

# CHOICE OF PEDAGOGICAL AGENTS AS VIRTUAL MATH TUTORS: PERSPECTIVES FROM CHILDREN AND COLLEGE STUDENTS

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## ABSTRACT

*The central research question of this empirical study was: How do student demographics, math self-efficacy, and math anxiety relate to and predict their choice of pedagogical agents serving as virtual math tutors? A total of 152 middle school students and 135 college students were surveyed on their perceived math self-efficacy, math anxiety, and their choice of virtual math tutors. The collected survey data were analyzed using chi-square tests and logistic regressions to answer the research question. Results suggest that (1) student gender predicted choice of agent gender for both groups of samples; (2) student ethnicity predicted choice of agent ethnicity for the middle school students but not for the college students; and (3) student math self-efficacy predicted choice of agent gender for the middle school students and choice of agent age for the college students. Overall, the results supported the similarity-attraction theory in terms of gender with both groups of samples in their agent choice. However, similarity in ethnicity seemed a more important factor for the middle school participants than for the college participants in their agent choice. The results also indicate that students' agent choice might be influenced by their perceptions of their own self-efficacy level and the perceived agents' self-efficacy level. Future research should be conducted to verify the results.*

*Keywords: pedagogical agents, virtual math tutors, math self-efficacy, math anxiety, similarity-attraction theory*

## INTRODUCTION

Pedagogical agents (PAS), i.e., virtual lifelike characters intended to serve instructional goals (Veletsianos, 2010), have been used frequently in technology-enhanced learning environments due to their advantages such as their availability for learners and capability of customization for meeting specific learners' needs (Baylor, 2009). PAS help establish a social relationship between a computer-based learning environment and a computer user (Lane, 2016; Nass & Moon, 2000; Reeves & Nass, 1996). Researchers have been

interested in examining the design elements of PAS that facilitate cognitive, affective, or motivational outcomes for learners. Previous research summarized the design characteristics in PAS in two categories: internal properties and external properties. Internal properties include the instructional methods embedded in PAS to facilitate various learning outcomes, e.g., modeling and providing feedback, whereas external properties include the social features exhibited in the agent, e.g., age, gender, and ethnicity (Moreno, 2005; Moreno & Flowerday, 2006). The careful

design of the social features of PAS can lead to a variety of learning benefits for learners. However, the design of the physical characteristics of PAS is often overlooked, which could result in unintended learning and motivational outcomes (Veletsianos, 2007, 2010). Visible characteristics or social features of an agent may “activate stereotypes and expectations of agent usefulness, credibility, and intelligence” (Veletsianos, 2010, p. 577). Lack of identification with agents may hinder learning and cause computer anxiety and lower interest in learning (Kim & Baylor, 2006; Kim & Wei, 2011; Littleton et al., 1998). These PA design elements are especially important to consider in technology-enhanced mathematical learning environments. Learner anxiety levels tend to be high while self-efficacy (confidence) levels tend to be low even in face-to-face mathematical learning settings (Beilock & Willingham, 2014; Hill et al., 2016; Huang et al., 2019; Maloney & Beilock, 2012), not to mention the unique challenges brought by technology-enhanced online environments.

Two related theories in the literature may have implications for designing technology-enhanced learning environments involving PAS, including the similarity-attraction hypothesis (Byrne & Nelson, 1965; Johnson et al., 2013; Nass & Moon, 2000) and Bandura’s (1997) notion of attribute similarity. Within this general theoretical framework, the present study investigated the relations between the social features designed in PAS and students’ demographics as well as their perceptions of affective and motivational factors in math, including math anxiety and math self-efficacy.

## LITERATURE REVIEW

Based on the theory of similarity-attraction, people are more likely to be attracted to those who share similar physical characteristics or behaviors (Byrne & Nelson, 1965; Johnson et al., 2013; Nass & Moon, 2000). The similarity-attraction hypothesis is also consistent with Bandura’s notion of attribute similarity (1997) between a model and an observer: Various learning outcomes can be enhanced when learners observe a model with similar attributes performing a task. For example, research has shown that children tend to be attracted to a model whose age and gender are similar to their own (Schunk et al., 1987), and that similarity can exert a positive

impact on learning and motivational outcomes (Schunk & Hanson, 1985).

