Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

Abstract

Compared to boys, many girls are more aware of a social context in the learning process and perform better when the environment supports frequent interactions and social relationships. For these girls, embodied agents (animated on-screen characters acting as tutors) could afford simulated social interactions in computer-based learning and, thereby, supply a girl-friendly instructional context. This study examined the effects of the age and gender of an agent on 9th-grade Caucasian and ethnic-minority girls' perceptions of the agent, mathematics attitudes, and learning in a computer-based algebra-learning environment. In general, the findings support that an agent plays both social and instructional roles that favor teenage girls and could be a viable tool to create a favorable context for girls learning challenging topics.

Keywords: Embodied agents, Interactive learning environments, Human-computer interaction, pedagogical agents, Agent personal attributes

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

The Role of Agent Age and Gender for Middle-Grade Girls

It is well documented that girls' lack of interest and confidence in learning mathematics is often attributable to social stereotyping and insufficient instructional support in conventional classrooms (Steffens, Jelenec, & Noack, 2010). Also, gender difference in motivation and learning has been acknowledged broadly. Many girls seem to be better motivated when a learning environment supports interpersonal connections and collaborative interactions than when these interactive features are missing (Belenky, Clinchy, Golberger, & Tarule, 1997). Similarly, educational technology research over the last decade has attested to gender difference in the use of interactive learning technologies: that is, girls are more likely than boys to benefit from frequent feedback and interactive help embedded in the tutoring system (Arroyo, Burleson, Tai, Muldner, & Woolf, 2013). Furthermore, girls increased their self-efficacy beliefs in learning mathematics after working with an animated agent embedded in computer-based learning (Kim & Lim, 2013).

Embodied agents could be used to create a social and instructional context that favors girls: providing the girls with informational guidance and social encouragement to counteract the gender-related stereotypes in the real world. According to theories in social cognitive psychology, an individual's personal attributes largely affect the credibility of the person and greatly impact the persuasive power of the person. Researchers in agent technology have examined the impact of an embodied agent's personal attributes matching or mismatching the learners' own but the results are often contradictory. Furthermore, although there is a consensus that females in general respond to an agent's help more positively than do males, it is not yet clear how the personal attributes of an agent would influence the effectiveness of the agent's

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

instructional and social messages on middle-grade girls who learn mathematics. This paper presents a classroom-based experiment that has examined the effects of an agent's age and gender on 9th grade girls' evaluations of their agent, mathematics attitudes, and learning gains.

Theoretical Background

Social and Interactive Contexts for Girls

It is acknowledged that females, more than males, tend to value social connections and construct their identities as a result of the interpersonal relationships they have maintained. As they try to access another person's ideas or knowledge, many females seem to count on the quality of the relationship with that person and the shared features in their personal experiences (Belenky et al., 1997). Similarly, compared to boys' participation, girls' participation in class is affected more by teacher behavior (Sandler, Silverberg, & Hall, 1996). In their learning processes, girls are more likely to be motivated when they establish supportive relationships with teachers and peers (Crosnoe et al., 2010).

Girls' natural tendency toward social interaction and collaborative relationship is demonstrated in a consistent fashion when they work in computer-based learning. When using educational software, girls like the programs that present frequent and direct verbal feedback (Littleton, Light, Joiner, Messer, & Barnes, 1998). Girls use the verbal help more frequently than do boys and perform better when they receive highly interactive and proactive hints than when they receive non-interactive and low-intrusive hints (Arroyo et al., 2013). In social networking sites, females are significantly more likely to post agreements and show higher levels of emotional support than males (Joiner et al., 2014).

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

Digital Embodied Agents

Embodied agents are animated human-like on-screen characters embedded in computer-based learning that act as tutors or co-learners (Kim & Lim, 2013). When people use computers, they do not merely perform tasks but also treat the computers as social actors (Veletsianos, 2010). Indeed, even college-aged students expected their agent to be *nice and friendly* (Kim, 2007) and learned better when the agent was *polite* to them (Wang et al., 2008). In this sense, an embodied agent might be able to enrich learners' experiences (especially girls' learning experiences) in computer-based learning with its social and instructional affordances. While an agent assists a learner by presenting instructional content and personalized feedback, the learner might also build social and intellectual partnerships with the agent.

