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Examining Students' Perceived Competence, Gender, and Ethnicity in a Digital STEM Learning Game

Ginny Smith, Florida State University, USA*
https://orcid.org/0000-0002-4415-9123

Curt Fulwider, Florida State University, USA
Zhichun Liu, Florida State University, USA
https://orcid.org/0000-0002-6402-9174

Xi Lu, Florida State University, USA
Valerie J. Shute, Florida State University, USA
Jiawei Li, Florida State University, USA

ABSTRACT

The present study explores how gender, ethnicity, and performance-based perceived competence impact students' learning, performance, and enjoyment from playing a digital STEM learning game. The authors had 199 ninth-eleventh grade students play a 2D digital STEM learning game across six science classes. Based on the results of demographic surveys, matched pretests and posttests, and satisfaction questionnaires, they found no interaction between gender and ethnicity for performance-based perceived competence, performance, and enjoyment. They found a significant difference between males and females in performance-based perceived competence and in-game performance both favoring males over females. Among ethnic groups, they found a significant difference with in-game performance favoring White and Hispanic students over Black/African American students. However, the differences in gender and in ethnicity were insignificant once the authors controlled for both perceived competence and pretest scores. This supports the idea that neither race nor gender truly influence one's ability to perform in digital learning games.

KEYWORDS

Digital Game-Based Learning, Ethnicity, Gender, Perceived Competence, STEM Education

INTRODUCTION

As a nation with a great need to increase its number of graduates in science, technology, engineering, and math (STEM) fields STEM fields (President's Council of Advisors on Science and Technology (PCAST), 2010), US educators and researchers have been tasked with finding solutions and resources that address academic and career-based barriers. While barriers to learning can exist in any field,

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*Corresponding Author

certain educational areas are known for having a steep learning curve, like the STEM fields. Within the STEM disciplines underrepresentation of minority populations are most severe (Hill et al., 2010; Congressional Commission on the Advancement of Women and Minorities in Science, 2000). And while much STEM content has the reputation of being tough, students' *beliefs* regarding their success or potential to succeed in these areas could be just as tough a barrier to overcome (Pajares, 2004). For example, the phrase "I'm just not a math person" is commonly used to avoid math related tasks—preferring to defer responsibility to someone perceived to be more skilled. This doubt of ability and deference of challenge demonstrates the connection between a person's belief about their ability to perform a given task and their actual performance (Bandura, 1997). And this trend is common among various fields (Rodgers, et al., 2014), but perhaps most prevalent in STEM (Lauermann et al., 2017; Nosek et al., 2002; Nosek & Smyth, 2011; Patall et al., 2018). So, how is a barrier of self-belief overcome?

Evidence has shown incorporating digital game-based learning can increase student learning outcomes and interpersonal outcomes, such as motivation and positive self-evaluation across content areas (Clark et al., 2016; Mayer, 2020; Sung et al., 2017), including STEM disciplines (Hwa, 2018; Kebritchi et al., 2010; Shute et al., 2021f; Vu & Feinstein, 2017). However, the relationship between students' beliefs regarding their abilities to perform, *performance-based perceived competence*, and their performance in STEM across different populations remains unknown. This analysis takes a step towards better understanding how differences between underrepresented populations (i.e., gender and ethnicity) and their reported performance-based perceived competence, may affect their ability to learn from, perform in, and enjoy a digital learning game for physics.

BACKGROUND

Gaps in STEM Education

Women continue to be underrepresented in STEM (National Science Foundation (NSF), 2017) as the gender gap favoring boys and men remains in the United States (Fouad & Santana, 2017; Liben, 2015). In computer science and engineering, two fields with rapid growth and high potential earning rates, the gender gaps are particularly high. According to the US Bureau of Labor Statistics (2019), women make up only 25.8% of the *computer and mathematical occupation* workforce, and only 15.7% of the *architecture and engineering occupation* workforce. Men also vastly outnumber women majoring in most STEM fields in college (National Science Board, 2018).

