"Thanks Alisha, Keep in Touch": Gender Effects and Engagement with Virtual Learning Companions

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Abstract. Virtual learning companions have shown significant potential for supporting students. However, there appear to be gender differences in their effectiveness. In order to support all students well, it is important to develop a deeper understanding of the role that student gender plays during interactions with learning companions. This paper reports on a study to explore the impact of student gender and learning companion design. In a three-condition study, we examine middle school students' interactions in a game-based learning environment that featured one of the following: 1) a learning companion deeply integrated into the narrative of the game; 2) a learning companion whose backstory and personality were not integrated into the narrative but who provided equivalent task support; and 3) no learning companion. The results show that girls were significantly more engaged than boys, particularly with the narrative-integrated agent, while boys reported higher mental demand with that agent. Even when controlling for video game experience and prior knowledge, the gender effects held. These findings contribute to the growing understanding that learning companions must adapt to students' gender in order to facilitate the most effective learning interactions.

Keywords: learning companions, pedagogical agents, gender, engagement, game-based learning

1 Introduction

Pedagogical agents have shown great potential to improve learning experiences [1]. They engage with students on both social and cognitive levels and are well suited to addressing emotions, beliefs, and attitudes [2]. Among pedagogical agents, virtual learning companions are characterized by sharing the learning experience with the student and taking on the persona of a knowledgeable peer.

Learning companions present a promising vehicle for adapting to affective and social needs by virtue of their peer-like role [3].

How best to design learning companions to support and balance these complex needs in different students is a question of growing interest [4, 5, 1]. The emerging picture is one in which gender, among other factors, consistently drives differences in students' perceptions and outcomes with learning companions [6, 7]. Specifically, girls seem to prefer learning companions more than boys do, and to benefit more than boys from the experience [4].

The present work compares two approaches to integrating a learning companion for affective support into a game-based learning environment for middle school science. By comparing two different design approaches with a functionally identical agent, we investigate the research question, ***What gender effects are observed on engagement and learning when integrating a virtual learning companion into a game-based learning environment?*** By examining the relationship between agent design and student gender, we aim to discover design recommendations for learning companions to better accommodate both male and female students.

2 Related Work

Virtual learning companions act as near-peers to engage students and foster learning [2, 8, 9]. Virtual learning companions, in contrast to virtual tutors, do not play an authoritative role or pose new learning tasks. Rather, they are designed to experience learning tasks alongside the student and may play a peer or near-peer role. These virtual characters have the potential to motivate learners to persist in the face of failure, in part by improving interest [10] and self-efficacy beliefs [11]. They may promote academic skills through modeling [8], reducing frustration by offering common ground [7], and boosting confidence by affirming and empathizing with the student [11].

Gender is an influential factor in children's interactions with virtual learning companions and more broadly with all virtual agents for learning, with differences in outcomes such as learning, motivation, engagement, and self-efficacy often associated with the learner's gender [6, 7, 10, 11]. While benefits of affect recognition and adaptation have been shown to be effective in educational settings [12, 13], pedagogical agents that provide affective support have been shown to be particularly effective for female learners [6], but benefits for both boys and girls have also been established. For example, after interacting with a pedagogical agent for engineering education, both male and female middle school learners showed increased interest and self-efficacy (regardless of the agent's gender), and interacting with a female agent decreased stereotyping among boys [10].

3 Game-based Learning Environment

Prior work on virtual learning companions in other types of learning environments leads us to the current study, which is contextualized within a game-based

Fig. 1. Game-based learning environment, with the virtual learning companion's image shown as an icon in lower left corner.

learning environment for middle school microbiology, Crystal Island [5]. In the learning environment, learners find themselves on a remote island along with a team of research scientists who have been infected by a mysterious illness. Students learn that their mission is to investigate the illness in order to help those who have fallen ill. To accomplish this mission, learners explore the storyworld (Figure 1) to gather evidence from non-player characters and science texts they find in the game. Through this process, learners refine their hypotheses about the illness and its source, then test the suspected sources of contamination to ultimately solve the science mystery. The game presents significant challenge in terms of both strategy use and hypothesis formation and testing. Extensive classroom studies and empirical investigations have been conducted with this game, and it has been found to provide substantial learning and motivational benefits [5].

