AVATAR EFFECTS IN A STEM-GAME WEBSITE

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Abstract

The *STEM Game Crew* was developed as a portal to online STEM games. The website was used to test the expectation that science-related (versus non-science related) avatars and avatar customization would enhance users' STEM attitudes (i.e., STEM-learning self-efficacy and STEM interest). Data collected in a Midwestern public middle school ($N = 53$) partially supported this expectation. Science-related avatars were associated with higher STEM attitudes for boys only. Unexpectedly, avatar customization was associated with lower STEM attitudes across gender. STEM attitudes were positively associated with avatar identification and avatar embodiment, though gender differences were observed. This study illustrates the potential benefits and limitations of utilizing avatars in educational game websites, but also provides insights into the ways that avatars can be designed to enhance student learning and motivation.

Data from the U.S. Bureau of Labor Statistics (2014) suggests there will be a shortage of professionals in Science, Technology, Engineering, and Math (STEM) fields unless heavy incentives are provided to spark students' interest in pursuing STEM careers. It seems the earlier students become interested in STEM topics the better: 8th graders reporting high interest in science are three times more likely to pursue STEM careers in the future (Tai, 2006), which coincides with Maltese and Tai's (2010) finding that STEM graduate students and scientists usually report that their interest in technology topics started before or during middle school. One way of making middle-school students more interested in STEM topics is through the use of digital games in the classroom (Barab & Dede, 2007; Maltese & Tai, 2010). Although STEM games are prolific online, there is a lack of structure and pedagogy in most of the websites hosting those games.

Driven by this need, the *STEM Game Crew Website* (http://www.stemgamecrew.org/) was developed through a partnership between Michigan State University and WKAR television program *Curious Crew* (http://www.wkar.org/programs/curious-crew/). In the website, users can find more than 65 STEM online games related to different STEM topics and episodes of the *Curious Crew* science-learning show. Based on the Proteus Effect (Yee & Bailenson, 2007) and Bandura's (1977) Social Cognitive Theory, this study aims to examine whether science-related avatars can influence users' self-efficacy and STEM learning interest, and to investigate possible differences across gender.

Learning Science Through Digital Games

There is a growing body of literature connecting digital games and science education. Science learning games can facilitate learning, especially when the games are designed in ways that support social interaction, practicing science, and involvement in socio-scientific inquiry (Barab & Dede, 2007). Science games appeal to students because of their potential for engagement and fun (Marino, Israel, Beecher, & Basham, 2012). However, science teachers may struggle when including digital games in their curricula. The present project aims to address three specific challenges in this regard.

First, the *STEM Game Crew website* aims to simplify the process of identifying STEM games; games on the site were curated by the research team to be topically consistent with each *Curious Crew* episode. Second, a hypothesis-testing structure was used to guide game playing in order to motivate students to develop an inquisitive mindset, to broaden their definition of science, and to help augment their interest and self-efficacy in STEM fields (Bandura, 1977). Before playing a game, users are asked to create hypotheses based on the game's name and description. Then, after playing the game, users report reflective observations based on their gameplay experiences. Finally, the site aims to enhance engagement in the games and STEM attitudes through the use of avatars. Previous research shows that avatars can impact users' behaviors even after the mediated experience is over (i.e., a phenomenon known as the Proteus Effect; Yee & Bailenson, 2007), with the strength of such effects depending on the psychological attachment between users and their avatars (Ratan & Dawson, 2015). Such avatar-user attachment can include perceptions of avatar identification (i.e., feelings of similarity with the avatar's identity and appearance) or embodiment (i.e., feelings of physical presence in the avatar's body). These aspects of avatar perceptions may enhance the experience and outcomes of avatar use (Klimmt et al, 2010).

Gender Gap and Stereotypes in STEM

According to data from the National Science Foundation (2003), starting from middle school, girls consistently show lower scores on standardized science and math tests compared with boys of the same grade. This gender gap in STEM can be seen as an outcome of stereotype threat (Steele & Aronson, 1995), i.e., the phenomenon that people conform to negative stereotypes associated with identity when reminded of those stereotypes. The gender gap is part of a vicious circle driven by negative stereotypes regarding girls' abilities in hard sciences: because girls are led to believe they will perform worse than boys, they become less interested in pursuing STEM activities, which then detracts from their actual performance in these domains. This supports the stereotype and the gap widens. Initiatives such as the *STEM Game Crew* are designed to bridge the gender gap in STEM by showing that science games can engage young people regardless of gender. Moreover, the use of different types of avatars in the website might help users feel more motivated to learn about STEM topics.

