

Kim, Y., Wei, Q., Xu, B., Ko, Y., Ilieva, V. (2007). MathGirls: Toward developing girls' positive attitude and self-efficacy through pedagogical agents. In R. Luckin, K. R. Koedinger, and J. Greer (Eds.), *Artificial intelligence in education: Building technology rich learning contexts that work* (Vol. 158, pp. 119-126). Los Angeles, CA: IOS Press.

# MathGirls: Toward Developing Girls' Positive Attitude and Self-Efficacy through Pedagogical Agents

Yanghee KIM<sup>1</sup>, Quan WEI<sup>1</sup>, Beijie XU<sup>1</sup>, Youngah KO<sup>1</sup>, & Vessela ILIEVA<sup>2</sup>

<sup>1</sup>*Department of Instructional Technology*

<sup>2</sup>*Department of Curriculum and Instruction*

*Utah State University*

*United States*

[yanghee.kim@usu.edu](mailto:yanghee.kim@usu.edu)

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

**Abstract.** MathGirls is a pedagogical-agent-based environment designed for high-school girls learning introductory algebra. Since females are in general more interested in interactive computing and more positive about the social presence of pedagogical agents, the environment provides a girl-friendly social learning environment, where pedagogical agents encourage the girls to build constructive views of learning math. This study investigated the impact of agent presence on changes in the girls' math attitude, their math self-efficacy, and their learning; on the girls' choice of their agents; and, on their perceptions of agent affability. The results revealed that the girls with an agent developed a more positive attitude and increased self-efficacy significantly, compared to the girls without an agent. Both groups showed significant increase in their learning. The study also showed that the girls chose female agents significantly more than male agents as their learning partners and perceived peer-like agents as more affable than teacher-like agents. The finding confirms the instructional value of pedagogical agents functioning as a social cognitive tool [1].

**Keywords.** Pedagogical agents, Math education, Attitudes, Self-efficacy

## Introduction

Gender differences in academic interest and cognitive and interaction style are well documented [2-5]. In particular, the gender differences in motivation to learn science, technology, engineering, and math (STEM) have become more salient with recent concern about workforce imbalances in the fields of science and engineering. Many girls tend to hold beliefs, attributable mainly to social and cultural influences, that interfere with their learning of STEM and limit their pursuit of careers in those fields. Family, schools, and media are likely to impose stereotypic role expectations on girls. So girls need to be exposed to social environments that will encourage them to overcome ungrounded social stereotypes and to build constructive views of their

Kim, Y., Wei, Q., Xu, B., Ko, Y., Ilieva, V. (2007). MathGirls: Toward developing girls' positive attitude and self-efficacy through pedagogical agents. In R. Luckin, K. R. Koedinger, and J. Greer (Eds.), *Artificial intelligence in education: Building technology rich learning contexts that work* (Vol. 158, pp. 119-126). Los Angeles, CA: IOS Press.

competency in STEM. For women successful in mathematics-related careers, for instance, social influences such as encouragement and support from family members and teachers were found to be the foundation on which those women built their academic confidence to overcome obstacles in their progression through male-dominant academic programs [6]. The stereotypic views of family, teachers, or friends seem to be societal issues unlikely to improve immediately. However, girl-friendly virtual social environments might be instantiated to counter undesirable social influences in the real world.

Studies of interactive computing have indicated that male and female learners show distinctive patterns in their perceptions and their performances based on design or functional characteristics of the environment. For instance, girls performed better with highly interactive hints, whereas boys performed better with non-interactive and low-intrusive hints [7]. Girls were more sensitive than boys to help messages [2]. Also, regarding multimedia interfaces, girls' priority was display, such as color and appearance, whereas boys' priority was navigational support and control [8]. College male and female students reacted to pedagogical agents socially, with the females perceiving them more positively than males [9]. Given these findings, the authors assumed that pedagogical agents--virtual digital peers or instructors--might create a rich social context favoring female students, by presenting a more interactive environment.