To date, empirical evidence has established the effectiveness of an agent's presence in computer-based learning on learners' positive affect, especially on their motivation to learn and willingness to continue to work at the agent-based learning (D'Mello, Olney, Williams, & Hays, 2012; Graesser, Chipman, Haynes, & Olney, 2005; Kim, 2013; Wang et al., 2008). Recent studies have even suggested the use of embodied agents as persuasive role models to motivate girls to learn mathematics (Kim & Baylor, 2007; Kim & Lim, 2013) and also to improve the girls' constructive views of engineering (Rosenberg-Kima, Plant, Doerr, & Baylor, 2010). Just as social encouragement by teachers and parents in the real world plays an important role for girls' continued intellectual pursuit in mathematics learning (Crosnoe et al., 2010), so might an agent emulate such social cues, verbally encouraging girls to develop positive affect while assisting in their learning of challenging topics.

Defining Agent Attributes

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

Designers have full freedom to design an agent to facilitate positive learning experiences. But it is not yet clear how we could best optimize a human-like agent's personal attributes to different groups of learners. Media equation theory posits that people's interactions with media devices are similar to human-to-human interactions (Reeves & Nass, 1996), and researchers often refer to social psychological theories to define embodied agents' attributes appropriately for the target learner group.

According to classical social modeling theory (Bandura, 1986), attribute similarities (the similarities of personal characteristics between a social model and a learner such as age and gender) are considered a determinant of successful modeling. The more similar a model is to a learner, the greater the probability that the learner will repeat the model's actions. In classrooms, observing a peer model leads to higher posttest self-efficacy and achievement than observing a teacher model or observing no model at all (Schunk & Hanson, 1985). Likewise, traditional similarity-attraction theory indicates that people are more attracted to a person who is similar to them (Byrne & Nelson, 1965). This attraction influences both their interpersonal relations and behaviors. Indeed, in a computing application the mere physical similarity between a user and the avatar induced the user's self-disclosure to a greater extent and led the user to perceive that they shared similar values, beliefs, and attitudes (Hooi & Cho, 2014).

On the other hand, the classical role expectation theory posits that people expect social actors to look and behave according to their respective predictable identities and the situation (Biddle, 1986). When seeking a helper, students in middle and upper grades first consider the helper's competency and willingness to help. They are more likely to ask their teacher for help rather than to ask their peer (Barnett, Darcie, & Holland, 1982). Also, students in grades 3, 5, and

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

7 preferred the teacher as a helper to classmates and reported the teacher as more facilitating to their learning than their classmates (Newman & Schwager, 1993).

Along this line, researchers in agent technology have examined the impact of the personal attributes of agents on different age groups of students. The results by age groups were somewhat contradictory. In a study conducted by Moreno and Flowerday (2006), ethnically-diverse college students learned about science in a multimedia program equipped with one of five agents differing by gender and ethnicity. The students chose an agent looking similar to them, but the ethnic similarities were detrimental to their learning and to program ratings. Rosenberg-Kima et al. (2010) examined the effectiveness of an agent presenting a narrative on the benefits of engineering on college students. They found that the agent's age and gender significantly influenced the students' perceived utility of the agent and their interest in the agent. A study in Germany (Shiban et al., 2015) compared the effect of an older male agent and a young female agent on college-level psychology students' motivation and performance. The students showed higher interest in the young female agent, but their performance was not different based on the agent conditions. The difference in agent gender did not have influence on younger learners. The 4th and 5th-grade children who learned a reading comprehention strategy from either male or female agent did not show any difference in their motivation and learning based on the agent's gender (Kim, 2013). Thus, it seems that the learners' reactions to an agent' attributes might be related to the learners' developmental stage.

