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Gendered Socialization with an Embodied Agent: Creating a Social and Affable Mathematics
Learning Environment for Middle-Grade Females

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Abstract

This study examined whether or not embodied-agent-based learning would help middle-grade females have more positive mathematics learning experiences. The study used an explanatory mixed-methods research design. First, a classroom-based experiment was conducted with one hundred and twenty 9th-graders learning introductory algebra (53% male and 47% female; 51% Caucasian and 49% Latino). The results revealed that learner gender was a significant factor in the learners' evaluations of their agent ($\eta^2 = .07$), the learners' task-specific attitudes ($\eta^2 = .05$), and their task-specific self-efficacy ($\eta^2 = .06$). In-depth interviews were then conducted with 22 students selected from the experiment participants. The interviews revealed that Latina and Caucasian females built a different type of relationship with their agent and reported more positive learning experiences as compared to Caucasian males. The females' favorable view of the agent-based learning was largely influenced by their everyday classroom experiences, implying that students' learning experience in real and virtual spaces was interconnected.

Keywords: embodied agents, interactive learning environments, equity in mathematics education, human-computer interaction

Gendered Socialization with an Embodied Agent: Creating a Social and Affable Mathematics Learning Environment for Middle-Grade Females

A recent analysis of the National Assessment of Educational Progress data reported that the achievement gap between Caucasians and ethnic minority students (e.g., African-Americans and Latinos) in mathematics achievement has become stagnant during the last two decades (Vanneman, Hamilton, Anderson, & Rahman, 2009). Female students, despite their improved achievement in mathematics (Lindberg, Hyde, Petersen, & Linn, 2010), still report lower interest and lower self-confidence in mathematics as compared to males (Jacobs, Davis-Kean, Bleeker, Eccles, & Malanchuk, 2005). These underrepresented groups of students often “disidentify” themselves with mathematics learning (Steele, Spencer, & Aronson, 2002) and, as a result, are more likely to avoid taking advanced mathematics classes (Steffens, Jelenec, & Noack, 2010). Acknowledging the urgency in resolving these problems, the National Science Board (2010) has declared its commitment to equity and diversity as a focal area for developing the next generation of STEM innovators.

A variety of social, cultural, and economic factors might lead to the equity issues. However, gender and ethnic inequity in mathematics education is often attributed to the unsupportive learning context in schools (Moody, 2004) and undesirable social influences such as stereotyping (Steele, et al., 2002). Females and ethnic minorities often lack the instructional support that might motivate them to engage and succeed in the area. This lack of support, coupled with social stereotyping, leads them to hold a negative view of mathematics and to doubt their capability to succeed.

Re-shaping the school context and social influences might be a long societal process, requiring synergistic endeavors by a multitude of individuals and institutions. Nonetheless,

advanced learning technology might design supportive learning contexts that help close these motivational and achievement gaps. One such technology which uses animated digital characters (called *embodied interface agents*) promises to augment the bandwidth of a learner's interactions with computers (Bailenson et al., 2008) and to add social richness to the interactions (Iacobelli & Cassell, 2007). Many females' and ethnic minorities' learning styles favor active and multi-faceted interactions (Sciarra & Seirup, 2008); connectedness and relationships are characteristic of their learning process (Crosnoe et al., 2010). If designed carefully, agent-based learning might be able to create a favorable learning context for these students, accommodating their learning styles and characteristics.

This study was conducted to examine this expectation that the females' and minorities' affect and learning would improve in a more social and affable agent-based environment. The study, consisting of a classroom experiment and following in-depth interviews, investigated how middle-grade students learning introductory algebra would react to an agent and if the reactions would differ by the students' gender and ethnicity.

Theoretical Background

Socio-Cultural Aspect of Mathematics Learning

The socio-cultural context of learning plays a significant role in shaping students' motivation, learning behaviors, and academic outcomes in schools. The learning process is not merely a cognitive restructuring within an individual mind. It is a social and cultural process in which multiple facets of human development (e.g., identity & emotion) are intertwined with social, cultural, and historical forces (Nasir, Rosebery, Warren, & Lee, 2006). For example, a student's "sense of belonging" in school positively correlates with her strong and clear

identification with the goal of schooling, which ultimately leads her to full, active participation in all aspects of the learning process (Freeman, Anderman, & Jensen, 2007).

The mathematics learning context and its social and instructional dynamics play a critical role in motivating all students to learn and excel in mathematics. However, the context and dynamics seem to have even more critical influence on traditionally underrepresented groups of students (Geist, 2010). Feminist scholars argue that females' unique way of learning is not best supported by the traditional mathematics classrooms (Boaler, 2002). Females are "connected knowers," and tend to rely on interpersonal relationships and commonality of experience when they approach a new idea or knowledge (Belenky, Clinchy, Golberger, & Tarule, 1997). Supportive relationships with instructional authority and peers might be critical for many females' intellectual pursuit of mathematics and perseverance in the area (Crosnoe, Riegle-Crumb, Field, Frank, & Muller, 2008). However, the mathematics education community has a long tradition that views mathematics learning as a depersonalized activity disconnected from other aspects of students' everyday lives (Cobb & Yackel, 1998). This assumption about mathematics learning disregards the typical style of female learning. Not surprisingly, many females experience higher anxiety and discomfort in mathematics classes than boys (Geist, 2010). These females report lower interest and self-efficacy even when their performances are equal to or better than boys' during early school years (Lindberg, et al., 2010). As a result, the females avoid taking advanced mathematics courses in high school (Steffens, et al., 2010).

