the literature in pedagogical agents, attribute similarities, and learner choice, this study examined if learners' choice of their agent would be affected by learner/agent attribute similarities and also if learner attributes and learner choice have an impact on their affective and cognitive outcomes in an agent-based learning environment, with high school students learning everyday school mathematics.

2. Theoretical Background

2.1. Pedagogical agents

Pedagogical agents (PAs) are animated life-like characters embedded in educational applications (Johnson et al., 2000), designed to enhance a student's engagement and learning through simulated social interaction (Kim & Baylor, 2006). In both commercial and educational applications, characters have been integrated into the interface to take advantage of natural human *social* affordances (Cheng & Ye, 2009, In press; Isbister & Nass, 2000). Learning is not a solo activity occurring only inside one's mind, but is largely influenced by social interactions with others (Lave &

Wenger, 2001; Palinscar & Brown, 1984; Powell et al., 2003; Vygotsky et al., 1978; Wertsch et al., 1984). By PA presence in computer-based learning, instructional cues and assistance can be perceived as social and natural and, therefore, better engage a learner in the learning task (Gulz, 2005; Kim, Wei, Xu, Ko, & Ilieva, 2007; Lester, Towns, Callaway, Voerman, & FitzGerald, 2000; Moreno, Mayer, Spires, & Lester, 2001). With this simulated social affordance, a PA might expand the functionality of conventional computer-based learning that has focused mainly on individualized, cognitive process of learning (Kearsley, 1993; Kim & Baylor, 2006). While interacting with a PA acting as a tutor (Graesser, Person, Harter, & Tutoring Research Group, 2001) or a co-learner (Chan & Chou, 1997; Gulz & Haake, 2006), a learner may build a social and intellectual partnership with the agent.

Some studies have supported the effectiveness of PA presence in computer-based learning. For example, middle-school students who received worked-example instruction from an agent reported lower levels of perceived difficulty than did students in the control group who received the same information in text without an agent and outperformed their counterparts in both near- and far-transfer tests (Atkinson, 2002). College students who learned the human circulatory system with an agent achieved retention scores significantly higher than did their counterparts who learned the topic with on-screen text (Dunsworth & Atkinson, 2007). Both college students and 7th graders who learned how to design a plant with an agent produced significantly more correct solutions on difficult transfer problems and rated their interest in the material significantly greater than did their counterparts who learned without an agent (Moreno et al., 2001). Fifth-graders who interacted with agents generated deeper explanations in a virtual science learning environment than those who did not interact with an agent (Holmes, 2007). Children who had a PA in computer-based writing were more likely to use the program again than were children who had a traditional graphical interface (Robertson, Cross, Macleod, & Wiemer-Hastings, 2004). Kindergartners who played with the virtual peer *Sam* listened to Sam's stories carefully and mimicked Sam's linguistic styles (Ryokai, Vaucelle, & Cassell, 2003).

Being human-like, a PA is often equipped with a *persona* (Lester et al., 1997; Moundridou & Virvou, 2002) to better simulate human tutoring. Indeed, male and female college students *consciously* expect their pedagogical agent to be "knowledgeable, nice, and friendly," consistent with their expectations of human instructors (Kim, 2007). In the PA design, human-instructional roles have been simulated, such as *expert* (Johnson et al., 2000), *tutor* (Graesser, Moreno, & Marineau, 2003), *mentor* (Baylor & Kim, 2005), and *learning companion* (Chan & Baskin, 1990; Dillenbourg & Self, 1992; Hietala & Niemirepo, 1998) or *virtual peers* (Kim, 2007; Ryokai et al., 2003). The use of a peer role over a tutor has been increasingly popular (Chou, Chan, & Lin, 2003). Yet, there are a number of questions that must be answered in the design of a peer-like agent. In particular, it is unknown what type of personal attributes a designer should build into an agent to stimulate interaction and partnership building with a learner. It was not clear before this study that learner/PA attributes would have an influence on changing a learner's task-specific affect and performance in agent-based learning, which requires an rather substantial examination beyond the perceptual reactions to agent appearance.