Avatar Effects

In the context of mediated environments such as the *STEM Game Crew* or educational games, avatars can be used to increase engagement and boost learning (Falloon, 2010). However, most previous studies related to the Proteus effect have relied on adult populations, thus research on the use of avatars in mediated education environments for children is still scarce. Addressing this gap in the literature, the present study explores how different aspects of avatar design can impact STEM attitudes in the context of a STEM-game portal website (i.e., the STEM Game Crew site). People tend to conform behaviorally to their avatar's identity traits, for example, gaining confidence after using a taller avatar (the Proteus effect; Yee & Bailenson, 2007), thus, we expect users with avatars containing scientific characteristics to show more positive STEM attitudes. Specifically, we expect users with science-related avatars to be influenced by these scientific characteristics and thus be drawn to science and STEM in general, as hypothesized:

H1: Science-related (versus non-science related) avatars will lead to more positive STEM attitudes.

Moreover, avatar customization has been found to facilitate the Proteus effect because through customizing the avatar, the user perceives the avatar as more relevant to the self (Ratan & Dawnson, 2015; Ratan & Sah, 2015). Avatar identification, embodiment, and idealization may also facilitate the Proteus effect because they reflect a psychological merging of the user's perception of self and the avatar (Klimmt et al., 2010). These psychological aspects of avatar use have been conceptualized together (Van Looy, Courtois, De Vocht, & De Marez, 2012) but not with respect to avatar customization, so they are examined separately in this study. These provide the foundation for the following hypotheses:

H2: Avatar customization (versus non-customization) will lead to more positive STEM attitudes

H3: STEM attitudes are positively related to avatar perceptions — identification (H3a), embodiment (H3b), and idealization (H3c).

Finally, because the *STEM Game Crew* aims to help bridge the gender gap in STEM, we would like to explore how boys and girls are influenced differently by their avatar use. Avatars can trigger stereotype threat in STEM-related media, harming performance for minority users, when avatars display stereotyped demographic traits (e.g., race) compared to when they are devoid of such characteristics (e.g., displayed as a simple shape; Kao, & Harrell, 2015a; Kao, & Harrell, 2015b). The present study tests for gender differences in the effects of interest, proposing the following research question:

RQ1: Are there gender differences in the effects of avatar types and customization?

Methods Participants

Participants were middle-school students attending technology-related courses from a Midwestern public middle school (N = 53). Participants' age ranged from 12 to 14 years-old (M = 12.43) and 54.7% of the sample were girls, 45.3% were boys. Most of the participants were in the 7th grade (84.9%), 15.1% in 6th grade. Most of the participants were Caucasian (73.6%), and other percentages for ethnicity are the following: Native American (7.5%), Middle Eastern 3.8%, Hispanic/Latino (1.9%), Mixed (1.9%). Moreover, 11.3% of participants did not answer the ethnicity question.

Design and Procedures

We conducted a 2 (science-related avatar vs. non-science related avatar) x 2 (customizable avatar vs. non-customizable avatar) experiment for this study using the *STEM Game Crew*. Given the previously discussed findings that avatars that contain demographic identity traits have the potential to trigger stereotype threat (Kao, & Harrell, 2015a; Kao, & Harrell, 2015b), avatars were designed as simple shapes with eyes and mouths that users could customize (depending on condition). Science-related avatars were represented by beakers and non-science related avatars were represented by squares (see Figure 1).