A similar phenomenon is observed among many Latino students. Three types of engagement influence Latinos' achievement in mathematics: cognitive, emotional, and behavioral. Latinos show a higher level of engagement in mathematics when they are asked to work with peers than when asked to work alone (Uekawa, Borman, & Lee, 2007). They are more

likely to use a participatory communication style, which requires active response from the audience, such as verbal encouragement or even physical movement during speech (Gay, 2000). This form of communication is not readily accepted in conventional mathematics classrooms. Rather, it is often viewed as a disruptive behavior or, at best, an attitude less effective for learning (Neal, McCray, Webb-Johnson, & Bridgest, 2003). Not surprisingly, Latino students experience a higher level of mathematics anxiety than Caucasian students; Latinas' anxiety tends to be even worse than that of their male counterparts (Willig, Harnisch, Hill, & Maehr, 1983).

Embodied Agents to Create a Social and Affable Context

While computers are often regarded merely as a tool to perform tasks, computer users actually tend to expect computers to be like social entities (Lee & Nass, 2003). In response to animated digital characters, users build human-like relationships with the character (Bickmore, 2003); college students expect a digital character acting as a tutor to have a nice personality as well as content expertise (Y. Kim, 2007). Furthermore, just as girls' and boys' preferences for instructional content, activities, and methods are differentiated in classrooms, so are their reactions to the features in computer-based learning (Kinzie & Joseph, 2008). Females' inclinations toward interactions and relationship building in classrooms are consistently demonstrated in computer-based environments. For instance, girls like interactive and dynamic hints from the computer more than do boys (Arroyo, Murray, Woolf, & Beal, 2003).

Researchers in educational technology have explored the use of embodied interface agents in various theoretical and practical frameworks, e.g., in the framework of computer-supported collaboration (White, Shimoda, & Frederiksen, 1999), or as a way to render a sense of social presence (Graesser, Chipman, Haynes, & Olney, 2005; Moreno & Flowerday, 2006). Embodied agents even seem to play a persuasive role in shaping viewpoints, attitudes, and

behaviors. One experiment revealed that an agent's pedagogical perspectives were successfully projected into college students' own pedagogical perspectives. Preservice teachers who worked with an agent that took a constructivist perspective adopted the constructive perspective after their interactions with the agent; whereas, those who worked with an agent taking an objectivist perspective adopted the objectivist perspective (Baylor, 2002). In another study, middle-school students who had received instructions from an agent reported lower levels of perceived difficulty than did the students who had received textual information without an agent (Atkinson, 2002). Also, when kindergarten children played with the virtual peer *Sam*, they listened to *Sam*'s stories very carefully and, afterwards, mimicked *Sam*'s linguistic styles (Ryokai, Vaucelle, & Cassell, 2003).

Traditionally, human one-on-one tutoring has been considered the best form of instruction because it increased learning by two standard deviations as compared to the group instruction in a classroom (Bloom, 1984). Researchers in computer-based tutoring have strived to approximate the effect of human tutoring. As a result, successful tutoring systems were able to increase learning by one standard deviation higher than the control groups (Graesser, et al., 2005; Koedinger & Anderson, 1997). This success has raised the inquiry into how we can further make up the missing one-standard-deviation effect through our design. Stone (1998) identified three components of scaffolding -- perceptual, cognitive, and affective -- as necessary for effective learning and motivation. Many conventional tutoring environments, however, have focused on assisting learners in only the cognitive processes of learning. They often neglected to implement perceptual and affective aspects of scaffolding. Recently, researchers in educational technology have come to better understand the integral role of human cognition and affect in the learning process, and have made efforts to equip tutoring environments with affective capabilities

(Boulay et al., 2010; Graesser, Jackson, & McDaniel, 2008).

These trends in embodied agents and tutoring systems provides a further line of inquiry into the potential of embodied agent technology for addressing the equity issues in mathematics education. When teachers and parents simply presented the facts about the non-existence of gender difference in mathematics learning, adolescent females became able to resist negative stereotypes concerning girls and mathematics (Jacobs, et al., 2005). By presenting similar messages in the course of instructional guidance, an embodied agent tutor might inculcate positive attitudes toward mathematics learning and improve females' self-efficacy beliefs. If this expectation turns out to be true, embodied agent technology will be able to expand the functionality of conventional tutoring systems, which have typically assumed a motivated learner instead of generating motivation (Boulay, et al., 2010).

In this study, we conducted two phases of empirical inquiry. The first phase was an *in vivo* experiment, in which quantitative data were collected in natural classrooms. In the second phase, in-depth interviews were conducted to better understand the nature of students' learning experiences with their agent. The guiding research question was, Will middle-grade females' and Latinos' reactions to an embodied agent be qualitatively different from Caucasian males' reactions?