Students' attitudes toward STEM topics may, in part, explain why. Differing attitudes may be evident during the transition between high school and college. Female high school students continually earn more math and science credits in high school and maintain a higher math and science grade point average in high school compared to their male counterparts. In contrast, only 15% of female students, compared to 29% of male students intend to major in STEM fields during their first year of college (Hill et al., 2010). A survey of middle and high school students revealed male high school students reported significantly higher beliefs about their abilities in STEM ($M = 3.31$, $SD = 1.02$) than female high school students ($M = 3.03$, $SD = 1.01$), $t = 3.53$, $p < .05$ (Desy et al., 2011). Furthermore, while not statistically significant differences, the researchers found the female middle and high school students reported higher anxiety, lower motivation, and less enjoyment of STEM subjects when compared to their male peers. Within the individual STEM subjects, for example, looking specifically at students' beliefs about math, research again reveals gender differences favoring males (Nosek et al., 2002; Nosek & Smyth, 2011; Riegle-Crumb et al., 2011). In one study of adults across a variety of ages, Nosek and Smyth (2011) found that the adults' levels of acceptance of the traditional gender stereotypes in math (i.e., seeing math skill as a male trait) influenced their personal beliefs about math and was related to their prior performance in math as measured by their college entrance exam scores. Traditional stereotypes and the associated attitudes can act as barriers to female success in

STEM. Getting more females into STEM remains a challenge in the United States (Master et al., 2017); improving students' beliefs regarding STEM has the potential to help.

As with gender, ethnic inequities also appear within STEM fields. According to the National Science Foundation (2017), Black and Hispanic individuals make up only 6% of the STEM workforce in the United States. Ethnic inequities appear as early as elementary and middle school children, indicating that the ethnic gap begins long before students enter the workforce (Quinn & Cooc, 2015). According to a national survey, at the beginning of high school, the majority of Black students are enrolled in college preparatory math and science classes (Lamb et al., 2013). However Black student enrollment in college preparatory math and science courses at the end of high school is a much smaller percentage (Dalton et al., 2007). Black and Hispanic college students are also significantly more likely to switch from STEM to non-STEM majors (Riegle-Crumb et al., 2019). So, what is changing the educational direction of Black and Hispanic students? Hilts, Part, and Bernacki (2018) found that, regardless of gender or ethnicity, college STEM-majors' perceived competence had a significant positive correlation with achievement ($r = .33$, $p < .05$) and a significant inverse relationship with students' intention to leave their STEM major ($r = -.33$, $p < .05$). Differences between gender and ethnic groups' perceived competence may explain the overall increased likelihood of minority students switching to non-STEM majors. In other words, performance-based perceived competence may be an important factor to consider when attempting to close both gender and ethnic gaps in STEM.

Perceived Competence

Self-Determination Theory is one lens researchers have used to examine the impact of students' self-beliefs (Ryan et al., 2006). Competence—a primary component of self-determination theory along with autonomy and relatedness—is the drive to improve oneself by mastering new skills and overcoming difficult challenges (Deci & Ryan, 1985). Competence is a prerequisite to cultivating intrinsic motivation (Jaakkola et al., 2019; Ryan & Deci, 2000) and imperative to the success of academic endeavors. Self-Determination Theory, like previously mentioned research, illustrates the connection between belief and performance (Ryan & Deci, 2000). According to the theory, students' beliefs about their task-related performance (i.e., performance-based perceived competence) influences their actual performance and skill attainment.

Student's perceptions of their own competence in a given area or for a given task, while subjective in nature, may have just as much or more influence over their motivational drive as objective evidence of competence in said area. Miserandino (1996), for example, as part of a longitudinal study, investigated whether perceived competence influenced students' academic engagement and performance. The study focused on 77 highly talented children and found, controlling for achievement test scores, that perceived competence was a significant predictor of students' grades in both math and social studies but not in reading and spelling. Furthermore, students who reported lower perceived competence had higher anxiety, anger, and boredom and were more apt to avoid or cheat on schoolwork.

Students' beliefs about their competence not only relates to learning and development but also future educational choices, including attitudes toward and participation in STEM courses (Patall et al., 2018; Skinner et al., 2017). For example, in developing a measure of self-system, engagement, and identity, Skinner et al. (2017) measured 1013 undergraduate science students' beliefs about their ability to perform in science. They found a significant correlation between performance-based perceived competence and an identity related to science ($r = .70$, $p < .01$) and STEM career plans ($r = .31$, $p < .01$). As one feels more competence in their ability to achieve desired outcomes, their identity in the relevant area (e.g., STEM) increases. Thus, greater aspirations, such as a life-long career in STEM, appear within reach—as they were all along.

By better understanding the role performance-based perceived competence plays in students' pursuit of STEM-related careers, instructional and/or career-based supports may be designed to better solidify students' perceived competence towards STEM. Game-based learning is one method for implementing support. In this study, the authors examine the role of performance-based perceived competence in students' learning from, performance in, and enjoyment of a digital physics learning game.