Such a view has ample support. Researchers in agent technology are shifting their view of agent systems from tools to actors [10], finding in their studies that socially intelligent anthropomorphized agents play a social role and thus can build social relationships with users [11]. Reflected in this conference theme, social motivational factors to promote learning have drawn attention of researchers in advanced technology for learning. This project, funded by NSF (#05226343, <http://www.create.usu.edu>), sought to create a girl-friendly virtual social environment using pedagogical agents to enhance high school girls' motivation toward learning math. In this environment, named *MathGirls*, pedagogical agents demonstrated advanced performances, encouraged the girls to be confident in learning math, and provided persuasive messages to help the girls build a positive attitude towards math learning. While the girls practiced solving algebra problems, the agents, 3-D images representing peers and teachers, proactively provided the girls with verbal persuasion as well as with cognitive guidance according to their performances.

This study was conducted to examine the impact of the MathGirls environment, whether the pedagogical agents in the environment influenced high school girls to change their math-related attitude and self-efficacy beliefs. Because attribute similarities between a social model and a learner, such as gender, age, and competency, often have been predictive for the learner's efficacy beliefs and achievements in traditional classrooms [12, 13] and because several studies have found that both male and female college students show differing perceptions and preferences according to agent characteristics [9, 11, 14, 15], the current study implemented four agents differing by gender and age, allowed the learners to choose their agents at the beginning of the lesson, and investigated their choice patterns. Detailed descriptions of the study follow.

Kim, Y., Wei, Q., Xu, B., Ko, Y., Ilieva, V. (2007). MathGirls: Toward developing girls' positive attitude and self-efficacy through pedagogical agents. In R. Luckin, K. R. Koedinger, and J. Greer (Eds.), *Artificial intelligence in education: Building technology rich learning contexts that work* (Vol. 158, pp. 119-126). Los Angeles, CA: IOS Press.

## MathGirls Environment

### Curriculum

"Fundamentals in Algebra" was chosen as the curriculum, for two reasons. First, in the collaborating school district, ninth graders must take introductory algebra (Algebra I or Applied Algebra), regardless of their interests. This meant that the ninth grade sample would represent a population that included girls who did not have strong achievements in or motivation toward math learning. Second, the girls in the 9<sup>th</sup> grade were typically assumed to be imbued with social stereotypic expectations, but at an age where those social forces might be counteracted in the interest of positive attitudes toward and beliefs about science and math [16]. Following the Principles and Standards of the National Council of the Teachers of Mathematics [17], the curriculum content, developed in collaboration with participating school teachers, treated fundamentals in four areas of introductory algebra, each area providing one lesson. Lesson I covered the use of real numbers - addition, subtraction, multiplication, division, and order of operations. Lesson II dealt with combining like terms and with the applications of distributive property. Lesson III covered several different methods of factoring, including using the greatest common factor, grouping, and finding the difference of two squares. Lesson IV dealt with graphing linear equations using slope and y-intercept. Each lesson, taking a one-class period and including four to five subsections, consisted of two phases: Reviews and Problem Practice. In MathGirls, the students practiced solving problems by themselves after taking lessons from their teachers in traditional settings. Figure 1 presents example screens of MathGirls. The login screen was intended to invite the girls' attention by presenting the program logo conspicuously; in the problem practice, the female teacher agent is providing corrective feedback to the student's wrong answer. The student also can read her comments below the image.