Classroom Experiment

Hypothesis

This classroom-based experiment investigated whether or not learner gender and ethnicity would influence learners' evaluations of their agent, mathematics attitudes, mathematics self-efficacy, and learning gains. We tested four hypotheses: (a) females and Latino students would evaluate their agent more positively than Caucasian males, (b) females' and

Latinos' attitudes toward learning mathematics from their agent would be more positive than Caucasian males' attitudes, (c) females' and Latinos' self-efficacy in learning mathematics from their agent would be higher than Caucasian males' self-efficacy, and (d) females and Latinos would increase their learning similar to Caucasian males after the intervention. In addition, if an embodied agent would have a positive influence on females and Latinos, theoretically Latinas would be the group benefiting most from the agent; Caucasian males would benefit least. The two groups were compared in each of the dependent measures.

Method

Participants.

Participants were one hundred and twenty 9th-graders enrolled in Algebra I classes in two inner-city high schools in a mountain-west state in the United States. Sixty-four students were male (53%) and fifty-six female (47%). Sixty-one students were Caucasian (51%) and fifty-nine Latino (49%). In the participating school districts, students were able to start taking Algebra I in the 7th grade and required to complete it by the 9th grade. Thus, the participants who had delayed the course until required were assumed to be less interested in mathematics than the rest of the 9th graders in the schools. The average age of the participants was 15.93 ($SD = .87$).

Intervention: An agent-based algebra-learning environment.

The intervention was two computer-based lessons, integrated with an embodied agent. The lessons were designed as supplemental materials to classroom learning, in which a learner reviewed the concepts individually that he or she had learned from the teacher and practiced solving problems to master the concepts. The agent, designed as a tutor, presented curriculum-related information and feedback and also verbally encouraged the learner to sustain in the task.

The learning environment was self-contained, within which the learner typed in demographic information to log in, performed the learning task, and took pre and posttests.

Curricular content.

Following the *Principles and Standards of the National Council of the Teachers of Mathematics* (<http://www.nctm.org>), the curriculum was developed in collaboration with the algebra teachers in the participating schools, addressing their classroom needs. The two lessons, each taking one class period (approximately 50 minutes), dealt with combining like terms and distributive properties (Lesson 1) and graphing linear equations using slope and y-intercept (Lesson 2). The lessons consisted of four to five sections, each section including two phases, (a) Review of Concepts and (b) Problem Practice. In the Review, the agent presented brief overviews of key concepts and examples. In the Problem Practice, a learner solved problems one at a time by way of drill-and-practice, listening to the agent's feedback. The lessons were prescribed, so that every learner could be exposed to all overviews and solve the same number of problems. The teachers helped identify the errors that students typically made in the classroom and helped write corrective feedback messages. Figure 1 presents example screens of the lesson environment.

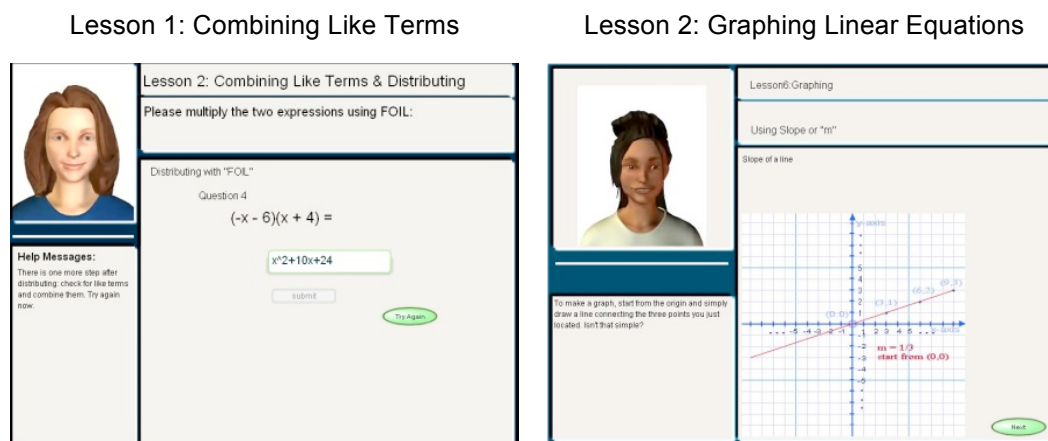


Figure 1. The example screens of the agent-based learning environment.

Agent design.