A limited number of studies examined the social features of PAS in different learning contexts (Baylor, 2009, 2011; Gulz, 2004; Gulz et al., 2007; Makransky et al., 2019; Moreno & Flowerday, 2006; Rosenberg-Kima et al., 2010; Schroeder & Adesope, 2015). For example, in one study, PAS matching students’ gender and ethnicity were found more effective in increasing female college students’ interest in engineering and reducing their stereotypes about the field (Rosenberg-Kima et al., 2010). The similarity in gender was also found effective in enhancing middle school girls’ self-efficacy and math performance (Plant et al., 2009) or their attitude when learning STEM-related content (Ozogul et al., 2013). A study on elementary through high school students supported the previously mentioned findings: Kids preferred PAS with social features that are similar to their own (Johnson et al., 2013). In addition, a more recent experiment by Makransky et al. (2019) found that in the context of middle schoolers learning science, girls performed better when learning with a female PA, whereas boys performed better when learning with a male PA. However, no consensus has been reached on the research in this area. For example, Kim (2016) investigated the effects of the age and gender of an agent on high school girls’ (White and ethnic minority) learning of algebra, perceptions of the agent, and attitudes towards math, and found that the benefits of learner-agent similarity were only partially observed for ethnic-minority girls but not for White girls. Furthermore, Schroeder and Adesope’s (2015) study found that agent gender did not have any impact on preservice teachers’ learning and perceptions of the agent in the context of studying multimedia learning theory.

In addition to external properties or social features of PAS (e.g., age, gender, and ethnicities) that were examined in previous research in line with the similarity-attraction theory, one recent PA study has explored the similarity-attraction hypothesis in terms of an internal property of PAS, i.e., agents’ expressed self-efficacy level. In a study with fourth graders playing an agent-based math game, Tärning et al. (2019) found that kids with low math self-efficacy who interacted with an agent with matching low self-efficacy significantly increased their performance and self-efficacy at

the end of the instruction. Tärning et al.'s (2019) study supported the similarity-attraction theory and indicated a possible relationship between learner self-reported self-efficacy and an agent's expressed self-efficacy in influencing learning and motivational outcomes. Overall, more empirical research is needed to test the similarity-attraction theory involving PAS serving various instructional roles to enhance their design for positive learning and motivational outcomes.

## PURPOSE OF THE STUDY

The first objective of the present study was to test the similarity-attraction hypothesis in terms of students' choice of gender, age, and ethnicity of PAS serving as virtual math tutors for middle school students and college students. More specifically, whether student characteristics would predict their choice of agent characteristics. We were interested in investigating both middle schoolers' and college students' perceptions because these two groups of students were at different stages in psychosocial development. For example, middle schoolers are transitioning to the critical stage of early adolescence and undergo various biological, cognitive, social, and educational changes during this stage (Wigfield & Eccles, 2002). Searching for a sense of identity is a constant theme of this stage (Erikson, 1997). College students in their early adulthoods, however, are more independent and more willing to blend their identities as compared to adolescences (Erikson, 1997). Considering these developmental factors, it would be interesting to see if the similarity-attraction hypothesis holds true for both groups when it comes to choosing a virtual math tutor for learning.

The second objective of the study was to examine whether affective variables related to math learning would also influence student choice of PAS as virtual math tutors. More specifically, we were interested in the variables of math self-efficacy and math anxiety and their relation to student choice of PAS. As mentioned earlier, the lack of identification with agents has been found to result in anxiety. This study attempted to see if student math anxiety levels would affect their choices of PAS serving as virtual math tutors. In addition, as anxiety serves as a source negatively impacting self-efficacy (Bandura, 1997), math self-efficacy was included in the model for testing as

well. Indeed, as discussed previously, a recent study showed similarity in math self-efficacy between learners and PAS influenced learning outcomes (Tärning et al., 2019). It will be interesting to explore how learners' math self-efficacy level predicts their choice of PAS.