2.2. Similarities in learner/agent gender and ethnicity

The concept of attribute similarities (Bandura, 1997; Schunk, Hanson, & Cox, 1987) explains that when a learner observes a social model who has similar personal characteristics (such as gender, ethnicity, age, etc.) to his/her own, the learner's self-efficacy beliefs in the task are enhanced, and the task performance is more likely to succeed. Also, similarity-attraction theory indicates that people are more attracted to a person who is similar to them (Berscheid & Walster, 1969; Byrne & Nelson, 1965). This attraction seems to influence their interpersonal associations (with whom individuals would choose to associate) and behaviors. Similarity-attraction in the real world seems to mirror human-computer interaction, given people's tendency to interact with computers socially and naturally (Johnson et al., 2004; Nass & Brave, 2005; Reeves & Nass, 1996). When a computer's personality is similar to their own, college students are more attracted to, assign greater intelligence to, and conform more with the computer (Nass, Moon, Fogg, Reeves, & Dryer, 1995); are more likely to give the computer credit for success and less likely to blame the computer for failure (Moon & Nass, 1998); and, evaluate the book review presented by the computer more positively and are more likely to buy the book (Nass & Lee, 2000), compared to when there is a personality mismatch.

It is a question, however, if this similarity attraction will be consistently applied to a learning context. This study focused on two attributes of gender and ethnicity, addressing equity issues in mathematics education in the United States. Many scholars have documented persistent disparities in mathematics achievement and enrollment in advanced-level mathematics classes between Caucasian males and other groups of students, such as females and ethnic-minorities (Fennema, 1990; Secada, 1992). Although a number of efforts to address the disparities have been made, the motivational and achievement gaps among those groups of students have been stabilized or even widened in some areas of mathematics over the last two decades (Lee, 2004; Lee, Grigg, & Dion, 2007). Researchers attribute this phenomenon to social and cultural context. That is, the context where mathematics is taught has led these students to having less positive mathematics learning experiences, discouraging their continued intellectual pursuit in mathematics (Gay, 2000; Sandler, Silverberg, & Hall, 1996). The authors were interested in finding out if PA-based learning could contribute to females and ethnic-minority students' positive affect and increased performance in mathematics learning. If the similarity-attraction would work, a similar looking PA is likely to build the students' positive mathematics attitudes and mathematics self-efficacy in the agent-based environment.

Furthermore, the effectiveness of similarity-attraction in regards to ethnicity and gender is conflicting yet and should be substantiated. In computer-mediated communication (Nass, Isbister, & Lee, 2000), college students matched with a same ethnicity partner make more similar decisions, rate each other to be more attractive and trustworthy, present more persuasive arguments, and elicit more conformity to each other's opinions. In computer-based learning, male children in the 5th grade evaluated a computer voice more positively, perceived the voice as more credible, and showed higher levels of confidence in learning content when the voice matched their own gender than when mismatched; however, this gender similarity effect was not shown among female children (Lee, Liao, & Ryu, 2007). Moreno and Flowerday (2006) reported that the ethnic similarity between college students and their agents, when chosen, interfered with the students' learning in a multimedia program. Hence, it was not clear yet if the high-school students in the current study would improve their task-specific affect and performance after they worked with a similar agent more than after they worked with a dissimilar one.

2.3. Learner choice

Social cognitive theory (Bandura, 2001b) highlights individuals' exercise of control over their environments as a determinant of their self-efficacy beliefs in daily task performance. In learning contexts, the positive relationship between student choice and intrinsic motivation toward the learning task is well established across varying age groups (Anderson & Rodin, 1989; Swann & Pittman, 1977; Zuckerman, Porac, & Lathin, 1978). Giving students choice in their learning process may increase their feeling of autonomy (Ryan & Deci, 2000), which, subsequently, enhances their motivation and engagement in the task (Flowerday & Schraw, 2000; Kohn, 1998). For example, college students who chose their reading materials rated the reading experience more favorable than did those who were given the same material (Schraw, Flowerday, & Reisetter, 1998); college students who were able to choose study time showed significantly higher affective engagement (Flowerday & Schraw, 2003). Moreover, even perceived choice without having actual choice behavior enhances adolescent learners' intrinsic motivation to do an exercise for a longer period of time (Dwyer, 1995).

