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Affective Gendered Learning Companions

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Abstract. We researched the impact of gendered pedagogical agents on student attitudes for math, motivation and achievement in math, within the context of an adaptive tutoring software for high school mathematics. Learning companions emphasize perseverance by valuing effort in challenging tasks. They are also empathetic, as they reflect students' emotional states. The results suggest that, across two studies, it was the male learning companion that produced the most positive impact on female students' state-based emotions, attitudes and learning. It is possible that girls transfer their stereotypes to the computer software.

Keywords. Intelligent tutors, gender differences, pedagogical agents, emotions, motivation and affect, evaluation, mathematics education

Introduction

Student learning is one of the most important outcomes of education, and research has increasingly documented the importance of emotions and attitudes in learning. In the case of mathematics, research (summarized in [1]) has shown that the subjective value of math and students' self-concept of math ability drops as students transition from elementary school to junior high school. In addition, there is a sharp rise in the perceived difficulty of math around 7th grade and persisting through grade 12, during which time subjective value of math and math self-concept declines steadily, and during which time, perceived difficulty of math steadily increases. These results are in contrast to the pattern for English learning which do not show grade related changes.

The shift in attitude about the value of math skills and student self-concept of math ability is particularly apparent among females and minority groups [2, 3]. Changes in math self-esteem among females are disassociated from indicators of math performance. In a very large study involving thousands of students, Catsambis [2] showed that 8th grade females in three ethnic groups were similar to their male counterparts in math test performance, generally better in math grades, and were taking more higher level math courses. Despite these objective indicators of performance, females from all three ethnic groups reported less interest in math intensive careers than their male peers, and showed less inclination to look forward to math class. These attitudinal gender differences are undoubtedly related to the fact that females transitioning into higher education chose math intensive career paths with less frequency that their male counterparts. This is a problem of concern in the United States where, for instance, women earn only 21% of both BS and MS degrees in engineering, and 25% and 31% of computer science BS and MS degrees, with lifelong implications for women's earnings [4].

Digital learning companions may prove to be important tools early in girls' lives during the time when girls are still developing their attitudes about science, technology,engineering and mathematics (STEM), within the real world setting of public schools. In order to encourage girls in STEM, it is necessary to obtain a fuller understanding of the impact of different strategies that can help girls improve their math attitudes and abilities at a young age in real educational settings. The contribution of our research is to examine the following questions: can human-like learning companions improve self-concept and attitudes towards mathematics? Does the presence of learning companions affect girls' learning? Are learning companions that resemble a student's gender more effective?

Past research on learning companions has not yielded clear results on their effectiveness. It is not clear if the cognitive advantage sometimes found with learning companions is due to the extra help they offer [5, 15] or because of the mere human-like presence of the agent as a study partner. For instance, one study did not find any advantage for the agent's visual presence or absence [6]. The goal of our research is to determine what impact – if any – *purely motivational* affective pedagogical agents (learning companions) can have on student motivation and attitudes (and probably learning) when the only assistance given by the Pedagogical Agents are encouraging student perseverance and showing empathy about students' emotional states. Cognitive assistance in solving math problems is provided on demand *via* the software's HELP button, independent of the learning companion.

1. Background research to designing Affective Learning Companions

In order to promote positive affective states in students one must first determine what are appropriate messages that pedagogical agents should transmit to students in order that they find the learning experience beneficial, and are therefore more willing to persist working on a task. When conceptualizing the appropriate messages, there are myriad details to take into account: How should pedagogical agents respond to affective states or traits of negative valence? Should students be praised when they are doing well? Dweck's research on human motivation sheds some light onto these questions [7]. She found that students who view their intelligence as an immutable internal characteristic tend to shy away from academic challenges; whereas students who believe that intelligence can be increased through effort and persistence tend to seek out academic challenges. This research suggests that teachers, parents and even technology may unwittingly lead students to accept an entity view of intelligence. By praising students for their intelligence, rather than effort, many adults are sending the message that success and failure depend on something beyond the students' control [8]. Students who are praised for their effort are much more likely to view intelligence as being malleable, and their self-esteem remains stable regardless of how hard they may have to work to succeed at a task.

At the same time, psychology literature suggests that *empathetic* responses might work well in situations were the student does not feel positive about the learning experience [17, 18]. The presence of someone who cares, or at least appears to care, can make someone persist at a task. Research has also shown that feelings are *contagious* as when we register a feeling from someone else, there are signals in our brain that imitate that feeling in our bodies [9].