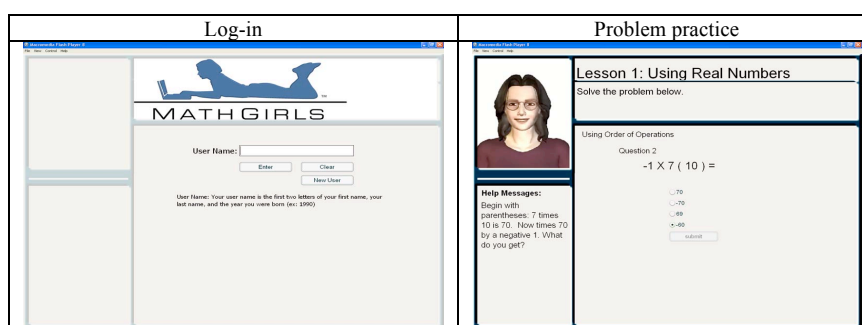


Figure 1. Screenshots of MathGirls

### Agent Scripts

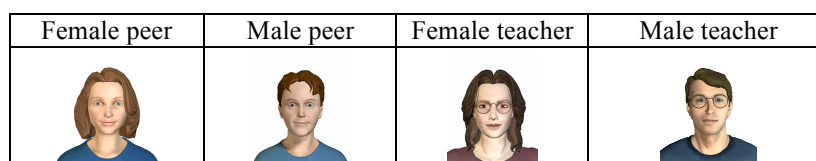
Three types of agent scripts were developed: informational, motivational, and persuasive. The informational messages were content-related, including reviews--the brief overviews of what the students had learned from their teachers--and feedback on students' performances. When a student made a mistake, the agent provided explanations to guide her to the right problem-solving path, which helped construct knowledge step by step. Motivational messages were words of praise or encouragement for the student's performance. When a student had the correct answer, the agent said "Good job" or "Great, I'm proud of you"; when the student had a wrong

Kim, Y., Wei, Q., Xu, B., Ko, Y., Ilieva, V. (2007). MathGirls: Toward developing girls' positive attitude and self-efficacy through pedagogical agents. In R. Luckin, K. R. Koedinger, and J. Greer (Eds.), *Artificial intelligence in education: Building technology rich learning contexts that work* (Vol. 158, pp. 119-126). Los Angeles, CA: IOS Press.

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 learning math and pursuing careers in STEM. At the beginning of each section, the agent proactively made statements to positively influence the girls’ perceptions of and attitudes toward math.

#### *Pedagogical Agents Design*

Four 3D virtual characters, representing male and female teachers in their forties and male and female teenagers of about 15, were designed using Poser 6 (<http://www.e-frontier.com>). Given the superior impact of human voices to synthesized ones, the characters’ scripts were prerecorded by four voice actors matched with the age and gender of the agent. The characters and the recorded voices were integrated within Mimic Pro for lip synchronization. Facial expressions, blinking, and head movements were added to make the agents look more natural. Then the 3D animated characters were rendered in Poser to produce AVI files, which were later batch-compressed to Flash files, using Sorenson Squeeze for web casting. Figure 2 shows the four agents used in MathGirls.



**Figure 2.** Images of four agents

#### *System Design*

The application system was designed to accommodate four principal users: a) the students, who needed an engaging, interactive web-based experience; b) the instructional designers, who needed an easy way to create new lessons with agent videos; c) the researchers, who needed comprehensive data collection and experiment implementation; and d) the system developers, who needed a friendly programming environment for updating codes.

The developers, on the back end, connected Flash movies to dynamic instructional content with ColdFusion. The back-end relational database stored instructional texts, questions, feedback, graphics, agent videos, students’ choice of agent, and students’ answers to the questions. By keeping all content in the database tables, the instructional designers could update lessons and agent information using a database browser. Once the schema was set up and the basic code was written, only a few modifications were necessary to implement a new lesson. The students could start working on the lessons immediately after they logged into the system, using an Internet browser. During implementation in schools, the front-end automatically captured all responses with timestamps.

#### **Research Questions**

The study was guided by five specific research questions:

- 1) Will the presence of pedagogical agents in the learning environment influence the girls to change positively their attitude towards learning math?

Kim, Y., Wei, Q., Xu, B., Ko, Y., Ilieva, V. (2007). MathGirls: Toward developing girls' positive attitude and self-efficacy through pedagogical agents. In R. Luckin, K. R. Koedinger, and J. Greer (Eds.), *Artificial intelligence in education: Building technology rich learning contexts that work* (Vol. 158, pp. 119-126). Los Angeles, CA: IOS Press.

- 2) Will the presence of pedagogical agents improve the girls' self-efficacy beliefs in learning math?
- 3) Will the presence of pedagogical agents influence the girls' learning outcomes?
- 4) Will agent characteristics (gender and age) influence the girls' choice of their agents?
- 5) Will agent characteristics (gender and age) influence the girls' perceptions of their agents?

## Method

Three experimental conditions were designed: choice, randomization, and control. In the choice condition, participants were immediately given four agents, varied by gender and age (see Section 1.3), and asked to select the agent that they would like to work with. In the randomization conditions, the participants were randomly assigned to one of the four agents. In the control condition, the participants worked through the lessons without an agent, reading text-based messages.