However, the effect of student choice on learning outcomes is somewhat contradictory and necessitates further investigation (Lunts, 2002). High-school students, who were able to choose solutions, engaged in the task more and remembered the material more than did students who were told exactly what to do (Rainey, 1965). On the other hand, Hannafin and Sullivan (1996) allowed high-school students to adjust preferred amount of instruction in a computer-based geometry program. Matching students with their preferred program length did not improve learning outcomes and was particularly ineffective with students who preferred a low amount of instruction. As aforementioned, Moreno and Flowerday (2006) reported that college students' choice of an ethnically similar agent functioned as an interfering factor that distracted the college students from their learning, but this distraction did not occur when a similar agent was assigned by the system. Hence, the current study included learner choice as a variable, to examine whether or not the interference effect would be consistently observed with high school students.

3. Study Purpose and Hypotheses

Much of research in pedagogical agents has typically assigned a learner to a certain type of an agent and examined the learner's reactions to the agent. This study was intended to understand if, when given a choice, high-school students performing daily school tasks would choose a same-gender agent and a same-ethnicity agent and also if the students' own gender and ethnicity and their choice would influence their task-specific affect and performance in computer-based learning. The study had five hypotheses. First, grounded in similarity attraction, it was expected that high school learners would choose a same gender agent or a same ethnicity agent (H1). Second, Baylor and Kim (2004) reported that college females, who learned introductory instructional design in a pedagogical-agent-based environment, perceived their agent more positively than did males. The same was true with college African-Americans, compared to Caucasians. So it was expected that high-school females and Hispanics would rate their agent as more affable than their counterparts (H2). Third, based on the positive impact of learner choice on learner affect (see Section 2.3), it was expected that high-school students who were able to choose their agent would demonstrate more positive task-specific attitudes than those who were randomly assigned to an agent (H3). Also, it was expected that the students who were able to choose their agent would demonstrate higher task-specific self-efficacy than those who were randomly assigned to an agent (H4). Lastly, given that learner choice interfered with college students' learning (Moreno & Flowerday, 2006), it was expected that high-school students who were given an agent would achieve greater learning than those who were able to choose (H5).

4. Method

4.1. Participants

Participants were 210 Caucasian (47.1%) and Hispanic (52.9%) students in the 9th grade in three inner-city high schools located in a mountain-west state of the US. 110 students were male; 100 students were female. The average age was 15.93 (*SD* = .87). At login to the intervention system, the participants were randomly assigned by system to the experimental conditions (Agent-Choice or Agent-Randomly Assigned).

4.2. Materials

The intervention was computer-based algebra learning integrated with a 3D animated agent as a peer tutor, where the participants worked on the fundamentals of algebra. The environment was self-contained: the participants entered demographic information, chose or were assigned to an agent, performed the learning tasks, and took pre and posttests in the environment. The development of the environment included three phases: curriculum design, agent message design, and agent development.

4.2.1. Curriculum

The curriculum dealt with two fundamental areas in algebra: Lesson I covering combining like terms and distributive property and Lesson II covering graphing linear equations using slope and y-intercept. The lessons were developed as supplemental materials for daily use in classrooms. Each lesson included four to five sub-topic sections consisting of Review and Problem Practice. In Review, the participants reviewed algebraic concepts that they had learned from their teachers; in Problem Practice, they practiced solving problems to master the concepts. A peer agent guided a learner through the tasks, providing content-specific explanations and feedback on the learner's performance. Figure 1 presents example screens of the learning environment.

[Insert Figure 1 about here.]