Study Purpose and Research Questions

This study was part of on-going efforts to explore how we could effectively design and use embodied agents to promote teenage girls' positive affect and learning in computer-based

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

mathematics learning. In the aforementioned social psychology theories, the personal attributes age and gender have been studied broadly and are considered most influential. Also, the lack of supportive relationships seems to be even more problematic for minority girls in ordinary classrooms. After in-depth interviews with 9th grade Caucasian and Latino girls, Kim and Lim (2013) found that the Latinas felt a lack of instructional support in mathematics classrooms even more intensely than their Caucasian counterparts; the Latinas developed a stronger companionship with their agent tutor and earnestly desired to continue learning assisted by the agent. From other studies conducted with college students, ethnic minorities (as compared to Caucasian students) in general responded more positively to their agent and benefited more from its instructional guidance, regardless of the agent ethnicity itself (Moreno & Flowerday, 2006).

Therefore, the present study examined the effects of an agent's age and gender on the perceptions of the agent, mathematics attitudes, and learning of the two groups of girls, Caucasian girls and ethnic minority girls. There were three research questions:

1) Will an agent's gender and age and learner ethnicity influence girls' perceptions of their agent?
2) Will an agent's gender and age and learner ethnicity influence girls' attitudes toward learning mathematics assisted by the agent?
3) Will an agent's gender and age and learner ethnicity influence girls' mathematics learning outcomes?

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

Method

Participants

Participants were sixty-seven females taking required introductory algebra in the 9th grade in two high schools located in a mountain-west state of the United States. The collaborating school district allowed students to take introductory algebra (Algebra I or Applied Algebra) beginning in 7th grade. We speculated that the participants who delayed the course until required in the 9th grade might represent a population of girls who did not have strong achievements in or motivation towards mathematics learning. Learner ethnicity was self-reported: 36 (53.7%) were Caucasian and 31 (46.3%) were ethnic minorities (20 Latinos and 11 Others). The average age of the participants was 15.51 (*SD* = 1.14). Random assignments to the agent gender and age groups were performed by computer system at a learner level, so the group assignments were equal across the schools.

Materials

Curriculum

The curriculum covered two areas of introductory algebra, developed in collaboration with mathematics teachers in the schools. One area (Lesson I) covered signed number arithmetic - addition, subtraction, multiplication, division, and order of operations. The other area (Lesson II) covered like terms and distributive properties. Each lesson took one-class period and included four to five subsections, each consisting of two phases (Reviews and Problem Practice). The lessons were used as a supplemental material, where an agent reviewed the concepts, presented problems to solve, and provided feedback. Students individually practiced solving problems to master the concepts, without the teacher's help. Figure 1 presents example screens of the

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

learning environment *MathGirls*. The login screen on the left was intended to invite the girls' attention with the obvious program logo; in the problem practice screen on the right, a female-peer-like agent is presenting feedback on the student's answer to the problem. The students were able to listen to the agent and also read her comments underneath the image.

Tutorial messages

Three types of tutorial messages were developed: informational, motivational, and persuasive. Informational messages were curricular-related, including the concept overviews and feedback on students' performance. When a student made a mistake, the agent presented error-specific explanations to guide a learner along the problem-solving path step by step. Motivational messages were words of praise or encouragement. When a student answered correctly, the agent said, "Good job" or "Great, I'm proud of you"; when the student gave a wrong answer, the agent said "Everybody makes mistakes" or "You're getting there. One more thing you need to consider is…" Persuasive messages were statements about the benefits or advantages of doing mathematics well and pursuing careers in STEM. At the beginning of each section, the agent started with persuasive messages (without a learner's request), so all learners listened to persuasive messages consistently.

