Animated Engineering Tutors: Middle School Students' Preferences and Rationales on Multiple Dimensions

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Abstract— **The goal of the study was to explore middle school students' preferences for an animated engineering tutor, and investigate their rationales for their choices. 77 middle school students participated in the study, and provided their preferences and rationales on various dimensions of an animated engineering tutor such as gender, age, personality, and clothing. Results showed that for teaching engineering in a computer-based instructional module, students preferred an animated engineering tutor that was similar to their age, matching their own gender, with a fun personality, and that speaks slowly.**

Keywords: animated pedagogical agents; engineering education; preferences; engineering tutor

I. INTRODUCTION

How can we help middle school students learn about engineering, focus their attention on relevant parts of a computer-based engineering instructional module, and keep them motivated to learn throughout the program? One technique used in multimedia research that could be applied to engineering education is to use visual presence of animated pedagogical tutors within the instructional module to facilitate students' engineering learning and influence perceptions of the learning experience.

An animated pedagogical agent (APA) is a human-like or otherwise animated on-screen character appearing in a computer-based instructional module [1][2][3]. Common objectives of pedagogical assistance provided by an APA are to keep students focused on important elements of the learning material, to keep them motivated, and to provide context-specific learning strategies [4]. By establishing a social interaction between learner and agent, APAs may maintain learners' engagement in a learning task, ultimately fostering student learning [5][6][7][8]. According to the persona hypothesis, the visual presence of an APA in computer-based learning environments can increase learning outcomes and positively affect learners' perceptions of the learning experience [9][10].

While designing an engineering instructional module for middle-school students, the animated engineering tutor that is present in the module may be a role model for students. Students perform in a certain way because either their behaviors are prompted, modeled, or valued by significant others to whom they feel or want to feel attached or similar [11]. In science and engineering this may suggest that relatedness, the need to feel belongingness, similarity, and connectedness with others, is centrally important for internalization, and improving learning. Sorge, Newsom, and Hegarty [12] examined the attitudes of Hispanic middle school students towards science and scientists, concluding that most of the middle school students in the study had difficulties perceiving themselves as scientists mainly due to a lack of exposure to role models and negative media stereotypes. Students develop a stereotypical image of a scientist as they get older and scientists drawn are predominantly male [13]. In order to increase minority involvement in science, students need early exposure to role models and after-school programs [14].

A. *Agent Similarity Hypothesis*

APAs have both internal and external properties which influence student learning [15]. The internal properties of APAs are related to the instructional methods used by the agent in facilitating learning. Instructional methods applied through APAs may include directing learner attention through gestures [16][17], visual signaling, coaching, delivering feedback messages, verbal guidance, and modeling [18][19][6]. External properties of APAs relate to the image and voice of the agent, and include agent characteristics, such as gender, age, ethnicity, clothing, appearance and tone of voice.

According to the similarity attraction hypothesis, humans are more attracted to others who appear and behave similarly to themselves [20]. The similarity attraction hypothesis in the context of learning with animated pedagogical agents would predict increased learning and more positive perceptions the greater the similarity between the learner and the agent.

Previous research has explored various agent similarity effects. Kim and Wei [21] conducted a research study with high-school students to examine learners attributes (gender and ethnicity) and their preferences for a pedagogical agent. The results indicated, first, that students preferentially chose a same-gender agent, and Caucasian students chose a Caucasian agent and Hispanic students chose a Hispanic agent significantly more frequently than a different-ethnicity agent. In studies [22][23] it was found that animated agents who match the observer in race and gender can have greater impact on women in increasing their interest in and reducing their stereotypes about gender in engineering fields.