4.2.2. Agent messages

The peer agent proactively presented three types of messages (informational, motivational, and persuasive messages) without a learner's request. Informational messages were content-related, including the brief overviews of the topics and feedback on a learner's performance. Motivational messages, words of praise or encouragement, were presented upon learner performance. Persuasive messages were the statements about the benefits or advantages of learning mathematics and were presented at the beginning of subsections to build positive attitudes toward and confidence in doing mathematics.

4.2.3. Agent development

Four variations of a peer-like agent were developed using Poser 6, representing male-Caucasian, female-Caucasian, male-Hispanic, and female-Hispanic teenagers. Agent messages were prerecorded by four voice actors matched with the agent's gender and ethnicity – for Hispanic PAs, male and female voice actors with Hispanic voice characteristics (i.e., local Mexican-Americans) were used. The agent images and the recorded voices were integrated with Mimic Pro for lip synchronization. To make the agents look natural, facial expressions, blinking, and head movements were added using parameters at Mimic Pro that kept the animation of the four agents consistent. The agent video clips were compressed and integrated into the learning environment that was delivered via the web. Figure 2 presents the four agents used in the study.

[Insert Figure 2 about here.]

4.3. Independent variables

There were three independent variables in the study: learner gender (male vs. female), learner ethnicity (Caucasian vs. Hispanic), and learner choice (Agent-Choice, AC vs. Agent- Randomly Assigned, ARA). At login, participants were randomly assigned, by system, either to AC where the participants were asked to choose a PA or to ARA where one of the four agents was assigned to a student randomly by system. Once an agent chosen or assigned, students were unable to change their agent.

4.4. Dependent variables

Dependent variables were learners' choice of an agent, learners' evaluations of agent affability, their task-specific attitudes, their task-specific self-efficacy, and their learning outcomes.

4.4.1. Learner choice of an agent

A total of 99 participants (51 males and 48 females; 43 Caucasian and 56 Hispanic) who were assigned to Agent-Choice were asked to choose one out of four agents, Caucasian-male, Caucasian-female, Hispanic-male, and Hispanic-female. Their choices were recorded by system.

4.4.2. Agent affability

Agent affability in this study was defined as the users' evaluations of an agent in terms of feelings of ease, friendliness, and helpfulness in learning. Agent affability was considered meaningful in learner/agent interaction, to build social relations and trust with the agent (Laurel, 1997). Agent affability was measured at the end of the intervention, with 17 items, each scaled from 1 (*Strongly disagree*) to 7 (*Strongly agree*). Item reliability was evaluated as $\alpha = .96$. For analysis, the mean scores were calculated.

4.4.3. Task-specific attitudes: Attitudes toward learning mathematics with an agent

People's attitudes toward an object are defined as one's overall evaluation based on some combination of one's affect, cognition, and behavioral tendencies toward the object (Petty, Desteno, & Rucker, 2001). Task-specific attitudes in this study referred to the combination of ones' cognitive and affective response to the task of learning mathematics in the PA-based environment. Pre and posttests were developed, derived from the Mathematics Attitude Survey (Ethington & Wolfe, 1988) and Attitudes Toward Mathematics Inventory (Tapia & Marsh, 2004). The pretest measured learners' general attitudes toward learning mathematics and was used as a covariate in the analysis: 1) *I like math*, 2) *I enjoy learning math in class*, 3) *I would like to participate or do participate in extra math activities after school*, 4) *I think math is an important subject for me to study*, and 5) *I think math is useful in everyday life*. Each item was scaled from 1 (*Strongly disagree*) to 7 (*Strongly agree*). The posttest measured students' attitudes toward learning mathematics specifically in the PA-based environment): 1) *I enjoyed solving math problems in this computer-based lesson* and 2) *I want to take another math lesson similar to this lesson.* The items were scaled from 1 (*Strongly disagree*) to 7 (*Strongly agree*). Item reliability was evaluated as coefficient $\alpha = .84$.