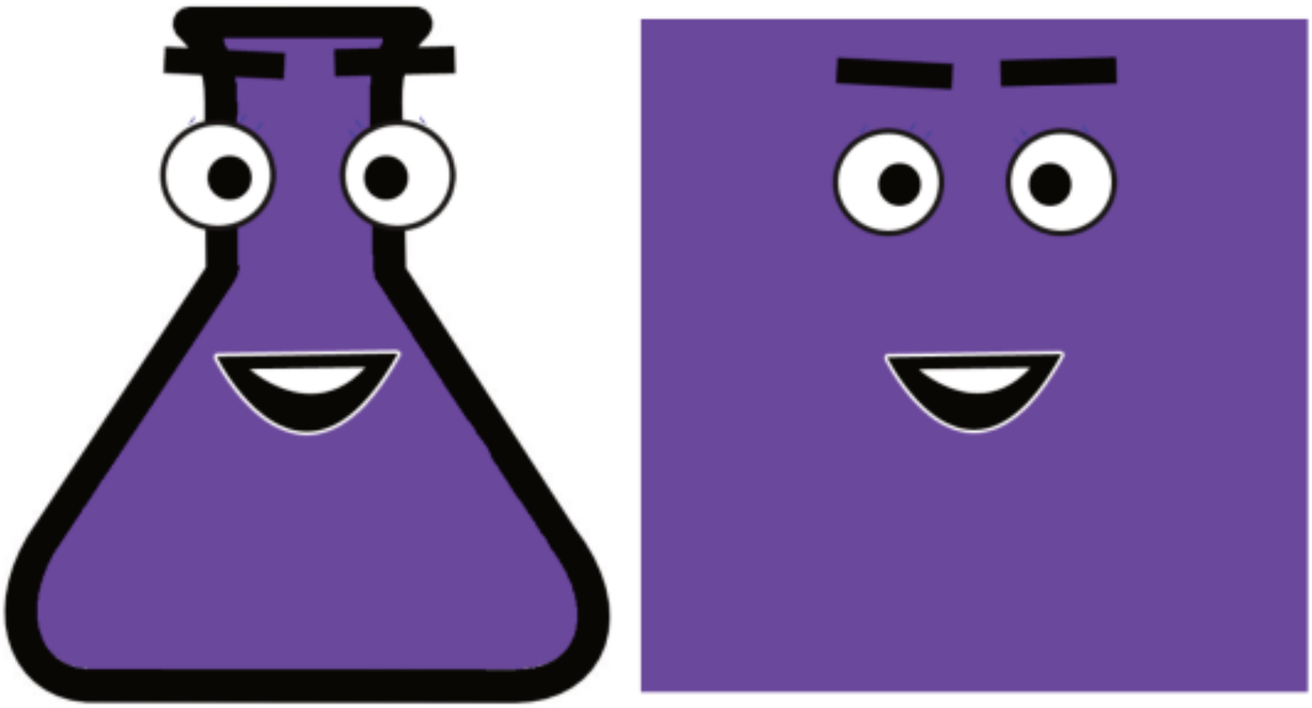

Figure 1: Examples of avatars: science-related (left) and non-science related (right).

Groups with customizable avatars performed the customization as soon as they entered the website ("Avatar Creation" page). The five customizable characteristics were: body color, shape of eyes, shape of eyelashes, shape of eyebrows, and shape of mouths (10 different possibilities for each – see Figure 2).

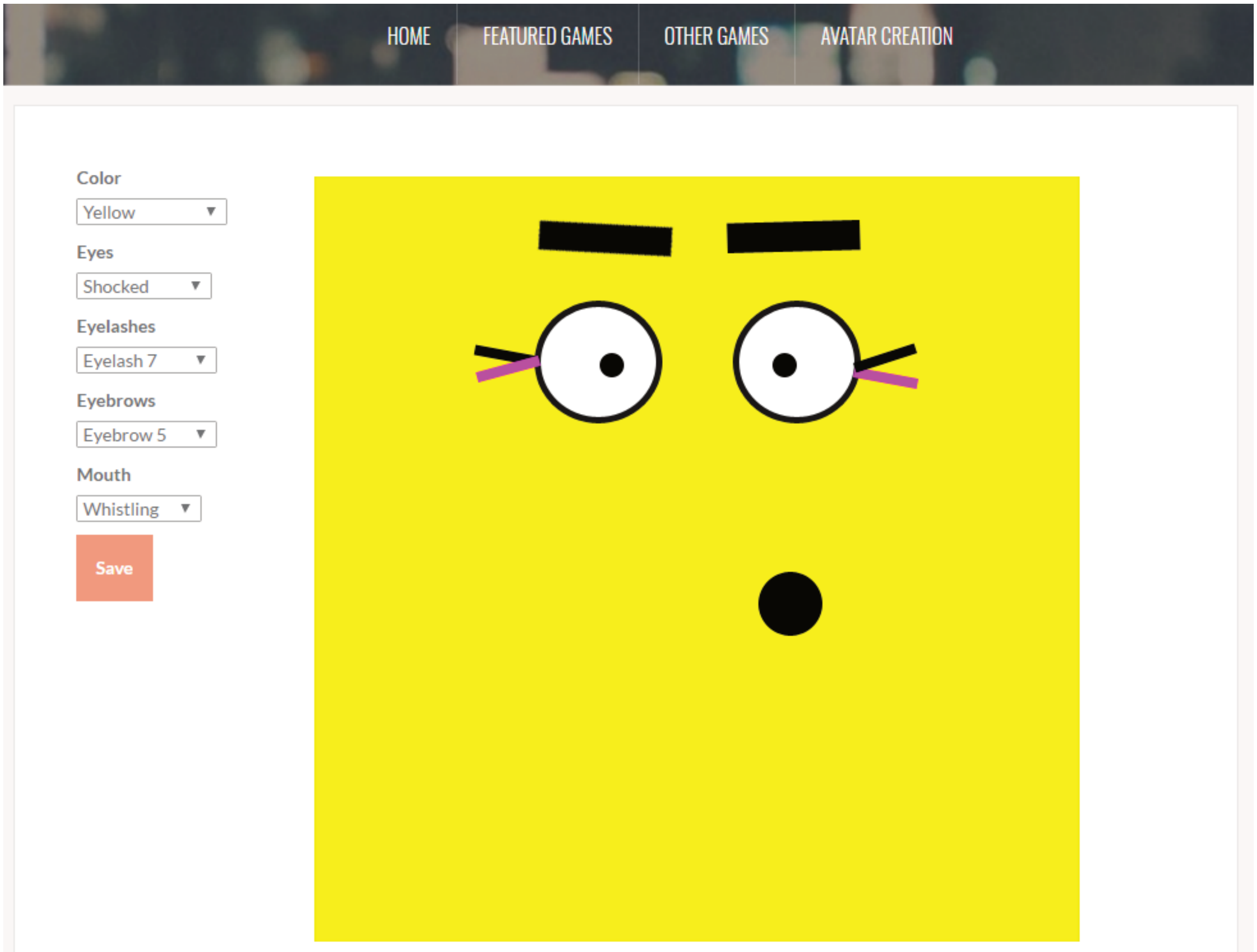

Figure 2. Example of customizable non-science related avatar in the "Avatar Creation" Page.

