MathGirls: Motivating Girls to Learn Math through Pedagogical Agents

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Abstract: MathGirls is computer-based algebra designed for high school girls learning algebra I. Given that girls are in general more interested in interactive computing and more positive about the social presence of pedagogical agents, the primary goal of MathGirls is to provide a girl-friendly learning environment that helps enhance girls' self-efficacy beliefs in and motivation towards learning algebra, through persuasive messages of human-like pedagogical agents. This study investigates the impact of agent gender (male and female) and instructional role (teacher-like and peer-like) on high school girls' feeling of affiliation with the agents and self-efficacy in and attitudes towards learning math.

1 Introduction

Researchers in agent technology are shifting their view of agent systems from tools to actors [1]. They have indicated in their studies that anthropomorphized agents play a social role [2] and put an emphasis on building social relationships with users (e.g., socially intelligent agents) [3]. This study, funded by NSF (#051503), examines the potential of pedagogical agents designed to persuade young girls to build positive attitudes towards learning math.

Gender differences in academic interest and cognitive and interaction style are well documented [4-7]. In particular, 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 that interfere with their learning of STEM and limit their pursuit of careers in those fields. These beliefs are attributable mainly to the social and cultural influences. Family, schools, and media are likely to impose stereotypic role expectations on girls. Girls need to be exposed to social environments that will encourage them to overcome ungrounded social stereotypes and build constructive views of their 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 and overcame obstacles in their progression through male-dominant academic programs [8].

Although the stereotypic views of family, teachers, or friends cannot be immediately changed or influenced, girl-friendly virtual social environments can be created through pedagogical agents to help girls build positive attitudes toward STEM. Considering that girls show high motivation towards interactive computing [9], those environments may include virtual digital peers as role models that may model advanced performances, encourage the girls to be confident in learning STEM, and persuade the girls to build positive attitudes towards STEM.

MathGirls is a pedagogical agent-based environment in which high school girls learning introductory Algebra practice problem-solving. Pedagogical agents with 3D images are included to render social presence in the environment, based on the previous findings indicating gender differences in interactive computing. For instance, college females perceived agents more positively than did males [10]. Girls performed better in highly interactive hints, whereas boys performed better in non-interactive and low-intrusive hints [11]. Also, girls were more sensitive to help messages than boys [4]. For multimedia interfaces, girls put the first priority to display, such as color and appearance, whereas boys put the priority on navigational support and control [12]. In MathGirls, the agents with 3-D images proactively provide the girls with cognitive guidance according to their performances and with verbal persuasion to help build the girls' positive attitudes in learning math.

The major goal of MathGirls is to provide a girl-friendly learning environment in which girls learn math while interacting with a human-like agent. As the girls progress in the environment, they may build social relations with the agent. To reach the intended goal, however, a question arises, what might an optimal agent look like? That is, what features of an agent can exert positive influence on strengthening social bonds between a teenage girl and the agent and also on the agent's persuasive power? According to Bandura [13], attribute similarities between a social model and a learner, such as gender, age, and competency, often have predictive significance for the learner's efficacy beliefs and achievements in traditional classrooms [14]. Also, it has been replicated in several studies that both male and female college students show differing perceptions according to agent characteristics [3, 10, 15, 16]. Hence, this study investigates how differing gender and instructional role of the agents in MathGirls would influence the impact of the agents' persuasion to improve the high school girls' self-efficacy, attitudes, and learning.

2 MathGirls Environment

2.1 Curriculum

Introductory Algebra was chosen as the curriculum for some reasons. First, in the collaborating school district, ninth graders must take algebra I, regardless of their interests. This means that the ninth grade sample will represent a population that includes girls who do not have strong achievements in or motivation toward math learning. Also, the girls in the 9th grade are typically assumed to be significantly influenced by social stereotypic expectations, but at an age where those social forces may be counteracted in the interest of positive attitudes toward and beliefs about science and math. Following the state-wide Standards, the content was developed in collaboration with participating school teachers. The content consists of five lessons in which students practice problem-solving after taking lessons from teachers in traditional settings. Each lesson in MathGirls takes a one-class period each and deals with Using real numbers (lesson 1), Combining like terms (Lesson 2), Factoring (Lesson3), Algebraic expressions and linear equations (Lesson 4) and Graphing linear equations (Lesson 5). The lessons have four or five sections dealing with sub-topics. Figure 1 presents example screens of MathGirls

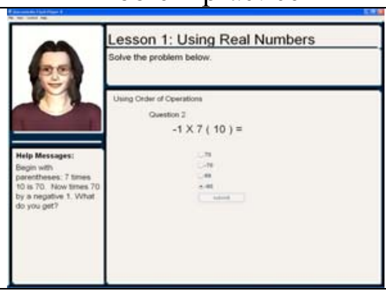
Log-in	Problem practice
	

Fig. 1. Screenshots of MathGirls.