In sum, the purpose of this study was to test: (a) similarity-attraction theory in terms of children's selection of PAS designed to serve as virtual math tutors, and (b) whether math anxiety and math self-efficacy affect student choice of these PAS. The central research question of the study was: How do student gender, ethnicity, math self-efficacy, and math anxiety relate to and predict their choice of pedagogical agents serving as virtual math tutors? A survey method was used to investigate the research question.

## STUDY 1: MIDDLE SCHOOL SAMPLE

### Method

#### *Participants*

Participants included 152 students ( $M_{age} = 12.70$ ,  $SD_{age} = .47$ ) in a middle school in the Mideast of the United States. These students were recruited from six sections of a seventh-grade math course in the school. Two female math teachers taught these sections. Table 1 indicates the basic demographic information of the participants on gender and ethnicity.

TABLE 1. DEMOGRAPHIC CHARACTERISTICS OF THE MIDDLE SCHOOL PARTICIPANTS (N = 152)

Characteristics	Description	n	Percentage
Gender	Male	73	48%
	Female	79	52%
Ethnicity	White	130	85.5%
	Black	7	4.6%
	Mixed	6	3.9%
	American Indian or Alaska American	4	2.6%
	Asian	2	1.3%
	Hispanic or Latino	1	0.7%
	Other	2	1.3%

#### *Instrument*

Three survey instruments were used, including a math anxiety measure, a math self-efficacy measure, and a student choice of agent measure. Math anxiety was measured by the Mathematics

Anxiety Scale for Children (MASC; Chiu & Henry, 1990). It is a 22-item, 4-point Likert scale (1 = not nervous to 4 = very very nervous) focusing on the learners from fourth to eighth grade. Participants were asked to read each of the 22 statements presented (e.g., walking into a math class) and rate the amount of anxiety they felt.

Math self-efficacy was measured by a 5-item, 5-point Likert scale (1 = not at all true to 5 = very true; Griggs et al., 2013), which was adapted from the Academic Efficacy subscale of the Patterns of Adaptive Learning Scales (PALS; Midgley et al., 2000). Participants were asked to read each of the five statements presented (e.g., I am certain I can master the skills taught in my math class this semester) and rate how true each was to them.

Cronbach alpha coefficients ( $\alpha$ ) were calculated for math anxiety and math self-efficacy to assess the internal consistency of the two scales used in this study. The results indicated that both scales are reliable, with  $\alpha$  reported as .93 for math anxiety and .89 for math self-efficacy.

Student choice of agent was measured by a multiple-choice question where eight PAS (see Figure 1) differing in gender (male vs. female), ethnicity (White vs. Black), and age (instructor vs. peer) were presented to the students. The students were asked to select one of the agents from which they would like to learn a math lesson. Immediately after the question, the students were asked to write three reasons for their choice.



Figure 1. Pedagogical Agents Presented as Virtual Math Tutors to the Middle School Participants

### Procedures

The two math teachers of the participating classes facilitated the study. They provided the paper copy of the survey to their students in the last week of the semester. Student consent and parental consent were obtained before the study. More specifically, before the start of the study, each student was provided with a paper copy of the consent form and asked to read and sign the

document if they would agree to participate in the study. In addition, a parental opt-out form was provided to the parents seeking their permission for their children to participate in the study. The teachers collected the students' completed surveys and parental forms and returned them to the main researcher of the study.

### Data Analysis

Both student gender and agent gender were coded as 0 for male and 1 for female. Both student ethnicity and agent ethnicity were coded as 0 for White and 1 for Other Ethnicities (due to the lack of diversity of the sample, consisting mainly of White students in terms of ethnicity, categories in other ethnicity groups for students were merged). The agent age was coded as 0 for instructor and 1 for peer. A chi-square test for independence was conducted to explore if student gender/ethnicity and their choice of agent gender/ethnicity were related (e.g., whether girls were more likely than boys to choose a female agent and boys were more likely to choose a male agent). To further explore if student gender/ethnicity would predict their choice of agent gender/ethnicity, logistic regression was conducted including math anxiety and math self-efficacy in the model. In addition, logistic regression was conducted to examine if student gender, math anxiety, and math self-efficacy would predict student choice of agent age.