### Participants

Participants were 83 girls in required algebra classes in two high schools located in a mountain-west state of the US. Access to the samples was achieved by including four math teachers who volunteered to participate in the project. The ethnic compositions (self reported) of the samples were Caucasian (58.3%), Hispanic (22.8%), African-American (3.9%), Asian (3.3%), and others (11.7%). The average age of the participants was 15.51 ( $SD = 1.14$ ).

### Procedure

The project was implemented in collaboration with the math teachers in participating schools, using their regular algebra classes for two consecutive days, one lesson (approx. 50 minutes) each day. The current study implemented Lesson 1 (Using Real Numbers) and Lesson 2 (Combining Like Terms). The *MathGirls* environment was self-inclusive, students completing pretests, learning tasks, and posttests within the modules. The overall procedures were as follows:

- Teachers gave the students a brief introduction to the activity and taught them how to use the interfaces; students then put on headsets so that they could concentrate on their own tasks without distraction;
- Students accessed the web site and entered demographic information to log onto *MathGirls*, where they were randomly assigned to one of the experimental conditions (choice, randomization, and control) by system programming;
- They took pretests (self-efficacy and attitude tests only on the first day; algebra tests on both days);
- They performed the tasks (solving problems in fundamentals of algebra with guidance by the agents), in an average of 30-35 minutes; and
- They took posttests (self-efficacy and attitude tests only on the second day; algebra tests on both days. Those who worked with an agent also answered questions about agent affability on the second day).

Kim, Y., Wei, Q., Xu, B., Ko, Y., Ilieva, V. (2007). MathGirls: Toward developing girls' positive attitude and self-efficacy through pedagogical agents. In R. Luckin, K. R. Koedinger, and J. Greer (Eds.), *Artificial intelligence in education: Building technology rich learning contexts that work* (Vol. 158, pp. 119-126). Los Angeles, CA: IOS Press.

In the lessons, the agents proactively provided information or feedback on students' performances without the students' requests. This way, students across the experimental conditions received the same amount of information.

### 3.3 Measures

Learning: Learning was measured by the girls' performances in pre- and posttests, with each having 10 question items. The mean scores were calculated for analysis.

Math self-efficacy: A questionnaire of six items was developed according to Bandura's guidelines [18] and was implemented before and after the intervention. The items were scaled from 1 (*Strongly disagree*) to 7 (*Strongly agree*). Item reliability evaluated with coefficient  $\alpha$  was .83 in the pretest and .88 in the posttest. For analysis, the mean scores of the items were calculated.

Math Attitude: A questionnaire of 10 items was developed, derived from the Mathematics Attitude Survey [19] and Attitudes Toward Mathematics Inventory [20]. The girls' attitude was measured before and after the intervention. The items were scaled from 1 (*Strongly disagree*) to 7 (*Strongly agree*). Item reliability evaluated with coefficient  $\alpha$  was .87 in the pretest and .79 in the posttest. For analysis, the mean scores of the items were calculated.

Agent Affability: A questionnaire of nine items was developed, derived from the Agent Persona Instrument [21]. The items were scaled from 1 (*Strongly disagree*) to 7 (*Strongly agree*). Item reliability evaluated with coefficient  $\alpha$  was .90. For analysis, the mean scores of the items were calculated.

Choice of an agent: Learners' choice was recorded by the program.

To analyze learning, math self-efficacy, and math attitude, Paired *t*-tests with group membership were conducted focused on each research question. To analyze agent affability, two-way ANOVA (by agent age and gender) was conducted. To analyze learners' choice of an agent, Chi-square analysis ( $\chi^2$ ) was conducted. For all the analyses, the significant level was set at  $\alpha < .05$ .

## Results

### Learning

The results revealed that all the participants, regardless of agent presence, significantly increased their math performances after working at the MathGirls environment: for the girls working with the agents,  $t = 4.32$ ,  $p < .001$ ,  $d = .41$ ; and for the girls without an agent,  $t = 2.70$ ,  $p < .01$ ,  $d = .50$ . The effect sizes (Cohen's  $d$ ) indicated medium effects by Cohen's guidelines.