4.4.4. Task-specific self-efficacy: Self-efficacy in learning mathematics with an agent

Self-efficacy is defined as a person's beliefs in their capability to successfully perform a particular task (Bandura, 1997). In this study, task-specific self-efficacy referred to ones' beliefs in their capability to successfully learn mathematics in the PA-based environment. Following Bandura's guidelines (2001a), pre and posttests were developed, with the items scaled from 1 (*Strongly disagree*) to 7 (*Strongly agree*). The pretest measured students' self-efficacy in learning mathematics in general and was used as a covariate in the analysis: 1) *I am confident in learning math*, 2) *I can concentrate on math learning in class*, 3) *I feel confident when I participate in math class activities*, 4) *I can achieve high grades in math*, and 5) *I am confident in solving math problems without help*. The posttest measured students' self-efficacy in learning mathematics specifically in the PA-based environment: 1) *I was confident in learning math in this computer-based lesson*, 2) *I was able to concentrate on learning in this lesson*, 3) *I can remember the topics presented in this lesson very well*, and 4) *I can achieve better grades if I would learn math in this kind of lesson*. Item reliability was evaluated as coefficient $\alpha = .86$.

4.4.5. Learning

Learning was measured with learners' performances in an immediate posttest. At the beginning of each lesson, a pretest with 10 open-ended problems was implemented to assess their prior knowledge and used as a covariate. At the end of the each lesson, another set of 10 analogous problems was implemented as a posttest. For each item in the pretest, there was a parallel item in the posttest, so the pre and posttest had different items, but assessed the same knowledge. The pre and posttest were implemented without agent presence. The mean scores were calculated for analysis.

4.5. Implementation procedure

The study was implemented as regular class activities in introductory algebra classes in two consecutive days, one lesson per day. Each lesson took one class hour (60 minutes). To control for implementer variations, the researchers implemented the study with the assistance of the classroom teachers. The overall procedures were as follows:

- The participants were given brief instructions to the lesson (approx. 1 to 2 minutes) and asked to put on headsets to listen to their agent without distraction;
- On the first day, the students entered demographic information to generate a username and password necessary to log onto the learning environment[1];
- At login, they were immediately either asked to choose an agent or randomly assigned to an agent. They worked with the same agent during the entire intervention;

[1] On the second day, the students used the system-generated username and password to continue the learning activity.

- They took pretests for 5 to 8 minutes (attitudes and self-efficacy pretests on the first day and an algebra pretest on both days);
- They performed the learning tasks, which took an average of 35 to 40 minutes; and
- They took posttests for 7 to 10 minutes (attitudes, self-efficacy, and agent affability tests on the second day; algebra tests on both days).

4.6. Design and analysis

To test H1 on user choice patterns, χ^2-tests of independence were conducted with 99 participants (51 males and 48 females; 43 Caucasian and 56 Hispanic) who were given an opportunity to choose a PA. For the rest of the hypotheses (H2 through H5), a 2 × 2 × 2 factorial between-subject design was used, in which the independent variables included learner gender (Male vs. Female), learner ethnicity (Caucasian vs. Hispanic), and learner choice (Agent-Choice vs. Agent-Randomly Assigned). To test H2 on agent affability, a 3-way ANOVA was conducted; to test H3, H4 and H5, a 3-way ANCOVA were conducted respectively, with a pretest set as a covariate. The significance level was set at $\alpha < .05$.

5. Results

5.1. Agent choice patterns

The χ^2 tests of independence revealed significant differences in learners' choice of their agent. First, there was a main effect of learner gender, χ^2 (1, N = 99) = 33.25, $p < .001$. Seventy-five percent of male learners chose a male agent; 25% chose a female agent. On the other hand, 83% of female learners chose a female agent; 17% chose a male agent. Second, there was a main effect of learner ethnicity, χ^2 (1, N = 99) = 56.08 $p < .001$. Eighty-four percent of Caucasian learners chose a Caucasian agent; 16% chose a Hispanic agent. On the other hand, 91% of Hispanic learners chose a Hispanic agent; 9% chose a Caucasian agent. The results supported H1 that high-school learners would choose a same-gender agent or a same-ethnicity agent.