### Results

#### Choice of Agent Gender

A significant result was obtained from the chi-square analysis of student gender by agent gender:  $\chi^2(1, N = 118) = 37.96$  (with Yates' Correction for Continuity),  $p < .001$ , indicating that student gender and agent gender were significantly related: Girls tended to choose a female agent whereas boys tended to choose a male agent.

A logistic regression analysis was further conducted to explore whether student gender was predictive of their choice of agent gender with the inclusion of math self-efficacy and math anxiety in the model. The results showed that math self-efficacy, Wald's  $\chi^2(1, N = 118) = 4.07$ ,  $p = .04$ ,  $e\beta = 2.07$  in addition to student gender, Wald's  $\chi^2(1, N = 118) = 28.39$ ,  $p < .001$ ,  $e\beta = 33.11$  was a significant predictor of student choice of agent gender. That is, the results indicated (a) girls were more likely to choose a female agent, and (b) students with higher

self-efficacy were more likely to choose a female agent. An independent samples t-test found no significant difference in math self-efficacy between girls ( $M = 3.82$ ,  $SD = .87$ ) and boys ( $M = 3.99$ ,  $SD = .86$ ),  $p = .23$ ; therefore, the second finding was unlikely related to the first finding (i.e., the group of girls and the group of students with higher self-efficacy did not overlap).

#### *Choice of Agent Ethnicity*

A significant result was also obtained from the chi-square test of student ethnicity by agent ethnicity:  $\chi^2(1, N = 119) = 7.03$  (with Yates' Correction for Continuity),  $p = .008$ . In addition, a logistic regression exploring student ethnicity, math anxiety, and math self-efficacy predicting agent ethnicity found that student ethnicity remained a significant predictor, Wald's  $\chi^2(1, N = 119) = 7.48$ ,  $p = .006$ ,  $e\beta = 5.29$ .

#### *Choice of Agent Age*

A logistic regression with student gender ( $p = .289$ ), math anxiety ( $p = .393$ ), and math self-efficacy ( $p = .926$ ) predicting agent age detected no significant predictor. That is, the choice of agent age was not affected by the variables of participant gender and their levels of math anxiety or math self-efficacy.

The learner-agent similarity findings above were supported by the qualitative data collected from student responses to the open-ended question asking them to explain their choice. Around 18% of the participants specifically mentioned one reason for their choice was the same gender with the agent (e.g., "she has the same gender as me" or "I choose him because I'm male"). It is also interesting to note that some boys who chose a female agent explained that they did so partly because "I have always had female math teachers" or "I would choose a girl teacher over a boy teacher because I have never had a guy math teacher." With regard to the choice of ethnicity, around 10% of the participants specifically mentioned the same ethnicity as one reason for their agent choice ("It is my skin tone and it makes me feel more welcome to learn new things"; "She is the same color as me so I feel more comfortable to say my opinion and learn from her"). At the same time, another theme of participant choice concerns agent age. Participants choosing an instructor agent often mentioned they did so because he or she "looks like a good teacher"

or "looks professional" or "older," sometimes with the subsequent assumption that they "will teach me effectively"; whereas participants choosing a peer agent often mentioned that they did so because of perceived easier communication ("He is a kid like me so I might be able to understand him better than the others").

## STUDY 2: COLLEGE STUDENT SAMPLE

### *Method*

#### *Participants*

Participants included 135 undergraduate students from a Mideast university in the United States ( $M_{age} = 20.06$ ,  $SD_{age} = 4.87$ ; males = 38, females = 97), including 67.4% White, 8.1% Black, 5.9% mixed, 4.4% Asian, 4.4% Hispanic or Latino, and 8.9% other ethnicities. Table 2 summarizes the basic demographic information of the participants on gender and ethnicity.