4 Learning Companion Design

Our goal in this study was to investigate the ways in which gender differences emerge with two different approaches to integrating a virtual learning companion into the narrative of a game-based learning environment. Accordingly, we designed two versions of a learning companion named Alisha, which varied in their narrative framing. We refer to the two conditions as *Diegetic* and *Non-Diegetic*, inspired by the narratological term *diegetic* which refers to narrative elements that are part of the internal world of a story, separate from the audience. For example, one character's dialogue with another is diegetic, whereas

a narrator addressing the audience is non-diegetic. In the Diegetic condition, Alisha's backstory and interactions are deeply integrated into the narrative of the game. Alisha introduces herself as a friendly artificial intelligence who is still learning a lot about solving science mysteries. The Diegetic design was intended to foster social closeness: this learning companion is situated inside the same storyworld as the student, uses collaborative language relative to the student in that storyworld, and frequently references the agent's backstory and affective state. The Non-Diegetic learning companion had the same physical appearance as the Diegetic companion but did not introduce herself with any backstory and did not use collaborative language such as "we" to indicate that she was experiencing the narrative events alongside the student. Example Diegetic and Non-Diegetic dialogue moves are shown in Table 1. Finally, the *Baseline* condition consisted of the game without any virtual learning companion.

Alisha uses information about the student's gameplay—such as location in the gameworld and scientific texts the student has collected, read, and completed embedded assessments on—to decide when and how to make a dialogue move. When Alisha sends a new message, players receive an alert, which they can ignore or view and respond to using a text chat interface. Although the dialogue moves Alisha made are worded differently across the Diegetic and Non-Diegetic conditions (Table 1), the underlying dialogue goals and the conditions that triggered them were identical. In general, Diegetic dialogue moves address the learner's task while also referring to the learner's role within the story (the mission) and Alisha's role within the story through the use of first-person plural pronouns "we," "us," and "our." Conversely, the Non-Diegetic dialogue moves address only the learner's tasks as posed by the game, not the learner's persona within the narrative. The average number of dialogue moves the agent made in each student's session in the Diegetic ($M = 43.9$, $SD = 20.0$) and the Non-Diegetic ($M = 43.0$, $SD = 18.1$) condition were not statistically different.

Alisha's persona, appearance, and dialogue were designed based on empirical research and a series of focus groups with middle school students. Her dialogue is designed to (1) encourage good problem-solving strategies, (2) mitigate negative affective states [14], and (3) foster a growth mindset [15]. Regarding strategy use, Alisha encourages note taking, reflection, hypothesis forming, and goal setting/planning, drawn from research on self-regulated learning [16] as this skillset has been shown to be an important predictor of success in this learning environment [17]. Alisha uses a mix of questions, hints, and suggestions. For instance, when the story context combined with the learner's typed natural language input trigger one particular dialogue state, the Diegetic agent says, *Let's see how that fits into our mission objectives. That could help us make a plan.* This dialogue move is intended to encourage learners to reflect on their goals when they may be feeling stuck while choosing a next step.

When student dialogue moves or in-game behaviors indicate that the student may be frustrated or bored (two key affective states that have been found to inhibit learning [14]), the agent is designed to offer affective support. The dialogue

Table 1. Selected equivalent agent dialogue moves in *Diegetic* and *Non-Diegetic* conditions.

Diegetic dialogue move	***Non-Diegetic dialogue move***
Introduction	
Hi, I'm Alisha! I'm a virtual assistant from the CDC. You can talk to me about your ideas as you work on this mission. By the way, my communication system is still under development. I might not understand some things you say, and I might say some things that don't make sense. But I will do my best!	Hi, I'm Alisha! I'm a virtual assistant, and I'm here to talk with you about your ideas as you play the game. By the way, my communication abilities are limited. I might not understand some things you say, and I might say some things that don't make sense. But I will do my best!
Resuming gameplay	
Hi again! I'm excited to get back to this mission. I'm learning a lot! Can you remind me about the last thing we were working on together?	Hi again! Welcome back to Crystal Island. Can you tell me about me the last thing you did when you were here last time?
Reassess hypothesis	
Isn't it exciting how each new piece of info can change the whole case? Try to keep questioning your hypothesis as we learn new things about this mystery!	It sounds like you've noticed how each new piece of information could change the entire problem. Try to keep questioning your hypothesis as you learn new things!