### Math Self-Efficacy

The results revealed that only for the girls who worked with agent was there a significant increase from the pre-test ( $M = 26.75$ ,  $SD = 7.21$ ) to the post-test math self-efficacy ( $M = 29.25$ ,  $SD = 7.27$ ),  $t = 2.44$ ,  $p < .01$ ,  $d = .35$ . The effect size of this difference indicated a small effect by Cohen's guidelines. Further, the detailed analyses revealed that the girls who worked with peer agents significantly increased their self-efficacy from the pre-test ( $M = 27.3$ ,  $SD = 5.3$ ) to the post-test ( $M = 30$ ,  $SD = 6.64$ ),  $t = 2.16$ ,  $p < .05$ ,  $d = .44$ . The effect size ( $d$ ) was medium. For the girls who worked

Kim, Y., Wei, Q., Xu, B., Ko, Y., Ilieva, V. (2007). MathGirls: Toward developing girls' positive attitude and self-efficacy through pedagogical agents. In R. Luckin, K. R. Koedinger, and J. Greer (Eds.), *Artificial intelligence in education: Building technology rich learning contexts that work* (Vol. 158, pp. 119-126). Los Angeles, CA: IOS Press.

without an agent, there was no significant difference between the pre- and posttest math self-efficacy.

#### *Math Attitude*

The results revealed that only for the girls who worked with an agent was there a significant increase from the pre-test ( $M = 44.16$ ,  $SD = 12.21$ ) to the post-test math attitude ( $M = 46.93$ ,  $SD = 9.88$ ),  $t = 1.96$ ,  $p < .05$ ,  $d = .25$ . For the girls who worked without an agent, there was no significant difference between the pre- and post-tests math attitude.

#### *Agent Affability*

ANOVA revealed a significant difference between the girls who worked with peer agents ( $M = 45.57$ ,  $SD = 8.92$ ) and those who worked with teacher agents ( $M = 40.05$ ,  $SD = 10.94$ ),  $F = 4.95$ ,  $p < .05$ . The girls perceived the peer agents to be significantly more affable than the teacher agents.

#### *Choice of an Agent*

The results revealed a significant difference in the girls' choice of their agents,  $\chi^2 = 10.36$ ,  $p < .05$ . Forty-eight percent of the girls chose the female peer agent; 32% chose the female teacher agent; 12% chose the male peer agent; and 8% chose the male teacher agent. That is, a total of 80% of the girls chose female agents as their learning partners.

## **Discussion**

The study investigated the potential of pedagogical agents to positively influence high school girls' math attitude, math self-efficacy beliefs, and math learning and the potential of the agents to play differing social roles, depending on their characteristics (i.e., gender and age). First, the results overall supported the instructional value of agent presence in the learning environment. The girls who listened to the agent's messages significantly developed their positive attitude towards and increased their self-efficacy beliefs in learning math, whereas the girls who read text-based messages in the control condition did not. Also, the girls chose female agents significantly more than male agents and perceived peer agents as significantly more affable than teacher agents. These findings, in line with Bandura's concept of attribute similarities in the traditional classrooms, confirm learners' tendency to perceive virtual characters socially. The uniqueness of the study, however, might be rigorously proving the value of agents in adding social richness to the environment in terms of this specific context: math-related attitude and self-efficacy beliefs of high school girls. Further, after working with MathGirls, the girls significantly increased their learning, regardless of agent presence, again confirming the current status of knowledge that agent presence has worked effectively for learners' affect but not for their learning outcomes. Three final cautions: First, the variations in the four voice actors were not controlled, which might affect the results. Second, the duration of the study was only two days. We may want to determine whether the immediate results endure over time. Third, learner attitude and self-efficacy were measured only by self-report. Other measures might be considered. These cautions may help guide future directions of this research. This study could be extended to examine long-term effects, self-reports might be

Kim, Y., Wei, Q., Xu, B., Ko, Y., Ilieva, V. (2007). MathGirls: Toward developing girls' positive attitude and self-efficacy through pedagogical agents. In R. Luckin, K. R. Koedinger, and J. Greer (Eds.), *Artificial intelligence in education: Building technology rich learning contexts that work* (Vol. 158, pp. 119-126). Los Angeles, CA: IOS Press.

complemented with behavioral indicators, and the girls' reactions to the agents could be compared with the reactions of a matched group of boys. In short, much still remains to be learned.