The design goal for the embodied agent named *Chris* was to simulate the instructional, social, and empathetic roles that might be played by an effective human tutor. We achieved the goal by including three features in agent design: (a) personalized instructions, (b) social and empathetic rhetoric, and (c) peerlike image and voice. Regarding personalized instructions, while a learner worked individually at his/her own pace, *Chris* used the personal pronoun *we* in its explanations and feedback, emphasizing “a sense of togetherness.” The problem for the learner to solve was not his or hers but “our problem.” For social and empathetic rhetoric, *Chris* used two types of messages in addition to curricular overviews and feedback: motivational and persuasive. Motivational messages were words of praise and verbal encouragement presented when the learner made a mistake. Persuasive messages were statements about the benefits or advantages of doing mathematics well. The persuasive messages were integrated into the introductions to new sections and subsections, so that every learner would hear persuasive statements. To promote agent-learner affinity, the messages adopted the teenagers’ style of speech. Two high-school students translated the messages developed by the design team into such teen-friendly speech. The appendix presents examples of the agent messages. Lastly, we used peerlike image and voice to increase a sense of affinity. To control for the confounding effect by learners’ biases toward agent gender or ethnicity (Y. Kim & Wei, 2011), we developed four versions of an agent to match the students’ gender and ethnicity. One of the four agents was randomly assigned to a student. Also, to control for the confounding effect by agent appearance (Gulz & Haake, 2006), we morphed the four versions from one base image. Following that, we validated the agent images with another group of two hundred high school students, which confirmed that the images looked as exactly as intended. Agent voices were recorded by four adolescent voice

actors, in consideration of the friendliness of the human voice as compared to a synthesized one (Mayer, Sobko, & Mautone, 2003). Lastly, we added facial expressions, eye gaze, and head nodding to make the agents look more natural and believable.

Variables and measures.

Independent variables included learner gender and ethnicity, each having two levels: male Caucasians (35), female Caucasians (26), Latinos (29), and Latinas (30). Dependent measures were learners' evaluations of an agent, mathematics attitudes, mathematics self-efficacy, and learning gains.

Learners' evaluations of an agent.

Learners' evaluations of their agent were measured with a 17-item questionnaire using Likert scale ranged from 1 (*Strongly disagree*) to 7 (*Strongly agree*). The items asked if the agent was friendly and helpful for learning and if the learner desired to work with the agent again, e.g., "Chris was friendly," "Chris was easy to understand," and "I'd like to learn from Chris again." Interitem reliability was evaluated as $\alpha = .96$.

Mathematics attitudes.

Mathematics attitudes were defined as learners' overall evaluative responses to learning mathematics (Petty, DeSteno, & Rucker, 2001). Pre and posttest items, scaled from 1 (*Strongly disagree*) to 7 (*Strongly agree*), were derived from the Attitudes Toward Mathematics Inventory (<http://www.rapidintellect.com/AEQweb/cho253441.htm>). The 5-item pretest measured learners' general attitudes toward learning mathematics, e.g., "In general, I like learning math." The pretest was used as a covariate in the analysis; the interitem reliability evaluated with coefficient α was .80. The posttest included two categories of attitudes. One category measured learners' general attitudes (same as the pretest); the other measured learners' attitudes specifically toward

learning mathematics from the agent in the lessons (two items), e.g., “I liked solving math problems with Chris in this lesson.” Posttest interitem reliability was evaluated as $\alpha = .84$.

Mathematics self-efficacy.

Mathematics self-efficacy was defined as learners’ beliefs in their capability to successfully learn mathematics (Bandura, 1997). Following Bandura’s guidelines (2006), pre and posttest items were developed and ranged from 1 (*Strongly disagree*) to 7 (*Strongly agree*). The 5-item pretest measured the learners’ general self-efficacy beliefs in learning mathematics, e.g., “In general, I am confident in learning math.” The pretest was used as a covariate; interitem reliability was evaluated as $\alpha = .84$. The posttest included two categories of self-efficacy. One category measured learners’ general self-efficacy (same as the pretest); the other category measured their self-efficacy specifically in learning mathematics from the agent (four items), e.g., “I was confident in solving problems with Chris in this lesson.” Posttest interitem reliability was evaluated as $\alpha = .86$.

Learning gains.

Learning was measured with a pretest and an immediate posttest. After logging into the system, the learners solved 16 problems; at the end of the lesson, they solved another set of 16 equivalent problems. For example, one item in pretest asked the learners to distribute the expression $3a(x+y)$; the matching posttest item asked to distribute the expression $5x(a+b)$. The items were presented one after another; the format was similar to Figure 1, Question 4 on the left, without agent presence. Students used scratch paper and pencil to solve a problem and typed in their answers in a blank. Each item was scored correct (1) or incorrect (0), with the maximum score of 16 and no partial scores.

Procedure.

We implemented the experiment as regular activities in the classroom (using 34 laptop computers) on two consecutive days, one lesson per day. On Day 1, students were given a brief introduction about the lesson and interface and then asked to put on headphones. They entered demographic information to log onto the lesson. Upon login, they took pretests. Following that, one of the four agents (differing in gender and ethnicity) was randomly assigned to a student. Students performed the learning task, listening to Chris' overviews and feedback. On Day 2, students were assigned to the same agent and performed the learning task in the same manner. Lastly, they took posttests without Chris.

Design and analysis.

A 2×2 factorial design was used, in which both learner gender and ethnicity had two levels. To analyze learners' evaluations of an agent, a two-way ANOVA was conducted. To analyze attitudes and self-efficacy (each having two sub-categories), 2 two-way MANCOVA's was conducted respectively, with a pretest set as a covariate to control for the group difference in the pretest. To analyze learning, a two-way repeated ANCOVA was conducted, with a pretest set as a covariate. The significance level was set at $\alpha < .05$.