2.2 Scripts

Three types of agent scripts were developed: informational, motivational, and persuasive messages. The informational messages are content-related, including instructions – the brief overviews of what the students have learned - and feedback on students' performances. When a student makes a mistake, the agent provides explanations to guide the student to the right problem-solving path, which can help construct knowledge step by step. Motivational messages are verbal praises or encouragements over the students' performances. When a student makes the correct answer, the agent says "Good job" or "Great, I'm proud of you"; when the student makes a wrong answer, the agent says "Everybody makes mistakes" or "you almost getting there, one more thing you need to consider is…" Persuasive messages are statements about the benefits or advantages of learning math and pursuing careers in STEM. At the beginning of each section in the lessons, the agent makes a statement to persuade the girls to build positive attitudes.

2.3 Pedagogical Agents Design

Four characters that represent male and female teachers in their forties and male and female teenagers (about 15 years old) were designed using Poser 6. Given the superior impact of human voices to synthesized voices, four human voices matching with the agents were recorded. First, the characters and the recorded voices were integrated within MIMIC for lip synchronization. Facial expressions, blinking, and head movements were added to make the agents look more natural. The avi files rendered on Poser were compressed to Flash files for web casting. Figure 2 shows the four agents used in MathGirls.

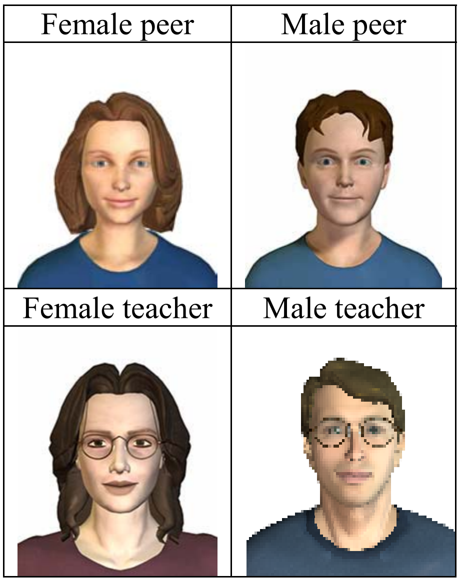


Fig. 2. Images of four agents

2.4 System Design

The software systems design and implementation was driven by the requirements from three principal users: a) the students, who need an engaging, interactive web-based experience; b) the instructional designers, who need an easy way to create and deploy new lesions and media; and c) the instructional researchers, who need comprehensive instructional data collection and clear experiment design. A state of the art web-based software and hardware architecture satisfies these diverse requirements. The system, illustrated in Figure 3, utilizes standard networked-browsers as a front-end, and a networked web and database server as the back-end. Deployment is through any standard browser with a high-speed internet connection. The client, or front end, utilizes Flash content for colorful and engaging student-agent interaction and high-quality agent video, illustrated in Figure 1 and Figure 2. No special software needs to be installed at the school's computer labs. Students login to the system at school and immediately enter the lesson sequence.

The back-end database/server design satisfies the requirements of the instructional designers and researchers. All system content is stored in the tables of the back-end relational database, including question, answer and instructional texts, graphics, choices, and agent videos for persuasive, motivational, and instructional messages. By keeping all content in the database tables, it is easy for the instructional designers to extend the system with new lessons, update existing lessons, and add new agents and student interactions. There is no need for the instructional designers to write any code; rather all content is entered using a specialized web-based interface.

The database enables experimental conditions to be randomized before deployment and records all experimental data during deployment at schools. Experimental variables include the assignment of an agent to each student, or whether the student as allowed to choose the agent. During deployment, the front-end automatically captures all responses and the time delays between responses of each student. Each student interaction is recorded as a trajectory of database states. The data is then exported to excel or SPSS, using a database report to enable easy data analysis.

While this database-centered design satisfies the requirements of the three kinds of users, an advantage to the software designers is the content independence of the back-end and front-end code. Once the schema for the lessons is designed, no new code needs to be written as new content is added. Both the pre-test and post-test, which capture important math attitude data, were implemented using the same schema as interventions.. The design utilized UML relational diagrams that enumerated each table in the database; use diagrams for the students, instructional designers and instructional researchers; and multiple state-flow diagrams choreographing alternative student interactions through the system. Initial internal and external deployments demonstrate the effectiveness of the approach.