Digital Game-Based Learning

Over the past decade, the transformative potential of digital game-based learning has received growing attention in the US K-12 classrooms. Learning games and simulations have been used to address educational equality issues and motivate underrepresented groups (Bachen et al., 2015; Khan et al., 2017). Digital game-based learning is defined generally as the use of digital games for acquisition of a specified set of physical, cognitive, and/or affective outcomes. However, the types of games used varies greatly. Learning games (i.e., games designed for educational purposes instead of entertainment) are often used in digital game-based learning research and can be used to train a variety of cognitive and noncognitive skills (Ke, 2016; Shute et al., 2015). Features of well-designed digital learning games include adaptive challenges, goals and rules, interactive problem solving, autonomous control of learning and game environment, ongoing feedback, and sensory stimuli (Shute et al., 2011; Wouters & Van Oostendorp, 2013). While traditional classroom instruction is still the primary means for learning STEM subjects, digital game-based learning provides a powerful addition to classroom-based STEM teaching, as optimal STEM education is real-world, relevant, and related to the learner (Klopfer & Thompson, 2020).

Research shows game-based learning can be equally beneficial to learners across gender in a variety of higher-order thinking skills (Cherney, 2008). For example, researchers assigned 77 undergraduate students to play either Portal 2 (a 3D first-person puzzle-platform video game) or Lumosity (a cognitive training program made up of 52 puzzle-like 2D games) for eight hours and found that Portal 2 players showed significant improvement on problem solving, spatial ability, and persistence and demonstrated transfer effects after gameplay, for males and females (Shute et al., 2015). Yang and Chen (2010) investigated the effects of spatial ability and gender in a digital pentominoes game for geometry with 34 fifth graders who played the game for 60 minutes. Their results demonstrated that the game significantly improved students' spatial skills and reduced gender differences in spatial abilities. While males outperformed females on their pretest scores, they did not outperform them in the posttest, meaning the initial gap in female participants' spatial skills was closed after playing the game.

Research Questions

According to Ryan and Deci (2020), "the need for competence is best satisfied within well-structured environments that afford optimal challenges, positive feedback, and opportunities for growth" (p. 1). Digital game-based learning has these same affordances. In the current study, the authors seek an explanation to the variation seen in student outcomes from digital game-based learning. More specifically, the authors investigate the relationship between students' self-reported gender, ethnicity, and performance-based perceived competence and their physics learning, in-game performance, and enjoyment from playing the digital learning game, *Physics Playground* (Shute, Almond et al., 2019). The specific research questions are:

1. Do differences in gender, ethnicity, and performance-based perceived competence have an impact on students' physics learning from playing a learning game?
2. Do differences in gender, ethnicity, and performance-based perceived competence have an impact on students' in-game performance?
3. Do differences in gender, ethnicity, and performance-based perceived competence have an impact on students' enjoyment of the game?

METHOD

Participants

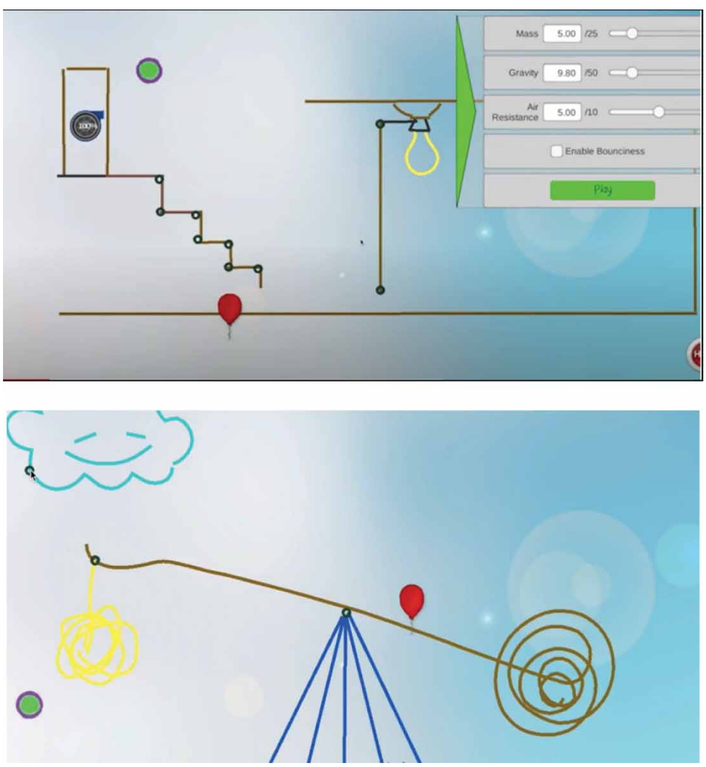
The sample consisted of 199 9th-11th grade students in a large K-12 school in Florida. The sample had a wide range of ethnicities and similar numbers of self-identified male students ($n = 104$) as it did female students ($n = 91$) with four students who did not identify as either male or female. Students participated across six 50-minute sessions during their high school science class and received a gift card upon completion of the study.