Groups with non-customizable avatars looked at their assigned avatar ("Your Avatar" page) and were asked to reflect on how to describe it in terms of the same five characteristics (see Figure 3). This procedure was essential because it forced participants to consider their avatar identity carefully even if they did not customize it.

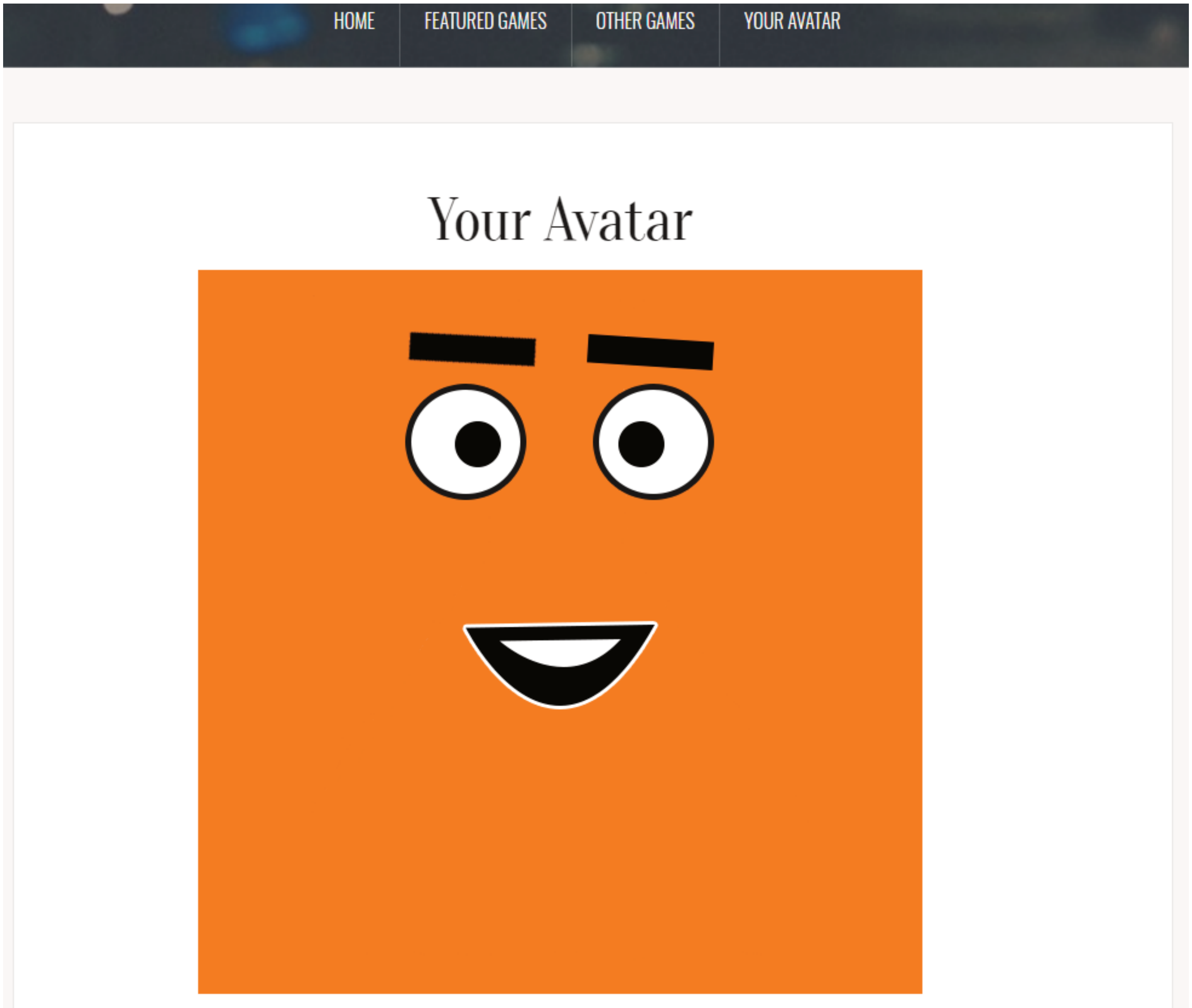

Figure 3. Example of a non-customizable non-science related avatar in the "Your Avatar" page.

Besides the avatar customization/visualization pages, avatars were displayed in the header of all pages and next to user IDs (see Figure 4). Moreover, on game pages, users' avatars were displayed next to user IDs and the game information (see Figure 5). Although the *STEM Game Crew* does not incorporate users' avatars into the games themselves, the avatars are expected to impact users' motivation in engaging in learning activities within the website because these images served as persistent reminders of the user's avatar identity in the website.