Capobianco, Diefes-Dux, Mena and Weller [24] found in draw-an-engineer tests that 58 % of elementary school students drew the engineer as a male, whereas 18 % drew a female, and 24 % drew a group or a person without discernible gender. A study conducted with college students [25] stated that a majority of students reported a preference for agents that were similar to them, at least in terms of gender, a majority reported a preference for avatars that were ''like'' them, suggesting that students may also want to match other characteristics, such as hair color and race, perhaps sexual orientation, or even hobbies. As humans often treat computers as social entities, social accounts of interaction such as the similarity attraction hypothesis may be relevant to computer-based instructional environments. How people perceive agents may influence both the self-perception and perception of others using a particular agent as well as message perception and retention [25].

A study conducted by Moreno and Flowerday [26] randomly assigned learners to a choice condition, in which learners selected an agent from 10 options, differing in gender and ethnicity, or a non-choice condition, in which learners were assigned to an agent. Results first indicated that overall learners did not more often select an agent that matched their gender or ethnicity, but students of color were more likely to select an agent with the same ethnicity than their Caucasian counterparts. Next, the results did not indicate positive effects of gender similarity or ethnicity similarity on retention, or transfer learning measures, nor on program ratings. Furthermore, the students who were able to choose had lower scores, lower transfer scores, and lower program ratings when the agent matched their ethnicity.

Behrend and Thompson [27] did not find positive effects of gender similarity and surprisingly found a negative effect of ethnicity similarity on utility ratings of the agent. However, these two effects were shown to be additive for engagement of students; the highest engagement ratings were obtained in the group where both gender and ethnicity was matched to the learners gender and ethnicity. But, the learning outcomes were not significantly influenced by gender or ethnicity similarity. Kim and Baylor [6] found that Caucasian students rated Caucasian agents as more engaging and affable, whereas African American students rated these characteristics higher for African American agents. Kim and Baylor did not find better learning, self-reported self-regulation or self-reported satisfaction for agents who matched the learners in gender or ethnicity.

Rosenberg-Kima, Baylor, Plant and Doerr [22] in experiment 2 explored participant perceptions of engineering (self-efficacy, interest, stereotypes, and utility) after learning with one of eight agents differing on three factors (age, gender, and 'coolness'). Rosenberg-Kima, Baylor, Plant and Doerr [22] expected that participant perceptions would be most impacted after viewing an agent they considered that was similar or aspired to (i.e., young and 'cool'). Results supported this hypothesis; the two conditions (male and female) with young and 'cool' agents led to higher self-efficacy and interest ratings than the remaining six conditions. Lee, Liau, and Ryu [28] explored gender similarity by using computerized voice only. The authors showed that male participants rated a male agent's voice more likeable than a female agent, whereas no difference in voice likeability was found for female participants. A similar pattern was found in participants' ratings of voice credibility, content quality, and self-confidence in the topic discussed (e.g., skin care and makeup or dinosaurs). In these studies, learning outcomes were not measured [22] or [28].

Our current study examines middle school students' preferences for an engineering animated tutor on multiple dimensions and their rationale for attractions to those dimensions for an engineering tutor. If we were to teach middle school students about engineering, who would they be more motivated to learn engineering with and why? Stereotypes and preconceived notions may be crucial to interpreting a character's purpose in a computer-based learning module. Engineering is mainly viewed as a male-dominated field. So what would be the middle school students' choice for animated engineering tutors? Who would they feel more comfortable with, and be more eager to learn from? Who would capture and keep their attention? This current study focuses on furthering the research by targeting middle-school students' preferences for an engineering tutor, and contributing to the body of research not only by investigating gender and gender match-no match preferences, but also by investigating further characteristics of an animated engineering agent, such as teaching style, age, outfit, talking style, and preferences for a cartoon or a realistic looks, as well as the rationale that leads to these preferences.

B. Research Questions

1. What are students' preferences for an animated engineering tutor?

2. What are the rationales for students' choices for specific tutors?
3. What are the preferred attributes of an animated engineering tutor for middle school students?
4. What are the rationales for the preferences for specific attributes of an animated engineering tutor?