Materials

Learning Game and Game Performance

Physics Playground (Shute, Almond et al., 2019) is a 2D digital game designed to help middle and high school students learn conceptual physics. The goal of the game is to move a green ball to hit a red balloon. The game includes two types of levels, sketching and manipulation. See Figure 1 for an example of each type. In sketching levels, students draw simple machines such as levers and springboards, using a computer mouse (or stylus). In manipulation levels, students adjust sliders that control different aspects of the level (e.g., gravity, air resistance) to solve manipulation levels. Game levels vary in difficulty and targeted physics concepts. The game covers nine competencies related to the basic laws of energy, force, and motion. Gameplay begins with tutorial levels to help students master the basic game mechanics. Students also have access to a help button during gameplay where they can receive additional game or physics support. Students can access a dashboard area to check their progress and purchase game modifications, such as a different ball or background. In this study, the game included 91 levels for students to solve. For the analysis, the authors used the total number of levels solved as the measure of students' in-game performance.

Figure 1. An example of the two types of levels in Physics Playground



Physics Understanding Test

The authors created two equivalent 18-item digital multiple-choice tests to assess students' physics knowledge before and after gameplay (pretest $\alpha = .77$; posttest $\alpha = .82$). Each item used examples and scenarios from the game (i.e., videos and screenshots) to pose questions meant to gauge player's understanding of the relevant concepts. Two physics experts helped develop the items, and the final instrument was subjected to several pilot tests before being implemented in the current study. See Figure 2 for an example of two test items. For the analysis, posttest scores were used as a measure of students' physics learning and pretest score as a measure of prior knowledge.

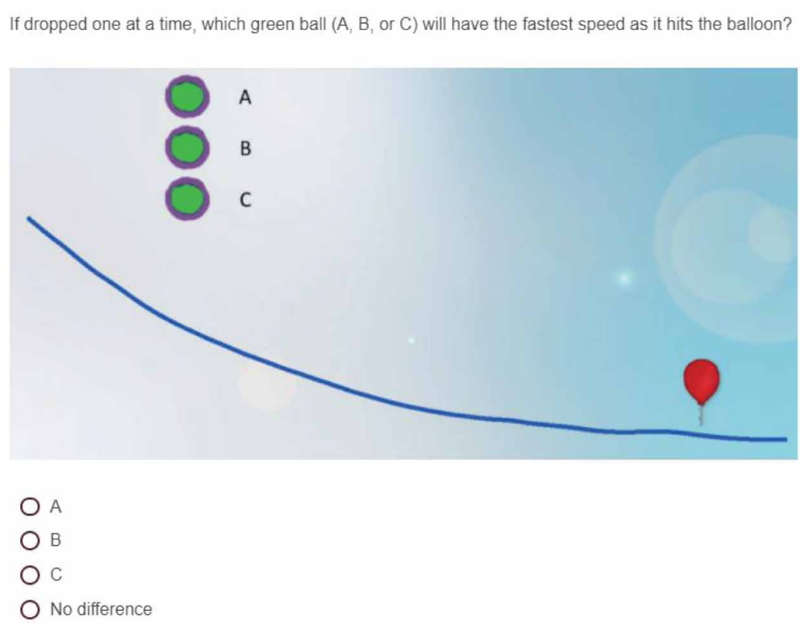
Satisfaction Questionnaire

To evaluate students' satisfaction with both the game and the supports, the authors used a 16-item questionnaire. Students responded on a 5-point Likert scale, from strongly disagree to strongly agree. Five of the items, when combined, measured student's enjoyment ($\alpha = .87$). Scores on the enjoyment subscale ranged from 5 to 25 points. Two items measured students' performance-based perceived competence (i.e., "I thought I performed well in the game." and "I was pretty skilled at playing the game.", $\alpha = .77$). Scores on the performance-based perceived competence subscale ranged from 2 to 10 points.

Procedure

Students participated in the experiment over six 50-minute sessions. Each session took place during students' regularly scheduled science classes. During the first session, students completed an online demographic survey and the physics understanding pretest. Then, students were introduced to the game and allowed to play for the remainder of the first session. Students played the game independently on laptops or desktop computers and wore headphones while playing the game. Students played the game for the entirety of sessions two through five. Students were monitored by members of the research team throughout each of the six sessions. During session six, students started by playing the

Figure 2. An example of two test items from the physics understanding test



game and then completed the online posttest and satisfaction survey. Once all items were completed, students received their gift cards from a member of the research team.