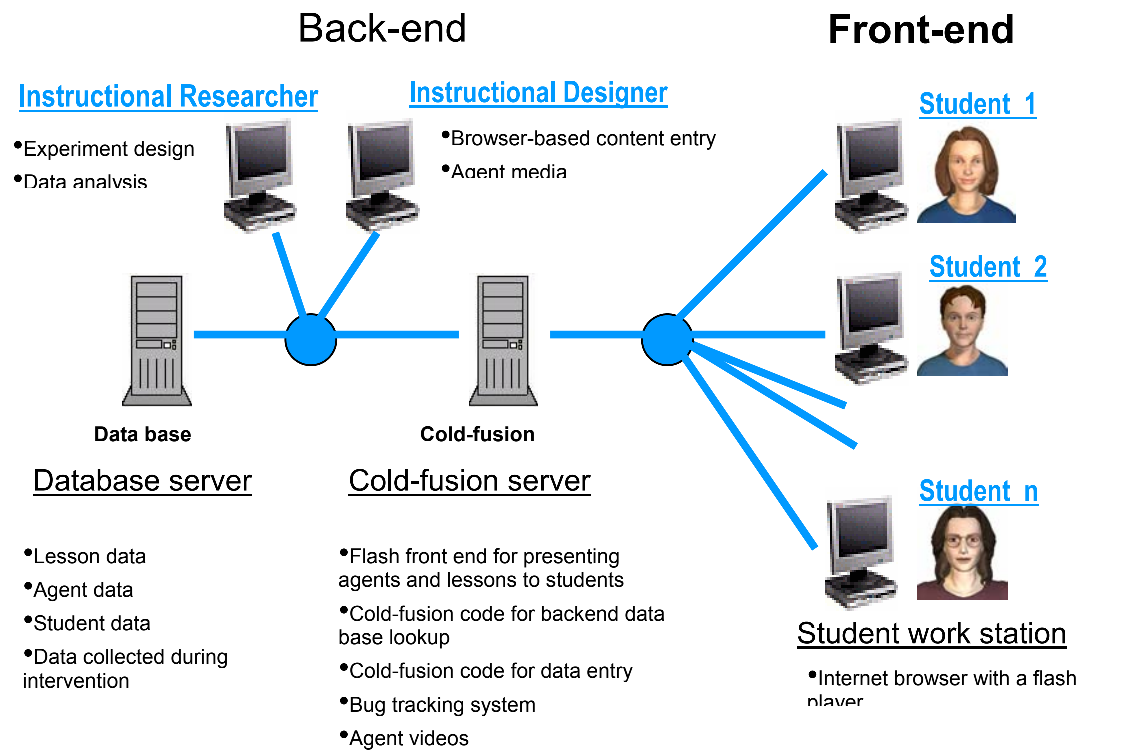


Fig. 3. System design. Back-end database and server support Instructional Researcher's and Designers. Front-end clients enable multiple school classes to interact with the system.

3 Study Implementation

The implementation of the project in classrooms is scheduled in mid February. *The final paper (due on Mar 21) will report the findings of the study*. Two types of experimental design will be used: choice and randomization. In the choice condition, participants will be given four agents varied by gender (male vs. female) and instructional role (teacher-like vs. peer-like) on the first screen of the intervention and asked to select a PAL that they want to work with. In the randomization conditions, participants will be randomly assigned to one of the four PAL conditions. A control condition without an agent will be included.

3.1 Participants

Participants will be approximately 100 girls in required algebra I classes in two high schools located in a mountain-west state of the USA. Access to the samples will be achieved by including four math teachers who volunteered to participate in the project. The ethnic compositions of the samples will be approximately Caucasian (57%), Hispanic (31%), and others (12%).

3. 2 Procedure

The implementation of the project will be done in collaboration with the participating math teachers for five consecutive days, with one lesson a day. Four teachers working at sample schools will implement MathGirls lessons in their regular algebra classes held in the computer labs. The modules will be self-inclusive, in which students will complete pretests, learning tasks, and posttests within the web-based modules. The overall procedures in each implementation are as follows: Students will

- be given a 5-minute introduction to the activity and taught how to use the interfaces by the teachers;
- be asked to put on headsets so that they can concentrate on their own tasks without distraction;
- be instructed to access the web site and enter demographic information to log on MathGirls, in which they will be randomly assigned to one of the experimental conditions (randomization and choice conditions) by system programming;
- answer pretest questions (algebra problems, self-efficacy, and attitudes);
- perform the tasks (algebra practice); and
- answer posttest questions (algebra problems, self-efficacy, and attitudes).

During the intervention, the agents will proactively provide information or feedback on students' performance without requests from the students. This way, students across the experimental conditions will be exposed to consistent amounts of information.

3.3 Measures

Dependent measures are learners' choice of agents, self-efficacy in learning math, attitude toward learning math, affability of agents, and learning progress.

Learners' choice of agents: Learners' choice will be recorded by the program.

Mathematics self-efficacy: The questionnaire of six items was developed according to Bandura's guidelines [17] and will be implemented before and after the intervention. Item reliability evaluated with coefficient α was .95 in a previous study conducted by the author [16] with a sample of approximately 200 undergraduates. Item reliability will be re-evaluated in this project.

Attitude toward learning math: A questionnaire was developed, derived from the Mathematics Attitude Survey [18] and Attitudes Toward Mathematics Inventory [19]. Learners' attitude will be measured before and after the intervention.

Affability of agents: A questionnaire of five items was developed, derived from the Agent Persona Instrument [20]. The items were scaled from 1 (*Strongly disagree*) to 5 (*Strongly agree*). Item reliability evaluated with coefficient α was .89 in a previous study conducted by the author [21] and will be re-evaluated in this project.

Learning: Learning will be measured by students' performance on practice questions, recorded by the system. At the end of each module, students will be given a posttest. Performance time on the both tasks will be recorded.

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