moves that provide this support are based on approaches used in dialogue design for a successful affective learning companion that conveys empathy and shared experience [7]. For example, if the learner expresses frustration, the Diegetic companion might utilize humor contextualized within her backstory as an artificially intelligent agent who was sent to help the learner. To convey empathy toward the student, the agent might say, *This is a tough mission! My circuits sometimes get fried when I feel like I'm not making progress.*

Growth mindset refers to the implicitly-held belief that intellectual ability can be increased with effort, and this belief shapes learners' motivation and approach to learning [15]. The virtual learning companion is designed to encourage growth mindset by emphasizing strategy and perseverance rather than innate intelligence. For example, the Diegetic companion always follows the *tough mission* move above with growth-mindset promotion: *This is a tough mission! My circuits sometimes get fried when I feel like I'm not making progress. But I know if we keep choosing good strategies, we can help those sick scientists!*

In both the Diegetic and Non-Diegetic conditions, the interface for chatting with Alisha is available to the student at all times except while they are engaged

in menu-based interaction with other game characters, and while interacting with scientific texts or embedded assessments. In the Diegetic condition, the student interacts with Alisha via a mobile device to convey the sense of interacting with another persona in the game world (Figure 2, *left*). In the Non-Diegetic condition, Alisha's dialogue appears with the same look-and-feel as other game interface elements, tooltips, and game menus (Figure 2, *right*).

Fig. 2. Dialogue interfaces for the two learning companion study conditions: Diegetic (left) and Non-Diegetic (right)

5 Virtual Learning Companion Study

We hypothesized that gender differences would emerge based on the learning companion condition. To explore this hypothesis, we carried out a three-condition study in six classrooms across two urban middle schools in the United States. A total of 132 students (75 from one school and 57 from another) were randomly assigned into one of the three conditions: Diegetic, Non-Diegetic, or Baseline. Out of the 132 participants, 63 students (48%) identified as female, 54 (41%) as male, 8 (6%) identified as Other, and 7 (5%) students did not report their gender. The mean age was 13.30 years ($SD = 0.76$). One learner did not report race, while 19 (14%) identified as Black or African American, 70 (53%) White or Caucasian, 30 (23%) as other races, and 12 (9%) as more than one race. Most of the students reported prior experience playing games, with only 17 (13%) reporting that they never played. We confirmed using separate one-way ANOVAs that there were no significant between-conditions differences among these students in pretest score or video game play frequency.

In the Diegetic condition there were 23 (61%) female and 15 (39%) male students, while the Non-Diegetic condition had 19 (45%) female and 23 (55%) male students. The Baseline condition included 21 (57%) female and 16 (43%) male students. Participants were given laptops and headphones and played in their regular classrooms and seating arrangements. Each student interacted with the version of the game to which they were randomly assigned for approximately one hour per day for three consecutive days.

Prior to interaction, participants completed a multiple-choice pre-test on the game's science content. After each of the three days of the classroom study, brief surveys were administered, including measures of engagement (the User Engagement Survey [18]) and mental demand (from the NASA Task Load Index [19]). A content knowledge post-test (identical to the pre-test) was administered after gameplay.

6 Results

Using the post-gameplay surveys completed by each student, we test our hypothesis that gender differences would be observed in different agent conditions. We excluded all students ($n = 15$) who either identified their gender as "other" or did not report gender, leaving 117 participants. Several significant differences emerged, which we present here. Normalized learning gain was calculated to obtain a proportional indicator of learning, and is simply referred to in the remainder of this document as learning gain.

Table 2. Descriptive statistics for engagement, learning gain, and mental demand by condition and gender. Starred pairs of means represent significant pairwise comparisons ($p < 0.05$) by Tukey HSD.

Condition		Learning Gain		Engagement		Mental Demand	
		Female	Male	Female	Male	Female	Male
Diegetic	*M*	**109.2***	**91.33***	.03052	-.1441	54.52	56.73
	SD	16.11	19.49	.2667	.3213	26.17	32.09
Non-Diegetic	*M*	104.5	97.17	.1639	.05788	**59.37****	**32.83****
	SD	14.04	15.94	.3515	.4448	24.70	22.27
Baseline	*M*	102.7	101.2	.02876	.1137	57.05	55.94
	SD	14.04	15.94	.3515	.4448	24.70	22.27
All conditions	*M*	105.6	96.74	.07016	.01831	56.83	46.31
	SD	16.34	17.83	.2979	.4108	25.45	30.17