5.2. Agent affability

The 3-way ANOVA indicated a significant main effect of learner gender on agent affability, F (1, 202) = 9.02, $p < .005$, $\eta^2 = .04$. Female learners (M = 78.28, SD = 23.49) rated the agent to be more affable than did male learners (M = 67.46, SD = 26.31). Also, there was a significant main effect of learner ethnicity, F (1, 202) = 31.94, $p < .001$, $\eta^2 = .14$. Hispanic learners (M = 81.83, SD = 20.93) rated the agent to be more affable than did Caucasian learners (M = 62.28, SD = 26.35). There were no interaction effects of learner gender, ethnicity, and choice. The results supported the hypothesis (H2) that female learners and ethnic-minority learners would evaluate the agent as more affable.

5.3. Task-specific attitudes

The 3-way ANCOVA revealed a significant interaction effect of student gender and agent choice, F (1, 201) = 4.35, $p < .05$, $\eta^2 = .02$. Male students in Agent-Choice (AC) (M = 8.22, SD = 2.99) showed more positive attitudes toward learning mathematics specifically in the PA-based environment than did males in Agent-Randomly Assigned (ARA) (M = 7.44, SD = 2.86). In contrast, females in ARA (M = 8.43, SD = 2.98) showed more positive attitudes toward learning mathematics in the PA-based environment than did females in AC (M = 7.68, SD = 3.20). Figure 3 illustrates this interaction. In addition, there was a significant main effect of student ethnicity on attitudes toward learning mathematics specifically in the PA-based environment, F (1, 201) = 5.25, $p < .05$, $\eta^2 = .03$. Hispanic students (M = 8.50, SD = 2.93) showed more positive attitudes than did the Caucasian counterparts (M = 7.28, SD = 2.97). The results supported H3 partially, in that only males demonstrated more positive task-specific attitudes after working with an agent of their choice than after working with an assigned agent.

[Insert Figure 3 about here.]

5.4. Task-specific self-efficacy

The 3-way ANCOVA revealed no significant main effect or interaction effect of learner gender, learner ethnicity, and agent choice on students' self-efficacy in learning mathematics specifically in the PA-based environment. The results did not support the hypothesis that the students who were able to choose their agent would demonstrate higher task-specific self-efficacy than those who were given an agent (H4). However, a similar interaction trend, as in task-specific attitudes, was observed: male students in AC demonstrated higher task-specific self-efficacy than did males in ARA whereas females in ARA demonstrated higher task-specific self-efficacy than did females in AC (p = .08).

5.5. Learning

The 3-way ANCOVA revealed no significant main or interaction effects of learner gender, learner ethnicity, and agent choice on learning gains. The results did not support the hypothesis (H5) that the students who were assigned to an agent would increase their learning more than those who were able to choose. Given that the pre and posttest included equivalent items, one-way repeated ANOVA was further conducted to test increases in student learning. The results revealed that the students, regardless of the conditions, significantly increased their learning from pre (M = 7.63, SD = 3.55) to posttest (M = 10.14, SD = 3.91), F (1, 116) = 85.58, $p < .001$, $\eta^2 = .43$. The summary of the results is presented in Table 1.

[Insert Table 1 about here]

6. Discussion

This study was intended to further understand how learner/agent attributes would influence the instructional effectiveness of a pedagogical agent (PA) and to provide implications for the design of an efficacious peer agent. Among a number of personal attributes, student gender and ethnicity were chosen to address equity issues in mathematics education. The authors expected that the pedagogical-agent-based learning would provide females and Hispanic students with positive learning experiences, enhancing their task-specific attitudes and self-efficacy. Further, given the contradictory findings on the effectiveness of learner choice, the students' choice of their agent was examined as a variable. Therefore, unlike many studies in pedagogical agents that examined students' perceptive reactions to an assigned agent (Mayer, Johnson, Shaw, & Sandhu, 2006; Plant et al., 2009; Reategui, E., & Campbell, 2008), the current study investigated the effectiveness of a pedagogical agent at a more practical level by including learner characteristics and focusing on task-specific affect and performance in daily school tasks. Overall, the findings support the social affordance of pedagogical agents for teenage students. That is, the high-school students in the study responded to their agent socially, in that they chose a similar looking agent over dissimilar one. More important, their gender, ethnicity, and choice interacted to influence their evaluation of agent affability and their task-specific attitudes toward agent-based mathematics learning. However, the study revealed that the similarity attraction between the learner and agent affected learners' choice of an agent, but the choice influenced neither their task-specific affect nor task performance. Likewise, learner gender and ethnicity did not influence learning mathematics with a pedagogical agent.