Results

A preliminary analysis of the data was conducted to ensure that the assumptions of the parametric statistics were met. Visual examination of scatter plots supported the assumption of normality and revealed linear relationships. Levene's Test was conducted to test the equality of error variance for each ANOVA procedure; Box's Test was conducted to test the equality of covariance for each MANCOVA procedure. These tests did not reveal any significant problems with the equality of error variance and covariance. Table 1 presents the means and standard

deviations for learners' evaluations of an agent, mathematics attitudes, and mathematics self-efficacy.

Gendered and ethnicity-based positivity of agent evaluations.

The two-way ANOVA indicated a significant main effect of learner gender, $F(1, 116) = 8.22, p = .005, \eta^2 = .07$. The females evaluated their agent significantly more positively than did the males. Also, there was a significant main effect of learner ethnicity, $F(1, 116) = 22.87, p = .000, \eta^2 = .17$. The Latinos evaluated their agent significantly more positively than did the Caucasians. A Planned Two Independent Group t Test was further conducted to compare Latinas with Caucasian males. The results revealed that the Latinas evaluated their agent significantly more positively than did the Caucasian males, $t = -5.54, p = .000, d = -1.39$.

Table 1

Means and Standard Deviations for Posttest Learners' Evaluations of an Agent, Attitudes, and Self-Efficacy

Measures	Learner groups (N = 120)							
	Female				Male			
	Latina (n = 30)		Caucasian (n = 26)		Latino (n = 29)		Caucasian (n = 35)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Evaluation of their agent	86.3	4.13	69.23	4.43	77.17	4.20	54.57	3.82
Attitudes toward the lessons	9.04	0.50	7.93	0.55	7.56	0.51	7.19	0.45
Self-efficacy in the lessons	20.11	0.80	19.68	0.86	18.46	0.80	18.93	0.75

Gendered inflection of attitudes.

The two-way MANCOVA revealed a significant main effect of learner gender, Wilks's lambda = .95, $F(2, 114) = 2.95, p = .046$, Partial $\eta^2 = .05$. Given the overall significance, a univariate analysis was further conducted to examine the contribution of each category of

attitudes to the overall significance. There was a significant main effect of learner gender on the attitudes specifically toward learning mathematics in the agent-based lessons, $F(1, 115) = 4.82, p = .030, \eta^2 = .04$. The females showed significantly more positive attitudes than did the males. A planned contrast between Latinas and Caucasian males revealed a similar pattern that the Latinas showed significantly more positive attitudes than the Caucasian males, $t = -2.42, p = .019, d = -0.6$.

Gendered enhancement of self-efficacy.

The two-way MANCOVA revealed neither main effect nor interaction effect of learner gender and learner ethnicity on learners' mathematics self-efficacy ($p = .783$). Nonetheless, the goal of the learning environment was to help students build their confidence in mathematics learning; we inquired about any group difference in the improvement of their self-efficacy after the intervention. A two-way repeated ANOVA was conducted to examine changes in learner self-efficacy from pretest to posttest. Because the number of the items in the two tests was not matched, the posttest scores were statistically converted to match the pretest scores. There was a significant interaction effect of the within-subject factor (time) and learner gender, $F(1,116) = 7.47, p = .007, \eta^2 = .06$. Females significantly increased their self-efficacy from pretest to posttest; whereas, males did not show the increase. A contrast between Latinas and Caucasian males revealed a similar interaction pattern that revealed only the Latina's significant increase in their self-efficacy, $F(1,63) = 4.98, p = .029, \eta^2 = .07$.

Mathematics learning in a socialized environment.

The analysis of learning included sixty-nine students, only those who had completed algebra posttests in both days. Table 2 presents the means and standard deviations of the pre and

posttests. The ANCOVA result revealed neither main nor interaction effect of student gender and ethnicity on learning, $F(1, 64) = 3.17, p = 0.080, \eta^2 = .05$. We also conducted a two-way repeated ANOVA to test the groups' learning gains over time. There was a significant main effect of the within-subject factor (time), $F(1, 65) = 53.28, p = .000, \eta^2 = .45$. A planned contrast between Latinas and Caucasian males did not reveal a significant difference in their learning gains. Overall, regardless of their gender and ethnicity, the student groups significantly improved their learning after working in the agent-based lessons.

Table 2

Means and Standard Deviations for Pre and Posttest Learning Measures

Measures	Learner groups (N = 69)								
	Female				Male				
	Latina (n = 14)		Caucasian (n = 18)		Latino (n = 14)		Caucasian (n = 23)		
	M	SD	M	SD	M	SD	M	SD	
Learning	Pretest	6.14	3.80	8.22	2.24	6.43	4.62	7.96	2.77
	Posttest	9.29	4.12	10.78	1.86	7.64	5.20	11.04	2.65

To summarize, the 9th-grade females evaluated their agent significantly more positively than did males; the Latinos significantly more positively than did Caucasians. Secondly, the females showed significantly more positive attitudes toward the agent-based learning than did males. Thirdly, the females significantly increased their mathematics self-efficacy after the agent-based learning; whereas, the males did not show the increase. These gender differences in evaluations of an agent, attitudes, and self-efficacy were even more clearly manifested between the Latinas and the Caucasian males. Lastly, regardless of learner gender and ethnicity, all the groups significantly increased their learning after the lessons. Overall, the results suggested that the males and females have qualitatively different experiences in agent-based learning. In-depth

interviews were conducted to better understand the nature of the students' experiences and the agent's characteristics that might most appeal to students of this age.