First, we evaluated the overall effect of learning companion condition: Diegetic, Non-Diegetic, and Baseline. One-way ANOVAs found no main effect of condition on engagement, learning gain, or mental demand. Gender was found as a main effect for both engagement and mental demand: a one-way ANOVA for engagement with gender as a factor found a significant main effect ($F(1,115) = 7.9233$,

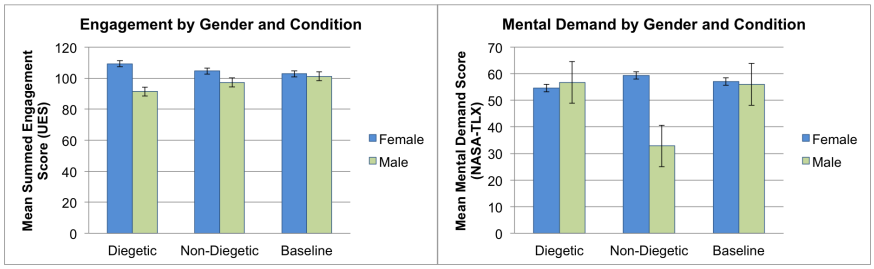

Fig. 3. Mean engagement (left) and mean mental demand (right) by gender and study condition.

p = .0057) of small-to-medium size (ω^2 = .05587), with girls reporting higher engagement than boys (Table 2). A separate one-way ANOVA found a significant main effect of gender on mental demand (F(1,115) = 4.1775, p = .0432), of small size (ω^2 = .02644), with girls reporting significantly higher mental demand than boys (Table 2).

To investigate the impact of learning companion condition on learning gain, engagement, and mental demand, we performed 2 x 3 ANOVAs with gender (male/female) and learning companion condition (Diegetic/Non-Diegetic/Baseline) as the independent variables. The ANOVA found no significant effects on learning gain. With engagement as the dependent variable, we observed a significant main effect of gender (F(1, 115) = 2.4579, p = .0375) of small-to-medium size (ω^2 = .05489) (Figure 3, left). Girls from all conditions reported a higher mean engagement score than boys from all conditions (Table 2). Post-hoc Tukey HSD tests showed that the difference between boys' and girls' mean engagement was significant only in the diegetic condition (Diegetic condition: N_{female} = 23, N_{male} = 15, p = .0237). Finally, taking mental demand as the dependent variable, the ANOVA demonstrated a significant interaction of gender and game condition on mental demand (F(1, 115) = 2.9512, p = .0154) with a moderately small effect size (ω^2 = .03733) (Figure 3, right). Post-hoc Tukey HSD tests showed that boys in the Non-Diegetic condition reported significantly lower mental demand than girls in the same condition (p = .0482).

Overall, boys scored lower (M = 6.222, SD = 2.567) than girls (M = 7.270, SD = 2.772) on the content knowledge pre-test (t(114.3) = -2.1207, p = .0361). Boys also reported more hours per week playing video games (M = 2.185 hours, SD = 1.36) than girls (M = 1.587 hours, SD = 1.04) (t(98.39) = 2.634, p = .0098). To confirm that neither of these differences explained gender effects, we controlled for pre-test score and video game experience by adding them alongside gender and condition within multiple regression models for engagement and mental demand. The same effects revealed in the ANOVAs held in each model.

7 Discussion

The results suggest that the extent to which a virtual learning companion is integrated into the story of a game-based learning environment has a significantly different impact on boys and girls. We observed significant impacts of gender on engagement and mental demand, but no effect of gender on learning outcome. Girls were more engaged than boys both overall and within the Diegetic condition; mental demand was statistically the same for girls and boys overall and within every condition, except for the Non-Diegetic condition, where boys reported much lower mental demand than girls.

First, we consider the gender difference in engagement, with girls more engaged than boys. While Tukey HSD post-hoc tests did not reveal significant pairwise differences except between boys and girls in the Diegetic condition, visual inspection of the means (Table 2) finds boys and girls reported nearly identical average engagement in the baseline condition and diverged more noticeably in the two learning companion conditions. Based on boys' conversations with the agent (e.g., Figure 4), one plausible explanation for this pattern is that boys were less engaged by the learning companion's attempts to provide affective support and encouragement to discuss their reasoning. This is consistent with prior studies of learning companions designed to influence affective outcomes [6, 7].