Tutor attributes design

Four 3D agent images, representing male and female teachers in their forties and male and female teenagers around 15 years old, were designed using the character design tool, Poser (http://www.e-frontier.com). The four images were morphed from a base image and differentiated to serve the respective roles. Given the superior impact of a human voice to a synthesized one, four matching human voices were recorded. Tutorial messages were

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

prerecorded by four voice actors matching the age and gender of the images. The images and the recorded voices were integrated for lip synchronization. Facial expressions, blinking, and head movements were added to make the agents look natural. Then the 3D animated agents were rendered to produce video files, which were later batch-compressed to be cast via the web. Figure 2 presents the four agents used in the study.

Independent Variables

The independent variables include agent age (peer-like vs. teacher-like), agent gender (male vs. female), and learner ethnicity (Caucasian vs. ethnic minority). Agent age and gender were operationalized by image and voice. Except the image and voice, the four agents were identical in their messages, gestures, and facial expressions. Learner ethnicity was identified by self-report (36 Caucasian girls and 31 ethnic-minority girls). Group assignment was randomized by system programming at a student level.

Dependent Measures

Learners' perceptions of the agent

How the learners would perceive their agent might be critical to build trust and rapport with the agent and also for them to engage in interactions with the agent (Dautenhahn, Bond, Canamero, & Edmonds, 2002). Learners' perceptions referred to learners' evaluations of their agent in terms of credibility, friendliness, and helpfulness for learning (Kim, Wei, Xu, & Ko, 2007). These perceptions were measured by a questionnaire with 9 items scaled from 1 (*Strongly disagree*) to 7 (*Strongly agree*). Item reliability evaluated with coefficient α was .90.

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

Mathematics attitudes

Mathematics attitudes were defined as learners' evaluative response to learning mathematics (Petty, DeSteno, & Rucker, 2001). Pre and posttest questionnaires were modified from the Mathematics Attitude Survey (Ethington & Wolfe, 1988) and Attitudes Toward Mathematics Inventory (Tapia & Marsh, 2004), with the items scaled from 1 (*Strongly disagree*) to 7 (*Strongly agree*). 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 α was .80. The posttest questionnaire with 8 items measured learners' general attitudes (same as the pretest, 5 items) and learners' attitudes specifically toward learning mathematics from the agent (3 items). Item reliability evaluated with coefficient α was .84.

Learning gains

Learning gains were measured with a pretest and an immediate posttest. Prior to the lesson, students were asked to solve 10 open-ended problems in the topic, and the scores were used as a covariate in the analysis. At the end of the intervention, the students were asked to solve another set of 10 comparable problems. The scores were calculated by correctness, and no partial scores were awarded. The pre and posttests were integrated into the learning environment, where students solved the problems without tutor presence.

Procedure

The study was implemented as part of regular class activities for two consecutive days (one lesson per day). The learning environment was self-contained, in that the participants completed pretests, learning tasks, and posttests within the lessons. On the first day, the students were given a brief introduction about the lesson and interfaces; then asked to put on headsets.

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

They entered demographic information to log on to the lesson. Upon login, they were randomly assigned to one of the four agent conditions by the system. They took pretests and performed the learning task (taking an average of 40 minutes). On the second day, they continued to work on the next lesson and took posttests.

Design and Analysis

The study employed a 2×2×2 factorial design. For Question 1 on learners' perceptions, a three-way ANOVA was conducted. For Questions 2 on mathmatics attitudes and 3 on learning, a three-way ANCOVA was conducted respectively, with the pretest set as a covariate. The significance level was set at $\alpha < .05$.

Results

Preliminary Data Analysis assured the assumption of normal distributions. No significant findings from Levene's statistics satisfied the assumption of homogeneity of variance for ANOVA procedures.

Learners' Perceptions of the Agent

The ANOVA revealed a significant three-way interaction effect of agent age, agent gender, and learner ethnicity, $F(1, 59) = 5.23$, $p < .05$, $\eta^2 = .08$. Further analyses revealed a significant interaction of agent age and gender only for ethnic-minority girls, $F(1, 27) = 5.97$, $p < .05$, $\eta^2 = .18$. For a male agent, the girls evaluated a peer-like agent ($M = 50.50$, $SD = 4.37$) as more credible, friendly, and helpful than a teacher-like one ($M = 34.89$, $SD = 3.57$). For a female agent, they evaluated a teacher-like agent ($M = 47.00$, $SD = 3.78$) as more credible, friendly, and helpful than a peer-like one ($M = 43.63$, $SD = 3.78$).