In-Depth Interview

Interviewees

The interviews were focused on deeper understanding of the females' experiences and the clear contrast between Latinas' and Caucasian males' reactions. Initially, twelve interviewees were randomly selected from the participant pool that had completed both lessons, which resulted in a sample of eight Caucasian males, two Caucasian females, and two Latinas. A second round of sampling was conducted to obtain a theoretical sample (six to eight) from each comparison group, to ensure a meaningful, thematic analysis. The sampling targeted the two female groups, from which six Caucasian females and four Latinas were further selected randomly.

Procedure

All interviews were conducted individually at the high schools and followed the lesson implementations. Three trained doctoral students conducted the interviews (each taking 20 to 30 minutes), using a loosely structured interview protocol that listed a set of main questions, e.g., "What did you like or dislike about the lessons with a peer-like tutor?" and "What would you suggest for the improvement of the lessons?" The protocol allowed room for exploration and probing when necessary. To ensure the confidentiality of the interviewees, all identifiable comments were eliminated from the transcripts, and pseudonyms were used in the analysis.

Data Analysis

The Constant Comparison method (Charmas, 2006) was used to identify major differences between the female and male groups. To ensure the quality and trustworthiness of the

findings, the research team analyzed the interview data through a collaborative, reiterative process. Both authors read all transcripts individually and brainstormed several salient themes. Following that, the second author with the help of two graduate assistants launched a more systematic, thorough analysis, using the software Atlas ti. Next, they summarized key information about the interviewees' experiences with the agent, their classroom experiences, and other critical information, such as the perceptions of the agent, familiarity with computers, and the level of their attention to the agent. Based on recurring information in the summary, a list of open codes was developed. These codes were appended to relevant quotations in each transcript. A code output was generated. The team examined the output carefully to detect major patterns across the twenty-two interviewees and possible consistent relationships in the patterns. Lastly, the team elicited three main themes.

Results and Interpretation

Gendered perspectives and relationship building.

The females and males demonstrated different views of their agent and developed different types of relationships with it while they engaged in the learning task. The males seemed to treat the agent as a mere tool and showed detached attitudes toward it, describing it as an “unnatural” or “fake” person and not being able to recall its name, gender, or ethnicity. They listed both positive and negative aspects of the agent. In most cases, their negative comments were longer and more varied than the positive ones. They found the agent's unsolicited explanations rather “annoying” and “boring.” About half of the males reported that they “turn[ed] off the voice,” “skipped,” or “ignored” narratives of their agent that they found not helpful. Mark's comments demonstrated this distant view of the agent:

Interviewer: So how did you find Chris [the agent] similar to a peer or friend?

Mark: I didn't really think of it as a friend, I just thought of it as like a little computer thing. (Interviewer: Oh really?) But yeah. I just don't really think that like computers are supposed to be your friend.

In contrast, the females seemed to treat their agent as if it were as friend or companion, and they built a human-like, person-to-person relationship with their agent. They always called their agent by its name "Chris", used personal pronouns "she" or "he" to refer to the agent, and paid attention to various aspects of the agent (e.g., facial expressions, its hair style, the tone of speech). Not surprisingly, they reported their experiences with the agent-based learning very positively. This phenomenon was far more evident among the Latinas. Not one of the Latinas made negative comments about the agent, rather all of them were effusive about their enjoyment in working with the agent. Perla (Latina) described her agent as being "really nice always" and "just like human thing... that someone is telling you compliments." Janet (Caucasian) said that her agent was "the person next to you [who] would help you with whatever problem you need." By and large, the development of a human-like relationship with their agent seemed to generate positive effects on their learning process, but some negative consequences were also observed. Some girls were distressed by the agent's negative feedback. The agent was "not friendly" but "mean" and "rude" and made them feel "hurt." These girls seemed to project their interpersonal expectations onto the agent and were disappointed when their expectations were not met properly.

Consequences in learning: Students' evaluations of agent effectiveness.

Overall, both male and female students liked the agent's immediate and individualized feedback. However, the males said that the explanations were sometimes redundant or at other times, not specific enough. Although they valued the agent's ability to provide feedback and/or

to alert them to their mistakes, the males often skipped or turned off lengthy explanations to directly tackle the problem on their own. Only two males out of eight listed “good explanation” as a strength of the agent. The males’ complaints were mainly related to weak explanations not tailored “for me.” Rick’s comments exemplified the males’ reactions:

The only reason I marked that [evaluated negatively] I didn’t really like it ‘cause sometimes it explained like too much, like at the beginning of each section or something. It kept- it kind of went on and on for me, so it just kind of got annoying for me to have to keep listening.