Research Design

This research—focusing on the impact of performance-based perceived competence—was part of a larger game-based learning study. The larger study used a between groups repeated measure design with four conditions: adaptive sequencing, linear sequencing, free choice, and a no-gameplay control. The only difference between the three gameplay conditions was how the game levels were presented. The results of the game-based learning study revealed a positive impact of gameplay with students in the three gameplay conditions scoring significantly higher on the posttest than they did on the pretest ($t(198) = 3.10$, $p < .01$) (Shute et al., 2020). In contrast, students in the no-gameplay control condition showed no significant difference in their scores from pretest to posttest ($t(63) = -0.04$, $p = .97$). Performance-based perceived competence was not measured for students in the control group, so their results are excluded from the current analysis. Among the three gameplay conditions, no differences were found in terms of physics learning, in-game performance, or enjoyment (Shute et al., 2020). Therefore, the authors collapsed the three groups into one gameplay group and did not differentiate between conditions in the analyses of performance-based perceived competence, gender, and ethnicity. For the current study, the authors analyzed students' pretest scores, posttest scores, questionnaire responses, and number of game levels solved collected in the game-based learning study using correlational analysis and analysis of variance (ANOVA).

RESULTS

Descriptive Data

The authors first examined students reported levels of performance-based perceived competence in relation to their physics learning, in-game performance, and enjoyment of the game. As previously mentioned, the authors used two items from the satisfaction questionnaire to measure performance-based perceived competence and five items to measure enjoyment. Students across all genders and ethnicities reported an average performance-based perceived competence of 7.60 out of 10 ($SD = 1.77$), solved an average of 45.86 game levels across all gameplay sessions, improved their conceptual physics understanding by an average of 0.63 points out of 18 ($SD = 2.89$), and reported an average enjoyment level of 18.32 out of 20 ($SD = 4.64$).

The authors then made further comparisons by gender and ethnicity (Table 1). When comparing male and female students, male students, on average, had higher perceptions of competence and solved more levels than female students. However, female students showed higher gains in learning than male students but had lower average pretest and posttest scores when compared to male students. In other words, female students appeared to learn more from playing the game but still did not score higher than their male counterparts. Both male and female students reported similar levels of enjoyment from playing the game.

Students were asked to select their ethnicity from a list and could check all that applied. There was also a space for students to write-in an ethnicity. The variety of response options meant a variety of ethnic backgrounds were identified in the sample, shrinking the size of each distinct self-identified ethnic group in the sample. Still, most of the students identified as White ($n = 81$), Hispanic ($n = 15$), Black/African American ($n = 62$), or Asian ($n = 8$). Among all ethnic groups, the Hispanic students reported having the highest average performance-based perceived competence and highest enjoyment. Asian students had the highest gain score from pretest to posttest and solved the most levels. The Black/African American students solved the fewest number of levels, reported the lowest performance-based perceived competence and enjoyment on average (Table 1). However, the mean and variance estimation for the Asian students may not be accurate because of the small sample

Table 1. Means and standard deviations for each variable across sub-groups

Group	n	Perceived Competence	Pretest	Posttest	Gain Score	Levels Solved	Enjoyment
White		7.76 (1.56)	12.52 (3.33)	13.22 (3.40)	0.70 (3.21)	48.90 (14.96)	18.50 (4.77)
Male	48	8.13 (1.48)	12.90 (3.20)	13.23 (3.85)	0.33 (3.35)	50.54 (15.44)	18.57 (4.66)
Female	33	7.24 (1.54)	11.97 (3.48)	13.21 (2.67)	1.24 (2.98)	46.52 (14.11)	18.39 (5.00)
Black		7.33 (1.91)	10.48 (3.73)	10.94 (4.17)	0.45 (2.87)	40.15 (16.83)	17.89 (4.48)
Male	28	7.79 (2.04)	12.04 (3.71)	12.00 (4.48)	-0.04 (2.36)	44.89 (19.43)	17.96 (4.13)
Female	34	6.94 (1.73)	9.21 (3.27)	10.06 (3.73)	0.85 (3.20)	36.24 (13.41)	17.82 (4.82)
Hispanic		8.20 (1.32)	12.13 (2.67)	12.33 (4.64)	0.20 (3.28)	47.60 (11.54)	19.53 (4.16)
Male	8	8.38 (1.41)	13.13 (2.53)	15.00 (2.73)	1.88 (3.14)	53.25 (6.43)	20.63 (3.85)
Female	7	8.00 (1.29)	11.00 (2.52)	9.29 (4.61)	-1.71 (2.36)	41.14 (13.08)	18.29 (4.42)
Asian		7.38 (2.33)	12.13 (4.02)	13.00 (3.55)	0.88 (1.81)	51.38 (26.88)	19.00 (2.83)
Male	3	8.67 (1.15)	15.67 (2.08)	15.67 (2.08)	0.00 (1.00)	56.67 (22.85)	20.00 (3.46)
Female	5	6.60 (2.61)	10.00 (3.32)	11.4 (3.36)	1.40 (2.07)	48.2 (31.14)	18.40 (2.61)
Total							
Male	87	8.06 (1.66)	12.74 (3.32)	13.08 (4.01)	0.34 (3.00)	49.18 (16.58)	18.62 (4.39)
Female	79	7.14 (1.68)	10.57 (3.50)	11.39 (3.69)	0.82 (3.05)	41.72 (15.69)	18.14 (4.69)