TABLE 2. DEMOGRAPHIC CHARACTERISTICS OF THE COLLEGE PARTICIPANTS (N = 135)

Characteristics	Description	n	Percentage
Gender	Male	38	28.1%
	Female	97	71.9%
Ethnicity	White	91	67.4%
	Black	11	8.1%
	Mixed	8	5.9%
	Hispanic or Latino	6	4.4%
	Asian	6	4.4%
	American Indian or Alaska American	1	0.7%
	Other	12	8.9%

#### *Instrument*

Similar to Study 1, three survey instruments were included in Study 2 to measure participants' math anxiety, math self-efficacy, and student choice of agent. Math anxiety was measured by a 10-item, 6-point Likert scale (1 = strongly disagree to 6 = strongly agree) Math Anxiety Instrument (Pajares & Urdan, 1996) ( $\alpha = .81$ ). Half of the items were worded positively (e.g., I have usually been at ease during math tests) and half of the items were worded negatively (e.g., My mind goes blank and I am unable to think clearly when doing mathematics). Positively worded items were reverse coded, and the mean of the 10 items was used to indicate student math anxiety level. A higher value

indicates a higher level of math anxiety. Math self-efficacy was measured by the same 5-item, 5-point Likert scale (1 = not at all true to 5 = very true) used in Study 1 (Griggs et al., 2013) ( $\alpha = .91$ ).

As in Study 1, student choice of agent was measured by a multiple-choice question with eight pedagogical agents (see Figure 2) differing in age (peer vs. instructor), gender (male vs. female), and ethnicity (White vs. Black). The instructor versions of the pedagogical agents were identical to those presented in Study 1. The peer versions were designed to match the age range of college students in this study. Participants were asked to select one of the agents if they had an opportunity to learn a mathematics lesson with their selected agent. Students were also asked to list three reasons for their choice.

Figure 2. Pedagogical Agents Presented as Virtual Math Tutors to the College



Participants

### Procedure

An email was sent to all freshmen at the university inviting them to participate in the study. A link to the study questionnaires was included in the email. Students who consented to participate in the study completed the questions online at a place of their choice. It is worth noting that not all participants were presented with the math self-efficacy measure. Since math self-efficacy is task-specific, and the measure focused on students' confidence in their performance in a math class they were taking at the time the study was conducted, only participants who answered yes to the question "are you currently taking a math class?" received the math self-efficacy questions. The other measures were presented to all participants. All responses were stored in the online system where the study was hosted and then downloaded locally for data analyses.

### Data Analysis

The same data analysis methods in Study 1 were used in this second study. Specifically, gender

was coded as 0 = male and 1 = female for both the agents and participants. Ethnicity was coded as 0 = White and 1 = Other ethnicity groups for both the agents and participants (similar to Study 1, due to the lack of diversity of the sample, students not in the White ethnicity group were merged). Agent age was coded as 0 = instructor and 1 = peer. A chi-square test for independence was conducted to examine the relationship of student gender/ethnicity and their choice of agent gender/ethnicity (i.e., whether participants were more likely to choose an agent of the gender of their own). To further explore if participant gender/ethnicity would predict their choice of agent gender/ethnicity, logistic regression was conducted including math anxiety and math self-efficacy in the model. In addition, logistic regression was conducted to examine if student gender, math anxiety, and math self-efficacy would predict student choice of agent age.

## Results

### Choice of Agent Gender

The chi-square analysis of student gender by agent gender detected a significant relationship between the two variables:  $\chi^2(1, N = 121) = 8.96$  (Yates' Correction for Continuity),  $p = .003$ . The male participants tended to choose a male agent, whereas their female counterparts tended to choose a female agent.

The logistic regression of student gender, math anxiety, and math self-efficacy predicting agent gender found that student gender remained a significant predictor for agent gender: Wald's  $\chi^2 = 7.05$ ,  $p = .008$ ,  $e\beta = .13$

### Choice of Agent Ethnicity

The chi-square analysis of student ethnicity by agent ethnicity found that the two variables were not significantly related:  $\chi^2(6, N = 121) = 2.82$  (Yates' Correction for Continuity),  $p = .831$ . The test of the logistic regression model of student ethnicity ( $p = .951$ ), math anxiety ( $p = .094$ ), and math self-efficacy ( $p = .964$ ) also found no significant predictor.