Conversely, the females spoke highly of the quality and relevance of the agent’s explanations. Almost all of them said that their agent had provided good explanations, which were “clear” and “very specific.” Selena said that the agent “explained every little part of it” and “when I would get confused, she would explain what I did wrong clearly.” The girls rarely mentioned the actions often taken by the boys, e.g., skipping lengthy explanations. As a result, the girls were more likely to attend to and benefit from the coordinated instructional features, e.g., voice narration with the accompanying texts on the screen. Abby’s positive view consistently appeared in almost all females’ comments, “I would really enjoy it because like it explained it how to do it and it had visuals of how to do it, and it would explain how to go step by step. So it would be really helpful.” Presumably, the companionship that the females had built with the agent established a positive context for the subsequent learning process and made the females willing to listen to even lengthy explanations.

Connection between real and virtual contexts in learning experience.

The gendered pattern of learning experiences with the agent did not seem to occur in a social vacuum. Rather, students’ views of their agent and the quality of their learning

experiences with it seemed to be influenced by their everyday classroom experiences. The students who felt less supported in classroom tended to develop positive attitudes toward the agent-based learning and reported positive learning experiences. The Caucasian males rarely expressed psychological stress in their classrooms; only two males showed a glimpse of social disconnection from their teacher. In contrast, all the females mentioned, at least once, a negative experience and/or feelings of insecurity in their classrooms. Most of them stated that their teacher did not care about their learning and was not willing to help them when they faced a difficulty.

This phenomenon was more manifested among Latinas. While three Caucasian girls out of eight mentioned some positive aspect of the classroom, the Latinas' narratives presented a greater disconnection in their relationships with the teacher and even a sense of fear and intimidation. Daniela (Latina) expressed discomfort with her teacher's tone of voice: "They [teachers] teach you but sometimes you don't get the thing and they teach again but in different voice." In response to the question about the difference between the agent Chris and the teacher, Selena contrasted "upbeat and friendly" Chris with her "kind of intimidating" teacher. While none of the Latinas showed difficulty with conversing in English, many indicated that the ordinary classroom instruction was "too fast" and the teacher was "leaving you alone" even when students did not grasp the concepts. They felt relieved working with their agent, who would never blame them for not catching up to its speed. Some even argued, "You can learn more, and they [agents] teach you more, better than the teacher."

To summarize, the interviews revealed that the males and females developed different relationship patterns with their agent. This gendered pattern of relationship building resulted in their differential evaluations of the quality and effectiveness of the agent's feedback and

explanations. Also, the students' experiences with the agent were closely related to their everyday classroom experiences. The females, psychologically marginalized in classroom, perceived the agent as a genuine companion who kindly helped them learn step by step.

Discussion

This study was grounded in two theoretical premises. First, inequity issues in STEM education are attributable to the unsupportive context in STEM classrooms for traditionally underrepresented groups of students. To address this issue, educators should contrive supportive learning contexts, in which these students feel cared for and encouraged to engage in STEM learning. These contexts should accommodate the learning styles of the students that favor multifaceted interactions and social relations. Second, an embodied agent, with its social and empathetic capabilities, might afford humanlike interactions with the students. If designed carefully, agent-based learning could create a socially rich and inclusive context for those groups of students and, thereby, support their positive learning experiences and sustained intellectual pursuit in STEM. On the whole, the results from both phases of this study support the premises and show agent technology to be a promising tool in the resolution of urgent educational issues. The results also argue for the expansion of advanced learning technology.

Consistent with the current literature, the classroom experiment revealed clear gender differences in responses to agent-based learning. Females' preference for social interactions and relationship building in classroom seemed to be reflected consistently in their evaluations of their agent. Females rated the agent with an average of 4.6 on the 7-point scale, and males with an average of 3.9. In particular, Latinas rated the agent with an average of 5.1, and Caucasian males with an average of 3.2. The females' favorable evaluations of their agent seemed to lead them to build more positive attitudes toward learning from the agent and to increase their self-efficacy

after the lessons. Moreover, the females significantly increased their mathematics learning comparable to their male counterparts after working with the agent. At a minimum, the conventional achievement gap favoring Caucasian males was not observed in the agent-based lessons. When the females realized that they had instructional support and were free from social embarrassment, they were more likely to engage and not afraid of making mistakes, as indicated in the interviews.

The interviews supported the quantitative results of the classroom experiment and illuminated the nature of gender differences in the responses to the agent-based learning. First, both Latinas and Caucasian females engaged themselves in interactions with the agent and responded socially. Although the females admitted their agent to be a computer program, their interactions with it resembled their everyday social interactions with a friend in many ways. This implies that quality relationships must be important for females' mathematics learning even in technology-based environments. Regardless of a virtual or real space, relationship building is an essential and natural part of many females' learning process as explained by feminist scholars (Belenky, et al., 1997; Noddings, 2003). The development of companionship with their agent provided the females with some advantages. It effectively engaged them in the task and let them be patient throughout the lessons. Also, it reduced the chance of experiencing the negative emotions that many females had in ordinary mathematics classrooms.