Note: Standard deviations are presented in parentheses.

sizes (Julious, 2005). Therefore, the authors removed the Asian group for the following inferential statistical analyses due to the lack of precision and power.

Correlations

Pearson correlations was computed for the variables of interest (Table 2). Performance-based perceived competence was significantly correlated with in-game performance ($r = .35$, $p < .001$) and enjoyment ($r = .36$, $p < .001$). Physics learning (i.e., gain score) was significantly correlated with in-game performance ($r = .21$, $p = .003$) and enjoyment ($r = .21$, $p = .003$). The results indicate performance-based perceived competence was a relevant factor to consider (Table 2).

Table 2. Means, standard deviations, and correlations with confidence intervals

Variable	*M*	*SD*	1	2	3
1. Perceived Competence	7.63	1.70			
2. Gain Score	0.56	3.07	.06 [-.10, .22]		
3. Levels Solved	45.34	15.92	.35*** [.20, .48]	.19* [.04, .34]	
4. Enjoyment	18.36	4.60	.37*** [.22, .50]	.23** [.08, .38]	.09 [-.07, .24]

Note. *p < .05. **p < .01. ***p < .001. Confidence intervals presented in brackets.

Intersection of Gender and Ethnicity

To further examine the impact of gender and ethnicity, a two-way ANOVA was used to test for differences between gender and ethnicity in the four outcome variables. Here the sample is further reduced, as only 160 students reported their gender as male or female and their ethnicity as White, Black/African American or Hispanic. The results of the multiple ANOVAs are provided in Table 3. The only significant difference found between ethnicity and gender was in gain score ($F(2, 154) = 3.83, p = .02$). No interaction was found between gender and ethnicity for performance-based perceived competence, performance, and enjoyment. Between males and females, however, a significant difference was found in performance-based perceived competence ($F(1, 154) = 8.91, p = .003$) and levels solved ($F(1,154) = 6.16, p = .01$) both favoring males over females. Among ethnic groups, a significant difference was found in levels solved ($F(2,154) = 6.57$, $p = .002$) favoring White and Hispanic students over Black/African American students.

Perceived Competence, Gender, and Ethnicity

Next, multiple linear regression was performed on each of the dependent measures respectively (i.e., gain score, levels solved, and enjoyment) on performance-based perceived competence, gender, and ethnicity (Table 4). To control for the impact of prior knowledge, pretest scores were included as one of the predictors in the models for levels solved and enjoyment. The only significant predictor for gain score was the Hispanic female ($p = .01$). However, this result should be interpreted with limited generalizability because of the small group sample ($n = 7$). Performance-based perceived competence was a significant predictor for both levels solved ($p = .001$) and enjoyment ($p < .001$). In addition, pretest performance predicted levels solved ($p < .001$).

DISCUSSION

The Relationship Between Perceived Competence and Students' Physics Learning, In-Game Performance, and Enjoyment

In this study, the authors examined performance-based perceived competence through gameplay in a physics learning game. Similar to previous literature (Hilts et al., 2018), performance-based

Table 3. Two-way ANOVA results using performance-based perceived competence, learning, game performance, and game enjoyment as dependent variables

Effect	*F* value	*df*	η^2
Perceived Competence			
Ethnicity	2.28	2	.02
Gender	8.91**	1	.05
Gain Score			
Ethnicity	0.32	2	.01
Gender	1.19	1	.01
Ethnicity × Gender	3.83*	2	.05
Levels Solved			
Ethnicity	6.57**	2	.06
Gender	6.16*	1	.03
Enjoyment			
Ethnicity	0.84	2	.01
Gender	0.32	1	.002

Note. *p < .05. **p < .01.