II. METHOD

A. Participants

The participants were a total of 77 middle-school students at a public school in the Southwestern U.S with the mean age of 12.83 years (*SD = 0.84)*. There were 35 (45.5%) males, and 42 (54.5%) females.

B. Materials and Procedure

Each student was provided with a survey form that included pictures for three agents that were of various age and gender. Students were asked who they would prefer to learn about engineering from (Which of the below would you want to teach you about electric circuits in the computer?) and asked to list three reasons for their choice. The survey had an image of old male agent, a young female agent, and a young male agent displayed side-by-side (see Fig. 1). Additionally, the survey form had six forced-choice items and each of these items had an open-ended portion for students to explain their choices in detail. These six survey items asked students their preferences for an animated engineering tutor on various dimensions, (e.g., I learn better from my engineer teacher if s/he is girl/boy, young/old, dresses serious/dresses cool, talks fast/talks slow, fun/serious, cartoon human/real human). Also, students' own gender and their choices for the agent gender were captured to conduct further statistical analysis.

Figure 1. Agent choices in the survey

C. Data Coding

Quantitative and qualitative data analysis techniques were used to analyze the collected data. Frequencies were obtained from student choices for each agent and analyzed quantitatively for significant differences between choices. Qualitative data that were obtained from the students open ended-responses analyzed by two researchers. During the analysis, researchers identified characteristics of the agents noted by the students. Any characteristic that was noted only once and did not fit into any already existing category was collected in the "other" category. As soon as a particular characteristic was noted twice or more frequently, a category was established. From the initial investigation seven superordinate and 30 subordinate categories emerged, and the data were coded into the seven superordinate categories that are displayed in Table 1.

Under each of these superordinate categories listed in the Table I, each superordinate category included various numbers of subordinate categories. For example under the "personality" superordinate category; personality_cool, personality_comfortable, personality_fun, personality_ interesting, personality_nice, personality_interested, personality_relatable, personality_ smart, personality_ trustworthy, personality_good subordinate categories emerged.

TABLE I. AGENT PREFERENCE SUPERORDINATE CATEGORIES

Superordinate Categories	Subordinate Categories	Example Statements
Age	Young Old	He looks younger He is older he may know more She seems more of my age
Appearance	Dress Pretty Professional Real	She has cool shoes He dresses like us He knows how to dress
Personality	Comfortable Cool Fun Good Interesting Interested Nice Relatable Smart Trustworthy	He looks like someone to trust She looks like she is interested Because he looks like someone I would get along
Gender	Male Female Opposite	She is a girl He is the opposite sex Women know a lot of thing
Speech	Boring Clear Slow	It looks he doesn't talk fast She talks at the right speed Talk clear
Teaching	Comprehensive Effective Examples Friend Gesturing Patient Understands	He is smarter as a teacher He looks like a person who explains things to you He might teach me a lot
Other	All other characteristics	Feels more better Because I don't know her, and I would like to know what she likes The others do not influence me

III. Results

A. Preferences for a Specific Agent:

Twenty-eight (36%) of the students chose a young male agent to be their engineering tutor. Thirty-six (47%) of the students preferred a young-female agent. Thirteen (17%) of the students preferred an old-male agent as tutor.

B. Rationales for Preferences for Each Agent

Young-male agent: When the open ended responses were analyzed the following categories were frequently cited for students' rationales for choosing the young-male agent (each student was able to list three categories); "teaching_effective" (13 students), "personality_cool" (11), age_young (9), "appearance_dress"(9), "personality_smart"(7), "appearance _real"(6), "personality_nice"(4), personality_relatable (3), "personality_fun"(3), "gender_male"(3), "personality_ trustworthy"(2), "personality_interesting"(2), "teaching_ comprehensive"(2). There were students who noted less frequent traits for young-male agent choice, such as having "personality_good" (1), "gender_opposite" (1).