The study revealed that a persistent cultural and social disconnection existed between the females (more with Latinas) and their teachers. The students acknowledged that their teachers were overburdened with teaching big class. Still, their feelings of disconnection were a challenge to their engagement and success in school mathematics (Lim, 2008). The features that they listed as supportive of their learning during the lessons were similar to the characteristics of *culturally*

relevant pedagogy (Gay, 2000). The Latinas earnestly expressed their need for a psychologically “safe” space, where they could ask for help freely as many times as needed. The provision of a communal sense of learning -- working together closely with someone willing to help -- was a strength of the agent-based learning. Their feelings of connection to the agent and the agent’s social encouragement seemed to lead them to full engagement in the task (Sciarra & Seirup, 2008).

The study also confirmed the trends in human-computer interaction and further extended our understanding in the area. The more computers present humanlike characteristics, the more likely they are to elicit social behavior from users (K. M. Kim, Jung, Kim, & Kim, 2006). Likewise, the agent Chris, looking peerlike, successfully elicited the females’ social responses. Once the females identified their agent as a helper for their learning, it did not matter if the helper was real or artificial (Turkle, 2011). More importantly, the study revealed that the boundary between real and virtual spaces was blurred. Students’ online learning experience, either positive or negative, could be better understood in relation to their everyday classroom experience. Their learning experiences in the two spaces are closely interrelated, each providing an important context for the other and each influencing the other. In similar fashion, the females’ (particularly the Latinas’) positive experiences with the agent-based learning were influenced largely by their marginalized experiences in the everyday mathematics classrooms. An implication for the designers of advanced learning technology is that the careful observation and accurate understanding of challenges that students face in the classroom might be a primary step in designing effective technology-based learning environments.

Several previous studies on embodied agents have reported that learners perceived a matched agent with their own gender or ethnicity more positively than a mismatched one (e.g.,

Moreno & Flowerday, 2006; Y. Kim & Wei, 2011), indicating that social biases in the real world were consistently applied to agent-learner relations. However, our interest was in examining the potential of agent technology for countering existing stereotypes and biases. We focused on the motivational and persuasive role that a peerlike agent would play, regardless of its gender and ethnicity. Neither agent gender nor ethnicity was examined as a factor; instead, four versions of an agent differing in gender and ethnicity were randomly assigned to students, to control for a confounding effect by the learners' biased perceptions. In the interviews, the Latinas who worked with a Latino agent tended to express a higher level of affection for the agent than the Latinas who worked with a Caucasian agent. Nonetheless, all the Latinas agreed that their agent, either Caucasian or Latino, was a great helper.

Recently, there has been a growing awareness about the social and cultural aspect of females' and ethnic minorities' learning processes (Carr & Steele, 2009; Nasir, et al., 2006). It is clear that more research is called for in designing effective learning technology for these students. This technology needs to support their identification with STEM topics and to include specific features that stimulate motivation. Technology-use trends in the United States show that African-American and English-speaking Latino youths use internet and mobile data more frequently than do Caucasian youths (Smith, 2010), thus games and mobile technology could be a functional space for inviting these students' attention to STEM topics.

Lastly, the study had a few limitations. First, the agent in the study was designed to be a whole entity with instructional, social, affective, and aesthetic attributes. The interactions among these attributes and their relative contributions to the females' positive experiences should be clarified in the subsequent research. Second, both quantitative and qualitative data were collected in specific locations and with two-day implementations. The findings should be generalized

judiciously. Third, based on the results of the experiment, the interviews were focused on the contrast between the females and Caucasian males. Much is unknown in regard to Latino males' interactions with their agent and their experiences in the learning environment. Future research is warranted to overcome the limitations and confirm the findings of the current study.

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Appendix: Agent Messages Examples

1. The agent presented persuasive (P) and informational (I) messages in the introductions to new sections and sub-sections.

At the start of the section on Distributing to Combine Like Terms, the agent said:

“Hey, we are doing great. You know, if we do well in math, we can major in anything we want in college because many jobs require an understanding of math. Developing math skills now will give us more opportunities later (P). Alright, in this section, we are learning how to distribute first and then combine like terms. Terms don’t always come combined . . .(I)”

2. The agent presented motivational and informational feedback in a sequence while students solved problems.

Question 5: Simplify the expression by distributing and combining the like terms.

$$4r + 4(r + s) = \underline{\hspace{2cm}}$$

Possible Answers Typed	Type of Errors	Agent Messages	
		Motivational feedback	Informational feedback
8r + 4s	None	<i>Excellent. Let’s keep up the good work.</i>	-
4r + 4r + 4s	Like terms not combined	<i>Everybody makes a mistake. Let’s learn from the mistakes we’ve made.</i>	<i>There is one more step after distributing. Let’s check for like terms and combine them.</i>
8r + s	Partial distribution		<i>Distribute the 4 to both terms in the parentheses and then combine like terms.</i>
Any other (1 st try)	Random		<i>First, distribute the 4 to both r and s in the parentheses, and then look for like terms.</i>
Any other (2 nd try)	Random	<i>It was a challenge, but hang on there. It will pay off in the end.</i>	<i>Distribute the 4; that means we now have 4r plus 4r plus 4s. The first two terms are alike, so we combine them and the answer is 8r plus 4s.</i>