2. Design of Affective Gendered Pedagogical Agents

We implemented and evaluated animated affective agents that work with students as learning companions, Figure 1. The characters are *gendered*: "Jake" and "Jane" are animated study partners who offer exactly the same advice and encouragement by talking to the student in both male and female human voices. The agents described in this paper were integrated into Wayang Outpost, a multimedia adaptive tutoring software that teaches mathematics (geometry, statistics) and prepares students for standardized state exams[1] [10, 11].

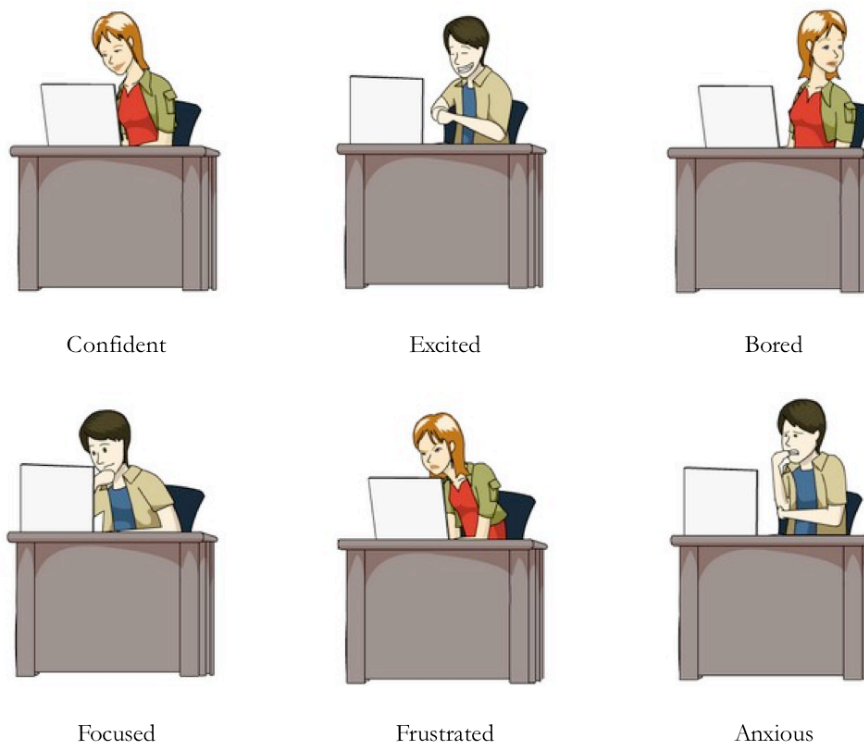

Figure 1. Emotional pedagogical agents show a range of emotion. They act out their emotion and talk with the student expressing full sentences of meta-cognitive and motivational feedback, see Table 1.

The mathematics software inquires how students are feeling every five minutes: confident/anxious, frustrated, excited, interested/bored -- classification of emotions based on [12]). Learning companions are *empathetic* in that they visually reflect the last emotion reported by the student (see figure 1). Characters act out their emotion and talk with the student expressing full sentences of meta-cognitive and emotional feedback after they answer the problem. In this sense, agents are non-intrusive –they work on their own computer trying to solve the problem at hand, and react only after the student has answered correctly or incorrectly. We implemented some of Dweck's recommendations about disregarding success, and valuing effort [13], see table 1. The agents described in this paper were developed in the Flash programming language using ActionScript, no graphics-based authoring tools were used.

	Low Effort	High Effort
Incorrect	*"We kind of rushed to answer that one. Shall we ask the computer for help? I am sure we will get it if we take the time to solve the problem."*	*"These are the hard questions that I like. There is an opportunity to learn. Let's click on the help button."*
Correct	*"That was good, however, I prefer harder questions so that we learn from the help that the computer gives, even if we get them wrong."*	*"Hey, congratulations! Your effort paid off, you got it right!"*

Table 1. Some of the messages given by learning companions that emphasize effort over success

3. Description of studies.

Two studies were carried out in Fall 2008. The first (HS) study was designed to evaluate the overall impact of learning companions on students' attitudes/learning. It involved 38 high school students aged 15-17, enrolled in three different math classes. Approximately half of students were male and half female. Students were assigned to either a learning companion condition (LC group) or a condition where the learning companions were absent (no-LC), and thus did not get the messages in Table 1. The gender of the learning companion assigned was randomly chosen for the LC group. The second (UG) study was designed to analyze the impact that the gender of the learning companion has on attitudes/learning on female students. It involved 29 female undergraduate students taking a mathematics class for elementary school teachers at UMass Amherst. Students were randomly assigned either Jake (male-LC group) or Jane (female-LC group) as a learning companion. The software was used as part of the class, though HS students had not seen most of the topics in class yet, while UG students had. Students took a mathematics pretest and a survey to assess self-concept in math and math value [14] and mastery-orientation [8].