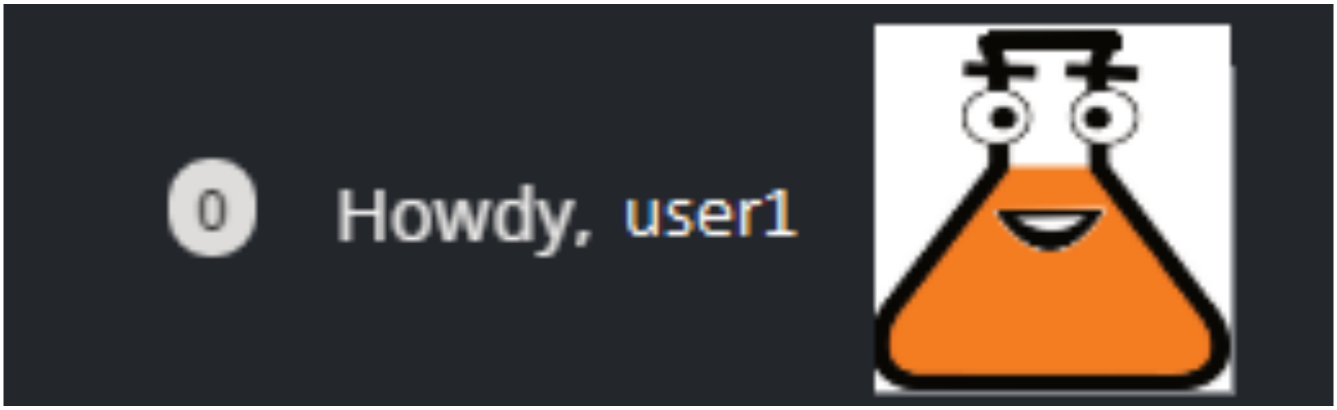

Figure 4. Example of avatar display (header).

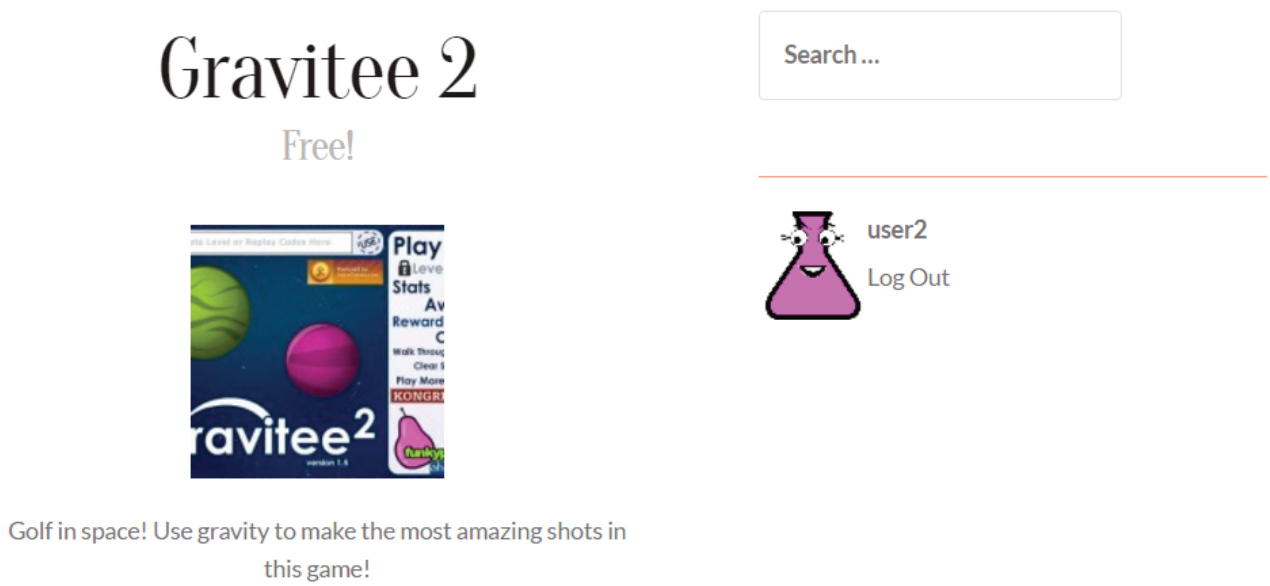

Figure 5. Example of avatar display (games' pages).

Data was collected over one randomly selected regular school day, during six class periods of 50 minutes each. Students were in 6th or 7th grade, all taking technology-related courses with the same teacher. Consent forms were sent one week in advance and students not taking part in the study were assigned another activity separately from study participants. The teacher was responsible for randomly assigning participants to one of four groups and dividing them across different computer labs. Each group had access to one of the four different versions of the website representing the four different study groups, and each participant used a unique but randomized identifier (thus maintaining anonymity) to log into the website. Before logging in, participants answered questions about STEM attitudes. After logging in, participants either customized their avatars or looked at them for 1-2 minutes. Then, participants described their avatars' visual and reflected on feelings towards their avatars via an online survey. This task was intended to enhance the participants' awareness of their avatar's identity. Next, participants were asked to play STEM games for about 30 minutes. Before playing each game, participants rated their perception of the game as fun, simple, capable of teaching something, and capable of explaining science ideas (predictive hypotheses) on a scale of one to five stars. After playing each game, participants rated the game again following the same item (reflective observations). After the play was over, participants answered questions measuring STEM attitudes, avatar perceptions, and demographics.