6.1. Hypothesis 1 on student choice of an agent

The first hypothesis stated that high-school students would choose a same-gender agent and a same-ethnicity agent. Indeed, male students chose a male agent and females chose a female agent significantly more frequently than a different-gender agent. Also, Caucasian students chose a Caucasian agent and Hispanic students chose a Hispanic agent significantly more frequently than a different-ethnicity agent. This finding is distinct from previous studies indicating that the ethnic similarity attraction was observed only among students of color (Moreno & Flowerday, 2006) and that African-American college students were more aware of their agent's ethnicity, compared to their Caucasian counterparts (Baylor & Kim, 2003). The current study confirms that the attraction exists in learners' choice behaviors, regardless of learner gender and ethnicity, at least for teenage students.

6.2. Hypothesis 2 on students' evaluations of agent affability

The second hypothesis stated that female students and Hispanic students would rate their agent as more affable than their counterparts. The results supported this expectation. The teenage females in the study rated their agent significantly more affable than did males; Hispanic students rated their agent significantly more affable than did Caucasians. To understand the reasons, the authors referred to literature in social psychology, which indicated that females, in general, valued relationships and connections with others greater than males and constructed their identities as a result of the interpersonal relationships they created and maintained (Gilligan, 1993). Likewise, in classrooms, females seem to be more aware of social context than males (Sandler et al., 1996); at computing, females prefer instructional programs that support frequent interactions and direct verbal feedback (Arroyo, Murray, Woolf, & Beal, 2003; Cooper & Weaver, 2003). Hispanic students' more positive evaluations of agent affability can be explained in a similar perspective. In classrooms, Latino students showed high engagement in learning when the environment supported interactions and teamwork involving verbal encouragement and active responses (Gay, 2000; Uekawa, Borman, & Lee, 2007). These inclinations of females and Hispanic students toward relationship building and social interaction seemingly induced them to evaluate their agent as affable more than did males and Caucasians. Another interpretation might be related to equity issues in mathematics education in the US. Females and some ethnic-minority students are lacking motivation toward and confidence in mathematics learning (Herbert & Stipek, 2005; Lee, 2004; Secada, 1992). As a reason, the dominant culture of mathematics classrooms is often said to be less favorable for those students. While working with their agent, the females and Hispanics in the study might feel more comfortable with the agent's individualized explanations and free of embarrassment even when making a mistake.

6.3. Hypotheses 3 and 4 on task-specific attitudes and self-efficacy

It was expected that high-school students who were able to choose their agent would demonstrate more positive task-specific attitudes (H3) and higher self-efficacy (H4) than those who were assigned to an agent. The results partially supported the hypothesis on attitudes, in that only males showed significantly more positive attitudes toward the agent-based mathematics learning when given a choice. In contrast, the opposite trend was observed for females, who showed more positive attitudes when assigned to an agent without a choice. The results might be explained in terms of gender difference. The literature in gender difference shows that males usually have stronger sense of control than females (Ross & Mirowsky, 2002). That is, agent choice, as a form of a learner's control over the task environment, was favored by high-school males more than by females. Another interpretation would be that, to be able to choose or take advantage of choice, a learner should have a certain level of confidence in a task domain. However, females are in general considered lacking confidence in mathematics learning (Herbert & Stipek, 2005). This lack of confidence in the task domain might lead the females to feeling less comfortable in choosing an agent. An analogy was found in a study in human/computer interaction that female college students evaluated the validity of the information presented by a computer differentially depending on the topic areas (Reeves & Nass, 1996). They became more critical about a more familiar topic, cosmetic-related information than about the sports-related information. To conclude, learner choice should be used judiciously with the consideration of learner characteristics (Hannafin & Sullivan, 1996). Prudent use of learner choice may help avoid frustration and distraction from task performance (Iyengar & Lepper, 2000).