Table 4. Regression table

Variable	Estimate	*SE*	95% CI	*p*
Gain Score				
(Intercept)	-1.41	1.30	[-3.97, 1.15]	.28
Perceived Competence	0.18	.15	[-0.12, 0.47]	.24
Gender				
Female	0.97	.79	[-0.59, 2.53]	.22
Ethnicity				
Hispanic	1.81	1.22	[-0.60, 4.22]	.14
White	0.32	.73	[-1.12, 1.75]	.66
Gender × Ethnicity				
Hispanic female	-4.50*	1.75	[-7.96, -1.03]	.01
White female	0.17	1.03	[-1.87, 2.21]	.87
Levels Solved				
(Intercept)	7.89	6.30	[-4.56, 20.33]	.21
Perceived Competence	2.21**	.68	[0.87, 3.55]	.001
Gender				
Female	-1.25	2.29	[-5.77, 3.26]	.58
Ethnicity				
Hispanic	2.44	3.97	[-5.40, 10.28]	.54
White	4.29	2.39	[-0.42, 9.01]	.07
Pretest	1.63**	.33	[0.96, 2.29]	< .001
Enjoyment				
(Intercept)	10.25**	2.01	[6.28, 14.22]	< .001
Perceived Competence	0.98**	.22	[0.55, 1.41]	<. 001
Gender				
Female	0.39	.73	[-1.05, 1.83]	.59
Ethnicity				
Hispanic	0.79	1.27	[-1.71, 3.29]	.54
White	0.13	.76	[-1.37, 1.64]	.86
Pretest	0.02	.11	[-0.19, 0.23]	.83

Note. *p < .05. **p < .01

perceived competence was correlated with the number of levels solved (i.e., in-game performance) and the post-gameplay rating of enjoyment. However, performance-based perceived competence was not strongly correlated with learning gains. These results were as expected. The measure of perceived competence targeted perceptions of competence for playing the game, not competence related to the concepts measured in the pretest and posttest.

The weak correlation found between performance and enjoyment is similar to that shown in Trepte and Reincke (2011), which hypothesized and found evidence to support the mediating role between performance and enjoyment of students' beliefs about their abilities to succeed in a task. In other words, performance leads to enjoyment by the experience of increasing ones' perceptions of their own competence. By demonstrating the stronger correlations between perceived competence and both performance and enjoyment, there may be a similar mediational relationship.

If there is mediation by perceived competence between performance and enjoyment, with enjoyment being correlated to the overall gain score, then there may be a more intricate relationship between perceived competence of gameplay with learning and is built upon presently unobserved variables. Further studies are required that include more robust and varied measures of perceived competence along with, perhaps, the use of path analysis to begin further connecting the pieces.

Research Question 1 – What are the Effects of Gender, Ethnicity, and Perceived Competence on Physics Learning?

Although White students demonstrated higher learning gains than both Black and Hispanic students, the differences were not significant. Gender differences in gain scores for physics learning favored females for White students, African American/Black students, and Asian students. Only Hispanic females had lower gain scores than their male counterparts. The interaction found between gender and ethnicity was likely related to a large decrease between pretest and posttest for Hispanic female students. Little credence should be given to this finding due to the low sample size of Hispanic females. Not accounting for ethnicity, female students' average gain was more than twice the average gain of the male students.

In short, the authors found that playing the game seemed to narrow the gap in learning between both White and Black males and females. Looking at the average pretest and posttest scores for White male and female students, white females started at an average almost one full point below the White males but ended with just a .02-point difference. In other words, White female students had more ground to gain compared to White male students and they gained it. For Black males and females, the average difference on pretest scores was 2.83 and then just 2.06 on the posttest. Black females cut over three-fourths of a point off the difference in test scores between themselves and their male counterparts after gameplay. While this difference was expected, it might be tied to perceptions of competence, once gain scores were regressed onto perceived competence and controlled for both gender and ethnicity, no significant predictors of gain were found.

Again, the low correlation between perceived competence and gain score is likely due to the focus of competence being on the game rather than on physics concepts. While students may have felt skilled at playing the game, the pretest and posttest take place outside of the game. And, while the items on the paired assessments were situated in gameplay scenarios (i.e., screenshots or gameplay videos), the multiple-choice format aligns closer with traditional academic activities than a game.

Students' perceptions of the two assessments as exercises more related to the typical academic environment may be evoking another sense of competence (i.e., academic abilities). In this case, different factors may be influencing students' beliefs. For example, parents' "sense of academic efficacy" and the expectations they place on their children are related to children's perceptions of academic competence (Bandura et al., 1996). Learners' perceptions of academic competence may be a better indicator of performance on these more traditional assessments, like an external pretest and posttest. In other words, learners who felt competent in their ability to play the physics learning game may not have felt competent with their ability to take a physics test. As perceived competence is specific to domain or task, it's likely there needs to be more focus on other forms of competence—such as academic or physics competence—to better understand the influence on more traditional learning activities such as multiple-choice assessments.

Research Question 2– What are the Effects of Gender, Ethnicity, and Perceived Competence on In-Game Performance?