Young-female agent: When students' responses to open-ended questions were analyzed, the following categories emerged as most frequently cited for preferring the young-female agent; "gender_female" (16 students), "teaching_ effective" (14), "appearance_real" (13), "personality_smart" (11), "appearance_dress" (5), "speech_clear"(5), "age_young" (4), "personality_cool"(3), "appearance_pretty"(2), "personality_nice"(2), "teaching_friend"(2), "personality_ trustworthy" (2), "personality_ interested (2)" There were students who noted less frequent traits for young-female agent choice such as; "personality_comfortable", "teaching_patient"(1), "personality _ fun" (1).

Old-male agent: When students' responses to open-ended questions were analyzed, the following categories emerged as most frequently indicated as a reason for their choice for the old-male agent; "teaching_effective" (13 students), "personality_ smart" (8), "appearance_professional" (4). "teaching_examples" (3), "age_old" (2), "personality_cool (2), "personality fun" (2). Some students who indicated less frequent traits for old-male agent choice, such as "speech_clear" (1), "speech_slow" (1), "personality_good" (1) and "personality_nice" (1).

C. Overall Preferences and Comparisons

Agent gender preference: Forty participants (52%) preferred a female engineering agent, and thirty-seven participants (48%) preferred a male engineering agent. Overall, male and female students demonstrated a significant preference toward a pedagogical engineering tutor that matched their own gender, $\chi^2(1) = 21.75$, $p < .001$. Thirty-two of the female students (76%) chose a female agent; twenty-seven of the male students (77%) chose a male agent for their animated engineering tutor. The learners were more likely to choose either a young female or young male agent for their learning interactions, $\chi^2(2) = 10.62$, $p = .005$. Thirty-six (47%) of all students reported preferring a young female agent and twenty-eight (36%) of the students reported preferring a young male agent. Example student rationales for choosing matching gender were "I am a girl too", "boys are better than girls", "they [boys] are easy to understand", "I would feel more comfortable", "I am a boy too", and "they [boys] would be cooler."

Agent age: Overall, students preferred a young agent over an old agent for their learning interactions, $\chi^2(1) = 17.78$, $p < .001$. Fifty-seven (74%) of all students reported preference for a young agent. Thirty-six (86%) of the females chose a young agent, whereas twenty-one (60.0%) of the male students chose a young agent. The preference for a young agent among female students was significant, $\chi^2(1) = 21.43$, $p < .001$, while there was no significant preference among male learners. Students had various rationales for preferring a young agent such as "[young] up to date", "I can relate to them", "they don't need to stop and think", "he understands us because he is young,", "it would be like a friend teaching me," and "old people don't get my attention."

Agent personality: Overall, learners are more likely to choose an agent with a 'fun' personality, compared to a more 'serious' personality, $\chi^2(1) = 12.48$, $p < .001$. Seventy percent (70%) of all learners reported preference for an agent with a fun personality. Thirty-four (81%) of females preferred a 'fun' agent, whereas twenty (57%) of male students preferred a 'fun' agent. When broken down by the learner gender, the difference in number of males preferring a fun agent over a serious agent was not significant, $\chi^2(1) = 0.71$, $p = .40$. However, female learners did demonstrate a significant inclination toward a 'fun' pedagogical agent, $\chi^2(1) = 16.10$, $p < .001$. Example student rationales for choosing a fun personality agent were as follows; "serious is boring", "fun is good", "I learn more", "make you laugh", "make subject fun", "to make the learning process fun", and "it will make learning easier."

Speech pace: All learners are more likely to choose an agent with slow speech pace for their engineering domain learning interactions instead of fast speech pace, $\chi2(1) = 31.18$, $p < .001$. Sixty-three (82%) of the learners reported preference for an agent with slow speech pace, and fourteen (18%) of the students reported preference for an agent with fast speech pace. Rationales for choosing a slower speech pace over a faster speech pace were as follows; "so I could understand it", "that is good that he talks slow", "slow is better", "so I can hear everything they are saying", "explains more clearly", "so he explains it step-by-step", and "it lets me memorize."