6.4. Hypothesis 5 on learning outcomes

This hypothesis stated that the learners who were given an agent would achieve greater learning than those who were able to choose. The results did not support the hypothesis; there was no main or interaction effect of user choice, gender, and ethnicity. Instead, the participants consistently achieved their learning after working in the PA-based environment, regardless of their differential evaluations of agent affability and attitudes toward the learning task. In contrast to Moreno and Flowerday's (2006) study, this study did not find the negative interaction effect of learner choice and ethnicity on learning.

6.5. Implications and future research

The findings of the study provide implications for the efficacious application and design of pedagogical agents, especially for teenage learners. First, a similar-looking agent might serve as a role model to attract young people to a domain not typically popular but necessary to be pursued, e.g., inviting females and some ethnic minorities to the domains of science and engineering (Plant et al., 2009). While working with the agent, those students are likely to better identify themselves with the domains (Kim & Baylor, 2007). Second, to make use of user choice, user characteristics (e.g., gender) should be a primary consideration. Third, when an application is geared toward cognitive task performance, the presence of an agent might not be warranted. However, for applications where learner affect is considered important, agent presence can be a viable option in the design. These applications might take advantage of the illusion of social relations between a learner and an agent (Johnston & Thomas, 1995). As learners are exposed to agents more and more, even new social rules may emerge (Petrakou, 2009, In press). Agent research, hence, should focus less on the media and place more emphasis on the agent's social intelligence (Wang, Johnson, Mayer, Rizzo, Shaw & Collins, 2008). Lastly, the study has some limitations. The study was implemented for a relatively short period of time. Due to the limited cell size, the study was not able to contrast the matched and mismatched gender and ethnicity between a learner and an agent. Subsequent research is necessary to overcome the limitations and confirm the findings.

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Table 1

Results summarized by dependent variables.

	Agent Affability		Task-specific attitudes		Task-specific self-efficacy		Learning outcomes	
	F	η^2	F	η^2	F	η^2	F	η^2
Learner gender (G)	9.02**	.04	0.79	.00	0.03	.00	0.13	.00
Learner ethnicity (E)	31.94***	.14	5.25*	.03	1.62	.01	3.69	.03
Agent-Choice (C)	0.20	.00	0.17	.00	2.61	.01	0.03	.00
G × E	0.86	.00	0.22	.00	0.39	.00	0.86	.01
G × C	0.38	.00	4.35*	.02	3.05[a]	.02	2.99	.03
E × C	0.15	.00	0.21	.00	1.87	.01	0.05	.00
G × E × C	0.01	.00	1.68	.01	2.08	.01	1.81	.02

Note: Significance of F values is identified by * at the .05 level, by ** at the .01, and by *** at the .001 level.

[a] $p = .08$

view Problem Practice

Fig. 1. Example screens of the learning environment.

Fig. 2. Four pedagogical agents used in the learning environment.

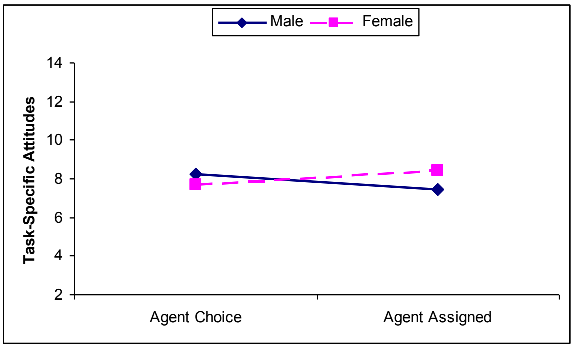

Fig. 3. Interaction of learner choice and gender on attitudes