4. Results

General descriptions of these studies can be summarized as follows: High school students (HS) had less math incoming ability than the undergraduate students group (UG). Students in the HS study had more negative attitudes and emotions than the UG

[1] See http://althea.cs.umass.edu/wayang/wayangindex.html

study, both in pretest surveys and self-reports of emotions –while UG students were most of the time not frustrated, HS students reported more frustration, less interest, confidence and excitement. Both the HS and UG groups learned, both improving an average significant 10% in math performance (25% proportional learning gain).

4.1. Impact of Affective Pedagogical Agents (HS Study)

Another paper submitted to this conference analyzes deeply the comparison of the LC and the no-LC groups [16]. For the purpose of this paper we will mention that, overall, results favored the LC group across all measures (attitudes, mastery-learning and learning), but were not significantly better. Students also reported a higher average confidence level, interest and excitement within the tutor emotion reports. Only 5 girls and 7 boys used learning companions. Girls liked learning companions more than boys (~75% of girls vs. ~25% of males liked having them present). Some students were not content about characters' reflecting their negative emotions.

We analyzed the impact of matching the gender of the character on students' learning. An ANOVA for math posttest (with math pretest as a covariate, and group as a fixed factor) showed that students performed marginally better when the learning companion *did not match* the students' gender ($F=3.8$, $p<0.08$). Females learned more with JAKE as a learning companion, and males more with JANE. We initially believed this might be the result of a Type I error, especially given that students did not express liking the character differently when the character matched/unmatched their gender (means for "liking the learning companion" were not significantly different). More discussion of this issue will appear in the next section.

4.2. Does gender matter when it comes to learning companions?

Study 2 (UG study) was designed to further explore the impact of gender on females' perceptions of the learning companions. All 29 students were females in this study, and were randomly assigned to a female (N=14) or male (N=15) learning companion condition. We call these groups the female-LC and male-LC groups respectively. Pretests and posttests were the same as the previous study.

Table 2. Changes in Mathematics Value (min=1, max=6)

	N	Pretest Mean	SD	Posttest Mean	SD	Post-Pre	SD
Male-LC	11	3.93	.84	4.06	.84	0.12	.25
Female-LC	11	4.04	.94	3.95	.94	-0.09	.54

Table 3. Changes in Mathematics Self-Concept (min=1, max=6)

	N	Pretest Mean	SD	Posttest Mean	SD	Post-Pre	SD
Male-LC	11	4.10	.84	4.29*	.82	0.18	.35
Female-LC	11	3.97	1.02	3.74*	1.09	-0.22	.45

Table 4. Changes in Learning Orientation (min=0, max=1)

	N	Pretest Mean	SD	Posttest Mean	SD	Post-Pre	SD
Male-LC	11	.45	.41	.59	.37	0.14	.39
Female-LC	11	.59	.43	.68	.40	0.09	.30

Results. While math pretest scores were not significantly different for the two groups, math posttest performance was significantly better for the male-LC group than the female-LC group (*mean posttest* male-LC=87.83, *mean posttest* female-LC=79.82; t=1.98, p=0.05). The effect is the same as the previous study, girls performing better with the male-LC.

We analyzed the changes in mathematics attitudes and motivation for the two groups, considering we had full survey data for 22 students. Results are summarized in Tables 2,3, and 4. Overall, students in the male-LC group had a higher gain in math value, learning orientation and self-concept. An ANOVA for posttest self-concept, with pretest self-concept as a covariate, group as fixed factor, showed that students receiving male-LC had significantly higher self-concept at posttest time (F=5.6, p=0.02).