### Choice of Agent Age

The logistic regression test of student gender, math anxiety, and math self-efficacy predicting agent age found that math self-efficacy significantly predicted agent age: As student math self-efficacy

increased, they were less likely to choose a peer agent, Wald's  $\chi^2(1, N = 42) = 5.38, p = .020, e\beta = .32$ .

Qualitative data collected from participant responses to the open-ended question asking them to explain their choice supported the quantitative data presented above. Around 15% of the participants specifically mentioned the same gender as a reason for their choice of the agent (e.g., "I can relate to her as being a woman"). The most frequently mentioned reason for agent choice was related to age (peer tutor vs. instructor tutor): Around 44% of participants mentioned they chose an instructor tutor because he/she looked like a teacher or displayed teacher-related qualities such as being "professional" or "knowledgeable." At the same time, around 15% of participants mentioned they chose a peer agent because they seemed a student or around the same age, and thus perhaps "understands where I am as a student." Whether a peer or an instructor agent, participant choice tended to reflect the alignment of their own gender as presented earlier: About 68% of the male participants chose a male agent, and about 63% of the female participants chose a female agent.

## DISCUSSION AND CONCLUSIONS

This study investigated how student demographics, math anxiety, and math self-efficacy related to their choice of pedagogical agents serving as virtual math tutors. First, the results supported the similarity-attraction theory (e.g., Johnson et al., 2013) in terms of gender for both middle school participants and college participants, confirming that students are more attracted to the agents who are similar to themselves in gender. In addition, middle school participants were found to be more attracted to the agents who were similar to themselves in terms of ethnicity; however, this was not observed for the college participants. This finding may be explained by the psychosocial development stages the two groups of participants were experiencing. Adolescence is a stage emphasizing identity formation (Erikson, 1997), with evidence reported even in virtual learning environments (Lee & Hoadley, 2007), thus similarity in ethnicity might be a more important factor for the middle school participants to look for than for the college participants when it comes to choosing a virtual agent.

Second, this study suggested that students'

perceived math self-efficacy influences their choice of gender of virtual math tutors for middle schoolers and choice of the age of virtual math tutors for college students. Middle school students with higher math self-efficacy were more likely to choose a female agent, and college students with higher math self-efficacy were less likely to choose a peer agent. This is an interesting new finding. Previous research has indicated a possible relationship between learner self-reported self-efficacy and an agent's expressed self-efficacy in influencing learning outcomes (Tärning et al., 2019). Therefore, it is reasonable to posit that students' choice of a PA might be influenced by their perceptions of their own self-efficacy level and the perceived agents' self-efficacy level; or more specifically, the students were looking for an agent with a matching self-efficacy level of their own. Although this study did not explicitly indicate the self-efficacy level of the agents, it is possible that the students unconsciously rated the agents' self-efficacy level based on their perceptions in the classroom and made their choices accordingly. We argue that the middle school students in this study might have perceived the female agents as having higher self-efficacy, and the college students might have perceived the instructor agents as having higher self-efficacy. According to the National Center for Education Statistics ([https://nces.ed.gov/programs/coe/indicator\\_clr.asp](https://nces.ed.gov/programs/coe/indicator_clr.asp)), the majority of public-school teachers were female (76% as reported in 2017-2018). In this study, the two math teachers of the middle schoolers were also female. Therefore, middle school students might perceive female agents as having higher self-efficacy in math than male agents. This may explain why middle school students with higher math self-efficacy in this study were more likely to choose a female agent, as they were selecting an agent with a matching self-efficacy level. Similarly, in the college students' context, it is possible that the college students perceived an instructor agent as having higher self-efficacy than a peer agent, and they considered this similarity in self-efficacy an influential factor in their choice; therefore, those college students with higher self-efficacy were less likely to choose a peer agent. It will be helpful in future research to duplicate the study with the added information of expressed self-efficacy of

pedagogical agents to verify the results and the reason behind this relationship.