## References

- [1] Y. Kim and A. L. Baylor, "A social-cognitive framework for designing pedagogical agents as learning companions," *Educational Technology Research & Development*, vol. 54, pp. 569-596, 2006.
- [2] I. Arroyo, T. Murray, B. P. Woolf, and C. R. Beal, "Further results on gender and cognitive differences in help effectiveness," presented at International Conference of Artificial Intelligence in Education, Sydney, Australia, 2003.
- [3] E. M. Evans, H. Schweingruber, and H. W. Stevenson, "Gender differences in interest and knowledge acquisition: The United States, Taiwan, and Japan," *Sex Roles*, vol. 47, pp. 153-167, 2002.
- [4] K. Hakkarainen and T. Palonen, "Patterns of female and male students' participation in peer interaction in computer-supported learning," *Computers & Education*, vol. 40, pp. 327-342, 2003.
- [5] V. Slotte, K. Lonka, and S. Lindblom-Ylänne, "Study-strategy use in learning from text. Does gender make any difference?" *Instructional Science*, vol. 29, pp. 255-272, 2001.
- [6] A. L. Zeldin and F. Pajares, "Against the odds: Self-efficacy beliefs of women in mathematical, scientific, and technological careers," *American Educational Research Journal*, vol. 37, pp. 215-246, 2000.
- [7] I. Arroyo, J. E. Beck, B. P. Woolf, C. R. Beal, and K. Schultz, "Macroadapting animalwatch to gender and cognitive differences with respect to hint interactivity and symbolism," in *Intelligent Tutoring Systems, Proceedings*, vol. 1839, *Lecture Notes in Computer Science*, 2000, pp. 574-583.
- [8] D. Passig and H. Levin, "Gender preferences for multimedia interfaces," *Journal of Computer Assisted Learning*, vol. 16, pp. 64-71, 2000.
- [9] A. L. Baylor and Y. Kim, "The role of gender and ethnicity in pedagogical agent perception," presented at E-Learn, the Annual Conference of Association for the Advancement of Computing in Education, Phoenix, AZ, 2003.
- [10] P. Persson, J. Laaksolahti, and P. Lonnqvist, "Understanding social intelligence," in *Socially intelligent agents: Creating relationships with computers and robots*, K. Dautenhahn, A. H. Bond, L. Canamero, and B. Edmonds, Eds. Norwell, MA: Kluwer Academic Publishers, 2002.
- [11] Y. Kim, "Pedagogical agents as learning companions: Building social relations with learners," presented at 12th International Conference on Artificial Intelligence in Education, Amsterdam, The Netherlands, 2005.
- [12] A. Bandura, *Self-efficacy: The exercise of control*. New York: W. H. Freeman, 1997.
- [13] D. H. Schunk, "Peer models and children's behavioral change," *Review of Educational Research*, vol. 57, pp. 149-174, 1987.
- [14] Y. Kim, "Learners' expectations on the desirable characteristics of learning companions," presented at the Annual Conference of American Educational Research Association, San Diego, CA, 2004.
- [15] Y. Kim, "Pedagogical agents as learning companions: The effects of agent affect and gender on learning, interest, self-efficacy, and agent persona," in *Educational Psychology and Learning Systems*, vol. PhD. Tallahassee, FL: Florida State University, 2004.
- [16] P. H. Dunham, "Procedures to increase the entry of women in mathematics-related careers," in *ERIC/SMEAC Mathematics Education Digest No. 3*, 1990.
- [17] NCTM, "Principles and standards for school mathematics," 2000.
- [18] A. Bandura, "Guide for constructing self-efficacy scales," vol. 2004, 2001.
- [19] C. A. Ethington and L. M. Wolfe, "Women's selection of quantitative undergraduate fields of study: Direct and indirect influences," *American Educational Research Journal*, vol. 25, pp. 157-175, 1988.
- [20] M. Tapia and G. E. Marsh, "An instrument to measure mathematics attitudes," vol. 2004, 2004.
- [21] A. L. Baylor and J. Ryu, "The API (Agent Persona Instrument) for assessing pedagogical agent persona," presented at International Conference of Ed-Media, Honolulu, Hawaii, 2003.

## Acknowledgements

This work was sponsored by the National Science Foundation (GSE-05226343).