Measures

STEM Attitudes. There is a broad literature on traditional learning environments and interest in STEM fields and/or STEM self-efficacy (Diekman, Brown, Johnston, & Clark, 2010; MacPhee, Farro, & Canetto, 2013; Rittmayer & Beier, 2009; Soldner, Rowan-Kenyon, Inkelas, Garvey, & Robbins, 2012). In this study, Bandura's (2006) children's self-efficacy scale was adapted to measure STEM-learning self-efficacy. For the question "How well do you think you would be able to perform the following tasks?," students responded on a 5-point Likert-type scale (from "Not able at all" to "Absolutely able") to items asking their "ability to learn" in multiple specific STEM fields (i.e., Math, Physics, Engineering, Chemistry, and Computer Programming) were included in the present analyses. Items were averaged into composite STEM-learning self-efficacy metrics for the pre- (α = .77) and post-survey (α = .81). For STEM interest, a scale was developed based on students' respondes to the question "How interesting do you find the content of the following fields?" on a 5 point Likert-type scale (from "Not interesting" to "Absolutely interesting") for Science, Technology, Engineering, Math, and Computer Science. Items were averaged into composite STEM interest metrics for the pre- (α = .75) and post-survey (α = .80).

Avatar Perceptions. To measure participants' avatar perceptions, they were asked "Regarding your avatar in the website, rate how strongly you agree with each statement," with items rated on a 5 point Likert-type scale, from "Strongly Disagree" to "Strongly Agree". The Items, taken from Van Looy et al. (2012), measured avatar identification (6 items; e.g., "my avatar is like me in many ways"), embodiment (6 items; e.g., "I feel like I am inside my avatar when in the website"), and idealization (5 items; e.g., "I would like to be more like my avatar"). These items were averaged into separate metrics for each construct (avatar identification α = .94; avatar embodiment α = .93; avatar idealization α = .88).

***Attention Checks.** Two attention check measures were used (e.g., "Please select 'strongly agree' for this question").*

Results

Overall, results suggest that: **H1** (Science-related (versus non-science related) avatars will lead to more positive STEM attitudes) was supported for boys but not girls; **H2** (Avatar customization (versus non-customization) will lead to more positive STEM attitudes) was contradicted for all participants; **H3** (STEM attitudes are positively related to avatar perceptions – identification (H3a), embodiment (H3b), and idealization (H3c)) was supported for boys and girls in different ways; and insight was provided for **RQ1** (Are there gender differences in the effects of avatar types and customization?) in different ways.

A 2-way ANOVA was conducted with avatar type, avatar customization, and gender as fixed factors, avatar perceptions as covariates, and STEM-learning self-efficacy as the dependent variable. A statistically significant main effect was found for avatar customization ($F(1,47) = 8.37$, $p<.01$, $\eta 2 = .19$) and gender ($F(1,47) = 24.72$, $p<.01$, $\eta 2 = .41$) on STEM-learning self-efficacy. STEM-learning self-efficacy was higher for participants who did not customize an avatar ($M = 3.71$, $SD = .74$) compared to those who did ($M = 3.51$, $SD = 1.03$), which contradicts **H2**; and higher for boys ($M = 4.05$, $SD = .71$) than girls ($M = 3.16$, $SD = .85$), which provides insight into **RQ1**.

There was also a significant 3-way interaction between avatar type, avatar customization, and gender ($F(1,47) = 6.30$, $p = .02$, $\eta2 = .15$) on STEM-learning self-efficacy. To interpret this effect, the analysis was rerun separately for boys and girls. For boys only, there was a statistically significant 2-way interaction effect of avatar type and avatar customization on STEM-learning self-efficacy ($F(1,24) = 16.11$, $p<.01$, $\eta2 = .49$). STEM-learning self-efficacy was highest for boys who did not customize a science-related avatar (*M* = 5.90, *SE* =.55) compared to those who customized one (*M* = 3.90, *SE* =.25) and those who used non-customized or customized non-science avatars (*M* = 3.65, *SE* =.21; *M* = 4.10, *SE* =.23, respectively), which partially supports **H1**. Because avatar customization was connected with the lowest values of STEM-learning self-efficacy, this finding contradicts **H2**.

There was also a significant main effect, for boys, of a positive relationship between avatar identification and STEM-learning self-efficacy ($F(1,24) = 6.46$, $p = .02$, $\eta2 = .28$), a finding consistent with **H3a**. For girls only, there was a statistically significant main effect of customization on STEM-learning self-efficacy ($F(1,23) = 8.26$, $p = .01$, $\eta2 = .34$), with STEM-learning self-efficacy higher for those who did not customize an avatar (*M* = 3.51, *SD* =.70) versus those who did (*M* = 2.62, *SD* =.79) which contradicted **H2**. There was also a significant main effect, for girls, of a positive relationship between avatar embodiment and STEM-learning self-efficacy ($F(1,23) = 4.84$, $p = .04$, $\eta2 = .23$), a finding consistent with **H3b**.