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

Also, there was a significant main effect of agent age, $F(1, 59) = 4.12$, $p < .05$, $\eta^2 = .07$. Both Caucasian and ethnic-minority girls overall evaluated a peer-like agent ($M = 45.55$, $SD = 1.95$) as significantly more positively than a teacher-like one ($M = 40.37$, $SD = 1.65$).

Mathematics Attitudes

Similarly, the ANCOVA revealed a significant 3-way interaction effect of agent age, agent gender, and learner ethnicity for learners' attitudes toward learning mathematics assisted by the agent, $F(1, 58) = 7.15$, $p < .01$, $\eta^2 = .11$. Further analyses revealed a similar pattern. The interaction was significant only for ethnic-minority girls, $F(1, 26) = 8.11$, $p < .01$, $\eta^2 = .24$. For a male agent, the girls showed more positive attitudes after working with a peer-like agent ($M = 50.36$, $SD = 3.73$) than a teacher-like one ($M = 41.50$, $SD = 3.11$). For a female agent, the girls showed more positive attitudes after working with a teacher-like agent ($M = 54.33$, $SD = 3.25$) than a peer-like one ($M = 42.97$, $SD = 3.17$).

Learning

The 3-way ANCOVA revealed a significant interaction effect of agent age and learner ethnicity, $F(1, 58) = 6.04$, $p < .05$, $\eta^2 = .09$. The ethnic minority girls achieved significantly higher post-test scores after working with a peer-like agent ($M = 10.95$, $SD = .73$) than after working with a teacher-like one ($M = 9.29$, $SD = .65$). In contrast, the Caucasian girls achieved significantly higher after working with a teacher-like agent ($M = 10.80$, $SD = .62$) than after working with a peer-like one ($M = 9.05$, $SD = .77$). Table 1 presents the summary of the results.

Discussion

Research in agent technology implies that an agent serves as a social model for learners in need. Based on the theories in social cognitive psychology, this study examined whether

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

middle-grade girls' affect and learning might be differentiated by agent age and gender. The study also examined how the difference would be patterned between the two groups of girls (Caucasian and ethnic minority) who might face unique cultural and instructional challenges in classrooms. Overall, the results revealed that the ethnic minority girls reacted more sensitively to the agent's personal attributes, implying that the agent's might have played a stronger social role for this group of girls. This is somewhat consistent with the agent literature and confirms that a virtual tutor could be a viable tool to create girl-friendly social and instructional dynamics in computer-based mathematics learning, enhancing girls' motivation to learn mathematics.

The first research question asked about the girls' perceived reactions to their agent. Both groups of the girls evaluated a peer-like agent more positively regardless of agent gender, but for the minority girls, agent age and gender interacted to influence their perceptions. This phenomenon was similar to previous studies conducted with college-aged male and female students. The studies reported that African-American college students tended to develop a closer attachment to their agent tutor as compared to their Caucasian counterparts. In the current study, it also appeared that the ethnic-minority girls had built a more developed social relationship with their tutor agent. Therefore, when the agent was male, they evaluated a peer-like one more positively, in line with social modeling literature. But when the agent was female, they seemed to feel that the agent was a real female peer, perhaps eliciting a somewhat competitive response. This might be why they evaluated the female-peer agent less positively and also showed less positive attitudes towards learning from the agent.

For learning gains, it is noteworthy that the Caucasian girls perceived the peer-like agent more positively but actually learned better with the teacher-like agent. A similar phenomenon

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

was observed in a previous study (Kim, 2013), in which 5th grade boys performed lowest after working with the agent they liked most whereas they performed highest after working with the agent they liked least. Perhaps students' favorite agent might distract them from the learning activity; conversely, when they had a less favorite agent, the students might pay attention to the learning task more than to their agent. Teachers often observe something similar in human peer relations in classrooms, e.g., a close friendship distracts from the learning task.