Alisha:	***Try asking yourself, "Does this fit in with anything else about the mission?"***	***Alisha:***	***Try to keep questioning your hypothesis as we learn new things about this mystery!***
Kiana:	*yes. It fits everything, the people sick claimed to have all eaten breakfast together*	Ava:	*ok*
Emily:	*it does....but samonella is still my top pick*	Lily:	*will you tell me when im right?*
Nerea:	*YOUR MY FAVORTE*	Chloe:	*true . thanks Alisha. keep in touch*
Carlos:	*I asked myself*	Isaiah:	*(no response)*
Ethan:	*nah dag*	David:	*(no response)*
Malik:	*no*	Jacob:	*de acuerdo*

Fig. 4. Examples of girls' (middle row) and boys' (bottom row) responses to two of Alisha's utterances from the Diegetic condition. All names are pseudonyms.

With regard to mental demand, it is unclear whether a higher rating of perceived mental demand is necessarily a negative reflection on the learning experience, either in terms of user experience (boys' engagement was not affected by condition) or in terms of learning (there were no condition or gender effects on learning gain). A more detailed investigation of this outcome is warranted.

The corollary of these interpretations is that girls were more engaged overall, and no condition showed a dip in girls' engagement. This suggests that our overarching design choices for both companion versions—to characterize the agent as female, to focus on affective support, and to encourage an ongoing dialogue with the agent—contributed to, or at least did not detract from, girls' engagement in the learning activity.

Key factors that could potentially have driven the observed differences (video game experience, prior content knowledge) significantly differed by gender. However, when we controlled for video game experience and for prior knowledge of the subject matter, we found that neither factor had an effect on the *outcomes* for which we observed the gender effects. This suggests that gender impacts engagement and mental demand above and beyond these gender-linked factors.

Limitations. The condition assignments were not strictly balanced by gender; for example, there were 15 boys and 23 girls in the Diegetic condition. While the statistical tests utilized are fairly robust to these imbalances, it is important to keep them in mind. We also observed social dynamics in which groups of boys disparaged the learning companion and the activity as a whole, which may have influenced a more negative view of the agent among boys. This dynamic seemed much less prevalent or absent among girls. Finally, the mean scores on engagement, learning gain, and mental demand were significantly different between the two schools from which the participants were recruited, and these school-level differences merit further analyses. Further studies are needed to address these limitations.

8 Design Recommendations

This study builds upon the emerging set of design recommendations regarding gender and virtual learning companions. The results suggest that designers of virtual learning companions should consider the following design implications:

1. The extent to which virtual learning companions are integrated into the narrative of a game-based learning environment has important effects on students. Narrative integration may benefit girls more than boys.
2. A learning companion design that is removed from the narrative of a learning environment may reduce mental demand for boys without affecting learning outcomes.
3. Overall, girls may feel more engaged than boys when interacting with virtual learning companions. This may have an important impact on girls' developing academic attitudes toward STEM subjects during a critical time in their lives when many girls lose interest in these subjects or come to believe they cannot succeed in them.
4. In order to achieve the highest possible effectiveness, designers should accommodate for factors driving different needs and expectations, including gender, for instance by giving students options to choose the kind of learning companion they prefer to interact with.

9 Conclusion

Gender is an important factor in children's outcomes with learning companions, but there are many unexplored questions about the role of design choices in gender-related outcome differences. This paper presented a study in which middle school students interacted with one of two differently designed learning companions, or no learning companion. The results indicate that gender indeed has important effects on students' affective experience during learning, and that these effects are not explained by differences that tend to co-occur with gender (such as video game experience). The findings suggest some design elements with gender-related differences in impact, such as a reduction in boys' mental demand when an agent is framed as a part of an interface and an improvement in girls' engagement when an agent is framed as co-experiencing the storyworld alongside them.

Future work should pursue more fine-grained and process-based analyses of gender differences in outcomes with virtual learning companions. The specific design elements of the Diegetic agent that made it so engaging for girls should be explored, as should the relationship between mental demand and other outcomes. Also called for is an investigation of beliefs and attitudes not measured in this study, which may drive differences in outcomes such as those reported here. It will be important to develop a deeper understanding of how virtual learning companions can most effectively support learners of all genders in engaging learning interactions.

Acknowledgements. The authors are grateful for the thoughtful input of the members of the LearnDialogue group. This work is supported by the National Science Foundation through grant CHS-1409639. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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