Similarly, a 2-way ANOVA was conducted to examine the effect of avatar type, avatar customization, and gender on STEM interest, with avatar perceptions as covariates. There was a statistically significant main effect of avatar customization ($F(1,47) = 9.20$, $p<.01$, $\eta2 = .20$), gender ($F(1,47) = 28.92$, $p<.01$, $\eta2 = .45$), avatar identification ($F(1,47) = 4.10$, $p = .05$, $\eta2 = .10$), and avatar idealization ($F(1,47) = 4.68$, $p<.05$, $\eta2 = .12$) on STEM interest. STEM interest was higher for participants who did not customize an avatar (*M* = 3.52, *SD* = 1.02) compared to those who did (*M* = 3.39, *SD* = 1.02), which contradicts **H2**; and higher for boys (*M* = 4.00, *SD* =.86) than girls (*M* = 2.90, *SD* =.85), which provides insight into **RQ1**.

Avatar identification was positively associated with STEM interest (which supports **H3a**), but avatar idealization was negatively associated with STEM interest (which contradicts **H3c**). Moreover, we found a significant 2-way interaction effect between avatar type and avatar customization ($F(1,46) = 6.78$, $p = .01$, $\eta2 = .16$) on STEM interest. STEM interest was highest for participants with non-customizable science-related avatars (*M* = 4.40, *SE* =.35) compared with non-customizable or customizable non-science avatars (*M* = 3.42, *SE* =.19; *M* = 3.32, *SE* =.23, respectively) and lowest for those with customizable science-related avatars (*M* = 2.99, *SE* = .22), which partially supports **H1**. Because avatar customization was connected with the lowest values of STEM interest, this finding contradicts **H2**.

There was also a significant 3-way interaction between avatar type, avatar customization, and gender ($F(1,47) = 4.73$, $p<.05$, $\eta2 = .12$) on STEM interest. As done before, the analysis was rerun separately for boys and girls. For boys only, there was a statistically significant 2-way interaction effect of avatar type and avatar customization on STEM interest ($F(1,24) = 13.91$, $p<.01$, $\eta2 = .45$). STEM interest was highest for boys who did not customize a science-related avatar (*M* = 6.10, *SE* =.67) compared to those who customized one (*M* = 3.73, *SE* =.30) and those who used non-customized or customized non-science avatars (*M* = 3.64, *SE* = .25; *M* = 4.05, *SE* =.27, respectively), which partially supports **H1.**

Because avatar customization was connected with the lowest values of STEM interest for boys, this finding contradicts **H2**.

There was also a significant main effect, for boys, of a positive relationship between avatar identification and STEM interest ($F(1,24) = 8.98$, $p<.01$, $\eta 2 = .35$), supporting **H3a**. For girls only, there was a statistically significant main effect of avatar customization ($F(1,23) = 5.76$, $p = .03$, $\eta 2 = .27$) on STEM interest. STEM interest was higher for girls who did not customize an avatar (*M* = 3.21, *SD* =.94) compared to those who did (*M* = 2.40, *SD* =.32), again, contradicting **H2**.

Discussion

The present study examined how the use of different avatars in a website dedicated to STEM-learning games can influence STEM attitudes. STEM-learning self-efficacy and STEM interest were highest for boys (but not girls) who used science-related non-customized avatars. Regarding avatar customization, STEM attitudes were unexpectedly lower for users of customized avatars, regardless of gender or avatar type. Avatar identification and embodiment were positively associated with STEM attitudes, as expected. Conversely, avatar idealization was negatively associated with STEM attitudes. Gender differences were found, with STEM attitudes higher for boys than girls. Furthermore, STEM attitudes were positively associated with avatar identification for boys only, and with avatar embodiment for girls only. Overall, these findings present consistencies and contradictions with previous research on the effects of avatars, providing insights into the limitations and potential to harness them in educational contexts.