On the other hand, unlike the performance of the Caucasian girls, the minority girls' performance improved more after learning from a peer-like tutor. These differential reactions by the two groups of girls might be interpreted in terms of the two groups' cultural backgrounds and also their experiences in ordinary classrooms. Researchers in culturally diverse teaching have argued that ethnic-minority students' culture of learning often favored *working together* more than individual effort (Gay, 2000). For example, Latino students showed the highest level of engagement in mathematics learning when they were asked to work with their peers in a group but a much lower level of engagement when they were asked to work alone (Uekawa, Borman, & Lee, 2007). In the present study, a peer-like agent might trigger a sense of collaboration. Once the minority students perceived the agent as their peer, they became willing to collaborate and were more engaged in its tutorial messages and so increased their learning. Also, consistent with the previous study that revealed the distinctive experiences of Caucasian girls and Latinas with their agent (Kim and Lim, 2013), the results of the current study shed light on ethnic-minority girls' unique challenge of double marginalization by both gender and ethnicity in ordinary mathematics classrooms, highlighting the need for further research on this group of students. In fact, there have been alarmingly few studies on culturally diverse students despite the growing

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

proportion of these students in the current U.S. K-12 school population (Vasquez et al., 2011). Much remains to be clarified about the quality of these students' learning experiences in school mathematics.

Overall, the findings of this and other studies highlight that agent presence might not be simply a matter of modality. In line with a trend in human/computer interaction, a virtual tutor plays a distinct social role in influencing girls' affective and cognitive outcomes. In this sense, agent technology might be able to effectively complement conventional computer-based learning that has commonly lacked social cues. Also, in ordinary classrooms, it is not feasible to diversify teachers and peers to a learner's need. A unique benefit of agent-based learning might be the flexible permutation of agent characteristics according to learner characteristics.

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

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Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

Table 1

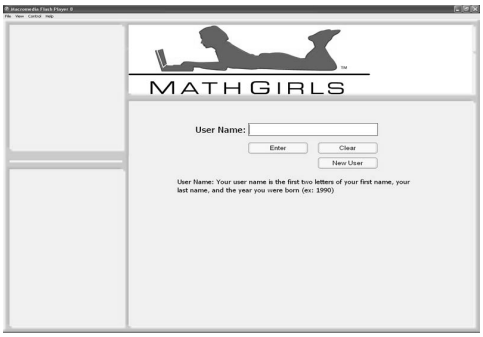
The Summary of the Results

	Caucasian	Ethnic-minority
Perceptions of the Agent	*NS*[1]	• *Male agent: peer-like > teacher-like* • *Female agent: teacher-like > peer-like*
	The combined group in favor of a peer-like agent.	
Mathematics Attitudes	*NS*	• *Male agent: peer-like > teacher-like* • *Female agent: teacher-like > peer-like*
Learning	*Teacher-like > peer-like*	*Peer-like > teacher-like*

[1]NS: Not significant.

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

Log-in



Problem practice

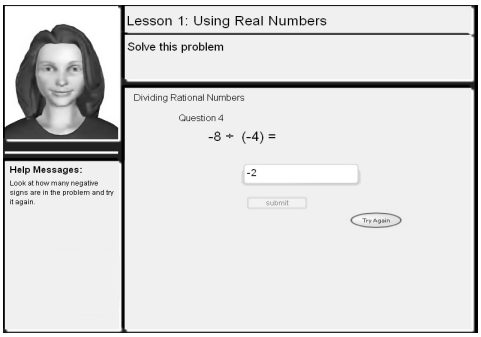


Figure 1. Screenshots of the agent-based lessons.

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. *Computers in the Schools, 33*(2). 59-70.

Figure 2. The four agents by age and gender.