Clothing: There was a marginally significant preference, across all participants, for animated agents with dress described as 'cool', compared to agents with 'serious' dress, $\chi^2(1) = 3.75$, $p = .053$. Forty-seven (61%) of all learners reported a preference for an agent with 'cool' wardrobe, whereas thirty (39%) of the students preferred an agent with a "serious" wardrobe. Example student quotations for reasons for choosing an agent with cool clothing instead of serious clothing were as follows; "I dress cool", "she looks great", "makes me want to pay attention", "class would go easy", "more fashion the better", "they look pretty", and "so you could learn fast."

Cartoon image or real human image: Overall no significant differences were found for the choices for a cartoon or real human image. Forty-two (55%) of the students preferred a cartoonlike image for the engineering animated agent. Rationales for choosing a cartoon-like image over a real human image were as follows "cartoon humans grab my attention", "it would be fun and educational", "funny" and "engineer teachers look like a cartoon", "I would focus more on the problems", and "it's cool and funny". Thirty-five (45%) of the students preferred a real-humanlike image for the engineering tutor, and the rationales for choosing that were as follows; "serious", "helps us understand more", "so I can ask questions back at her", "they explain better", "to explain easier and no distraction", "it would look better", and "it would be more realistic."

IV. Conclusion

The present study showed support for the similarity hypothesis, concluding that middle school students tend to choose animated engineering tutors that are similar to them in age and gender. Students may feel more comfortable learning a perceivable difficult topic such as engineering, from a peer like agent that is similar to them. It is clear from students' responses to open-ended questions that they feel close to same-age and same gender agents. As engineering is perceived as a difficult topic [29][30][31], middle school students tend to choose a fun personality engineering tutor compared to a serious one, primarily to keep the topic interesting and enjoyable, as well as a slow rate of speech to help them to follow easier and understand better.

Our results indicate that for middle school students, the use of a peer-animated engineering tutor agent that is similar to the students may improve interest and students motivation for learning. More research is needed to determine the effects of cool, young, same-gender, and fun-personality animated engineering agents on actual learning outcomes for this population.

The findings of this exploratory study shed light on future instructional modules that focus on teaching pre-college students about engineering fields and the design of recruitment materials. Computer-based and print-based, engineering outreach materials should be designed in a motivational manner by including suitable animated engineering tutors to capture students' attention and continuing motivation to learn from those agents.

V. Future Research

We will build on this study to develop a computer-based preference survey to investigate students' preferences for animated engineering tutors in more detail. The proposed computerized survey will aim to reach to a broader audience, including elementary, middle, and high school students. The categories that most frequently emerged in this study for choosing a particular agent, will be used as a base for the computerized version of the survey, while categories that occurred with low frequencies will be excluded. Specifically only one participant noted agents' personality as being "comfortable" as a reason which will be excluded.

Based on the present study, frequently stated categories will be used to prompt student responses in the computerized survey. Specifically, after students watch an introductory module on engineering disciplines that includes the different agents, students will be asked for their preference for an animated engineering tutor. Also they will be asked what they most and least liked about the displayed agents. The following options will be given for most liked categories for the agent: smart, young/old, male/female, realistic, professional, slow speech, fast speech, helpful, cool, dress, clear voice, nice, fun, interesting, trustworthy. The following choices will be given for the least liked attributes for the displayed agent: smart, young/old, male/female, realistic, professional, slow speech, unhelpful, boring voice. An old-female animated engineering tutor will be added. Students' preferences and opinions towards this old-female agent will be investigated.

Additional future research directions are to employ these agents in computer-based engineering instructional modules [1-3, 32] and study their effectiveness in specific pedagogical functions, such as signaling [17], prompting [33], and practice guidance [34].

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