4.3. Are emotions affected by the gender of the learning companion?

One possibility is that this overall advantage for girls receiving the male learning companion was also reflected in feeling different emotions while using the software. Remember that the software asked students how they felt every 5 minutes. Again we were surprised to find that, while these female students were somewhat more negative about Jake (see next section), students in the male-LC condition reported significantly more excitement, marginally more interest and confidence than students in the female-LC condition. Results are summarized in table 5.

Table 5. Mean emotion reports for students receiving JAKE or JANE

Emotion	Gender of LC	N self-reports	Mean	Stdev
Interested	Male-LC	37	3.3^{+}	.88
(5=very interested)	Female-LC	41	3.0^{+}	.93
Frustrated	Male-LC	36	2.0	.88
(5=very frustrated)	Female-LC	25	2.4	.25
Excited	Male-LC	28	3.5**	.63
(5=very excited)	Female-LC	34	2.9**	1.08
Confident	Male-LC	24	3.6^{+}	.83
(5=very confident)	Female-LC	33	3.2^{+}	.92

** Significant difference between groups (t-test, p<0.01) $^{+}$ Marginally significant difference (t-test, p<0.1)

4.4. What do students think of the characters qualitatively & quantitatively?

It seemed possible that girls might have enjoyed working with Jake more than Jane. We analyzed two question items in the post-tutor survey to verify this. The first one asked students to rate how much they liked the learning companion. For this question, there was zero difference between the Male-LC group and the Female-LC group (a mean of 2.6 for both groups in a scale from 1 to 4), suggesting that it was not the case that girls liked Jake better than Jane. In addition, we analyzed qualitative questions about what students liked about Jake and Jane and what they disliked. In general, students had less positive comments about Jake, the male-LC, as can be seen in table 6. We concluded that students did not enjoy working with Jake more than with Jane.

5. Discussion and Future work.

People relate to computers in similar ways that they relate to another humans, resembling real social relationships [19]. One reason to use pedagogical agents is to capitalize on this ‘personal’ relationship between computers and learners as a medium to potentially help girls counter negative myths and stereotypes that make them disregard mathematics as they grow older.

Table 6. Qualitative comments about the female and male learning companions

COMMENTS ABOUT THE FEMALE COMPANION (JANE)

	PEDAGOGY	PERSONALITY
POSITIVE	Gave positive comments. Gave helpful hints sometimes. Giving me the idea to use the help link when I was really stuck.	She is encouraging, Something pleasant & personal to look at; Always smiling and friendly.
NEGATIVE	Her comments weren’t too helpful or encouraging; She took too long to speak and it didn’t seem vital to the task at hand to listen to her; She should explain the problem again if I got many questions wrong	Negative tones sometimes; She had the same responses/ reactions; She got sort of boring after a while; The smoke above her head when she couldn’t figure out a problem; When she fell asleep; She was not encouraging, very annoying, and said the same thing every problem; She seemed to rush when I answered a question incorrectly.

COMMENTS ABOUT THE MALE COMPANION (JAKE)

	PEDAGOGY	PERSONALITY
POSITIVE	Offers encouragement.	Funny and entertaining.
NEGATIVE	Distracting, He was in the way; He did not always say something. He said the same comment over and over which got a bit repetitive; Not helpful	Did not really like him, did not like what he said; Some comments could have been more encouraging; He looked sad and mean; He could be more encouraging, enthusiastic and supportive; Did not like the volume of his voice; not very nice or friendly; His comments were a little harsh and made me feel bad; He is annoying; When he got frustrated, it made me a bit anxious.

This paper described the impact of gendered electronics study partners on student attitudes and achievement within a learning environment for high school mathematics. The results suggest that, even though students were more critical of the male learning companion, it was the male learning companion that had the most positive impact on female students’ attitudes and learning. The results in relation to learning are similar to [15] where female students learned more with male characters. It might be the case that female students transfer math stereotypes in real life on to the computer, and thus learn and feel better with what is perceived to be a more knowledgeable (male) study partner. This stereotype threat explanation, however, does not help to explain the fact that males learned more with female learning companions in the HS study. Another possibility is that, at least at this age, a presence of the opposite gender is more intriguing to students and thus they pay more attention to a learning companion of the opposite gender. Future studies will explore further the reasons for these results.

Future work includes the repetition of these experiments with students in the lower grades, and exploring the reasons for the unmatched-gender effect further at the high school level. In addition, both agents are currently being extended to multiple ethnicities (Hispanic, Black and Asian). Future studies will analyze the impact of matched or unmatched ethnicities on students of different ages.

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