Nevertheless, our studies did not find that math anxiety impacted the choice of PAS, for both children and college student participants. One possible reason could be that self-efficacy is a powerful predictor for a number of learning and motivational outcomes, and at the same time, anxiety, a physiological state, serves as an important source of self-efficacy (Bandura, 1997); therefore, when math anxiety is included in the same logistic regression model with self-efficacy, its effect on the choice of PAS may not show as significant. Future research with a larger sample size may explore the impact of math anxiety on the choice of PAS through a mediation analysis where self-efficacy serves as a mediator.

This study has empirical implications in online, technology-enhanced learning environments. Online learning has become increasingly important, especially in the time of the COVID-19 pandemic and beyond. At the same time, animated agents are often integrated into online self-paced video instruction. However, the selection of an agent is normally made without the consideration of its potential impact on the target learners. To maximize online learners' experiences, educators and instructional designers should be mindful of the social features of the agent (e.g., gender, ethnicity, age) they intend to integrate into their instruction and the role of the agent they intend to assign (e.g., peer or expert). As discussed previously, physical characteristics or social features are often an overlooked design aspect of PAS, leading to negative learning and motivational outcomes (Veletsianos, 2007, 2010). It will be helpful to integrate an agent that learners can identify with. Aligned with this line of thought, it may be important to provide multiple virtual agents, differing in gender and ethnicity, and give students the option of choosing an agent that they relate to, which could be especially beneficial for middle schoolers in their identity formation stage. In addition, if the goal is to promote students' math self-efficacy, it may be worthwhile to provide multiple agents with their varying self-efficacy levels explicitly stated, so that students can choose one that matches their own self-efficacy level. As females tend to have lower math self-efficacy than males (Seegers & Boekaerts, 1996), when the goal

is to promote math self-efficacy for females, then including female agents with differing self-efficacy levels may be particularly beneficial. Overall, integrating multiple PAS with various internal and external characteristics can be essential in online mathematical learning environments where learners tend to have a higher anxiety level and a lower self-efficacy level. Interacting with an agent that learners can identify with may facilitate their online mathematical learning process.

We acknowledge several limitations of the study. Caution should be exerted in generalizing the findings. First, our data were collected from a homogeneous sample, mostly White students from one middle school and one university in the Mideast part of the United States. Future research should investigate if the findings could be replicated in other settings with more diverse learners. Second, this study focused on learner choice or preference of social features displayed in PAS. No instruction delivered by the selected agent and corresponding assessment were provided to the participants; thus, it remains unclear if learner choice will subsequently impact their learning or motivation. This is a question worth further investigation, especially because previous research involving the impact of PAS' social features on cognitive, affective, or motivational outcomes have produced mixed findings (Baylor & Kim, 2004; Kim et al., 2007; Makransky et al., 2019; Moreno & Flowerday, 2006; Schroeder & Adesope, 2015). In addition, future research is encouraged to examine the learner choice of PAS in a more flexible manner. In this study, participants were presented with a set of predesigned agents for them to choose from. It will be interesting to investigate, in the context of having students design their own virtual tutor from scratch, how similar or different their agent will look like themselves. Finally, this study did not include high school students (middle adolescents) as participants. Rather, we focused on early adolescents—middle schoolers—and on young adults or late adolescents—college students. Although these two groups of learners represent two critical developmental stages, it will be helpful for future research to investigate how learner demographics, math self-efficacy, and math anxiety relate to and predict high school students' choice of PAS serving as virtual math tutors.

Despite the limitations of the study, it

contributes to research on technology-based learning environments as well as motivational processes related to mathematics education. Only a limited number of studies have examined K–12 students' preference and choice of pedagogical agents, let alone compared the findings with those involving college students. This study also adds to the literature of pedagogical agents by including math self-efficacy and math anxiety in a model together with student demographics and examining how they predict student choice of agent social features. The findings of this study have implications for designing technology-based learning environments. The relationship between student math self-efficacy and their choice of agent gender and age is especially worth further exploration, as little previous research has examined this relationship.

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