The finding that science-related, non-customized avatars led to more positive STEM attitudes for boys is consistent with the Proteus effect. This suggests that avatars can be designed in ways that promote intended outcomes in educational games and other media. Specifically, the science-related identity characteristics imbued in the avatar influenced the website user's perception of being capable of or interested in STEM fields. This finding is notable because it contributes to the sparse existing literature on the use of the Proteus effect in educational media for children. Designers and practitioners may apply these findings to develop more effective STEM education platforms that include avatars. This finding also raises an important theoretical question regarding the gender difference in the effect of avatar identity. Why did the science-related avatar only improve STEM attitudes for boys? As a post-hoc approach to addressing this question, we tested for gender differences in the avatar perception measures. There was a significant interaction between avatar type and gender for avatar identification ($F(1,47)= 15.25$, $p<.01$, $\eta 2 =.28$), embodiment, and idealization (similarly significant, also with medium/strong effect sizes). Across all three measures, girls reported stronger connections with beaker avatars than shape avatars, while boys reported the opposite. A visual inspection of the girls' qualitative descriptions of their avatars indicated that many recognized that the avatar was a beaker and some even mentioned science in their descriptions, suggesting that this difference was not driven by a misinterpretation of the avatar shape. However, the same visual inspection suggested that girls' interpretation of the avatar's feelings was associated with negative emotions (e.g., the same avatar was described as "happy" by boys, but "concerned" by girls). This further complicates the interpretation of the previous finding. Although girls felt more strongly connected to the beaker avatars, these avatars did not influence their STEM attitudes as it did for boys. One interpretation is that the gender gap in STEM is already so deeply ingrained by middle school that the avatars in this context were not a strong enough intervention to positively influence girls' STEM attitudes. Future research could test this explanation by utilizing more immersive science-related (versus non-science) avatars with this population and testing for gender differences.

The unexpected finding that avatar customization hindered STEM attitudes may relate to the design of the specific media environment used in this study. The avatars in the website were abstract, non-gendered entities, limiting enjoyment of avatar customization. Although this design decision was guided by the idea that abstract avatars would help circumvent gender stereotypes, this approach seemed to have unintended consequences. Perhaps avatars could be kept androgynous at their core, but be more anthropomorphized than simple shapes in order to enhance the enjoyment of customization. Or perhaps customization detracted from engagement in the website's main activities — rating and playing STEM games. Future research could examine such a potential explanation by having all participants customize an avatar, but then having only one group of participants assigned to use the customized avatar.

The findings that avatar identification and embodiment were positively associated with STEM attitudes are consistent with the expectation that these psychological aspects of avatar use may serve as mechanisms of the Proteus effect. However, this evidence should be considered with the caveat that causality cannot be determined definitively from this cross-sectional data. While the theoretical argument that avatar identification and embodiment should precede the STEM attitudes generated through site use, the possibility exists that participants with more positive STEM attitudes were more prone to experience avatar identification and embodiment. Future research should tease apart this issue by manipulating (instead of only measuring) avatar identification and embodiment directly.

The finding that avatar idealization was negatively associated with STEM attitudes contradicted the hypothesis but was not entirely unexpected. Avatar-self discrepancy (i.e., the perception of an avatar as being better than the self) is associated with lower well-being (Bessière et al., 2007). In this case, if the avatar is idealized and the user reports wishing to be more like the avatar, this may signal such self-discrepancy. Again, causality cannot be determined from this cross-sectional data. Using an avatar the participants idealized may have induced self-discrepancy, thereby hindering STEM attitudes. Alternatively, participants with more negative STEM attitudes (or negative psycho-social well-being in general) may have been more likely to idealize their avatars. Future research could tease apart this issue with a direct manipulation instead of measurement. Regarding other gender differences, the finding that STEM-learning self-efficacy and STEM interest were higher for boys than girls is consistent with previous research regarding STEM self-efficacy and interest in STEM fields (Ratan et al., 2016). This finding aligns with the gender gap in STEM, illustrating that girls show less interest in STEM-related content and less confidence in being able to learn such content. Furthermore, the findings that STEM attitudes were positively associated with avatar identification for boys only, and with avatar embodiment for girls only, are consistent with a previous study illustrating gender differences in the effects of using ideal-self avatars (Ratan et al., 2016). Together with the present findings, this may suggest that female avatar users are more susceptible to the negative effects of avatar idealization and thus avatar embodiment might be a better approach to augmenting the Proteus effect than avatar identification. Future research could test this expectation by manipulating avatar identification and embodiment separately, through different avatar characteristics and control settings, respectively.

The limitations of this study should be noted. First, the sample size was relatively small, due to a large rate of participants who did not fully engage in the study. This may have skewed the sample toward students who are more interested in STEM fields in general. Still, the differences found within the sample tested provide important theoretical and practical insights regarding the constructs of interest. There is no reason to believe that the Proteus effect is only relevant to more motivated students. Another limitation was the population sampled: although there was an approximately equal number of male and female participants, the sample was skewed toward 7th-graders and Caucasians. Future research should aim to include more representative populations. A final limitation is that the avatars in the website were not used extensively because they were not part of the games themselves. Thus, the effects of the avatar's traits on the users are potentially limited.

Conclusion

This study has shown that the Proteus Effect may be valuable in STEM Game context, though further research and analysis should be conducted. Future work includes making design changes in the website, modifying study design to better control participant activities, and including qualitative aspects of analysis to better understand user's thought processes. Overall, this study has illustrated that avatar type and customization can impact STEM attitudes, and that gender differences exist in terms of avatar effects. These findings are especially useful for designers and practitioners when developing education platforms.

Acknowledgements

Leticia Cherchiglia is a fellowship recipient of CNPq, Brazil (207633/2014-2).

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