The relationship between perceived competence and in-game performance is the clearest among all dependent measures. Perceived competence was a significant predictor of in-game performance. This relationship is straightforward. As a player experiences continued success, the mastery experience enhances their perception of competence. Increased perceived competence feeds back into gameplay proficiency. And the process continues cyclically in a feed-forward system, establishing a resilient perception of competence in the individual. This relationship is commonly known as the "hot hand" effect in sport psychology (Bar-Eli et al., 2006; Raab et al., 2012). Players who believe themselves "in-the-zone" can potentially play even better than they normally would have played.

By only looking at the descriptive statistics, it appears that males had the "hotter hands" compared to females. The same was true for White students compared to Black/African American students. However, the differences in gender and ethnicity were insignificant once both perceived competence and pretest scores were controlled. This supports the idea that neither ethnicity nor gender truly influence one's ability to perform in learning games. However, it also illustrates that the differences often seen between males and females, as well as White and Black/African American students, may be a result of subjective beliefs about their capabilities.

Research Question 3– What are the Effects of Gender, Ethnicity, and Perceived Competence on Enjoyment?

Beyond the simple reward of having won a level, research has shown that perceptions of competence mediate the relationship between performance and enjoyment (Trepte & Reinecke, 2011). Similar results were found in that in-game performance was weakly correlated with enjoyment ($r = .09$, *ns)*, but strongly correlated with perceived competence ($r = .34$, $p < .001$). A player's enjoyment of a game may be influenced by different factors (i.e., mood, personal matters, game preference, etc.), and it appears that perceived competence is one of those factors. Enjoyment is an additional component in the cyclical relationship between perceived competence and performance discussed prior. An increase in students' perceived competence can increase performance feeding back into perceived competence and also increasing enjoyment, which then feeds back into performance and perceived competence.

Student enjoyment is an essential factor to consider when designing a learning game. A learning game must keep the fun, engaging, entertaining part of games at the forefront or the outcome is what has often been called "chocolate covered broccoli", something neither a vegetarian nor a chocoholic would want. Learning game design is an emerging field of educational research with much debate still circling over what design decisions lead to optimal learning outcomes. The results of this study add to this discussion. The inclusion of competence building within gameplay may be one key design element worth further investigation.

Implications

Well-designed learning games offer an opportunity to help eliminate barriers in STEM education. The core issue at stake is the scarcity of underrepresented populations in STEM fields. Based on the results, one possibility is that many are discouraged from pursuing STEM degrees based on subjective perceptions of their own competence. The goal then becomes how to provide support that helps underrepresented populations overcome the idea that there are limitations to their success in STEM based on their ethnicity or gender.

Cognitive supports that address knowledge acquisition are a common approach in game-based learning as they align with the goal of facilitating learning and skill development (Wouters & van Oostendorp, 2013). However, based on the results presented in this study, students may also need affective supports during both gameplay and learning. Such supports (e.g., situation modification, attention deployment, cognitive reappraisal, and response modulation, see Shute, Ke et al., 2019) can help learners with poor perception of their competence regulate their negative emotional states and, thus, learn from, perform better in, and enjoy the learning activity. For instance, when students are presented with a game challenge that requires precision and thus persistence, those with low perceived competence would demonstrate lower persistence compared to those with higher perceived competence. However, cognitive reappraisal strategies (e.g., encouraging frustrated students to see that challenge can be both rewarding and enjoyable) are more likely to cultivate persistence and hence improve learning (Strain & D'Mello, 2015; Yeager & Dweck, 2012).

Limitations and Future Work

One limitation in the current study was the measure of perceived competence. It was limited in both scope and focus. The game satisfaction questionnaire included 16 items, only two of which were targeted towards students' perceived competence. Including more items targeting perceived competence would offer a clearer picture of its influence. Given the changeable nature of self-beliefs, future work should gather data before, during, and after gameplay to observe multiple instances of perceived competence. Including before and after measures is important because of the feedforward aspect of perceived competence. Meaning, after completing the pretest, game levels, or the posttest, the student is receiving information that influences their sense of competence. More measurements would provide a clearer picture of how perceived competence changed and what the change is associated with.

The focus of the perceived competence measure should also expand beyond game performance. Thus, future work should measure perceived competence on a variety of facets. Including items that assess perceptions of academic competence generally, and physics competence (external from gameplay) specifically would produce more robust results.

This study also suffered from a small sample size once dividing students into ethnic groups. The authors were only able to compare White students, Black/African American students, and Hispanic students. In addition, the imbalanced distribution of Hispanic students potentially biased the estimation. Therefore, the findings (especially for the Hispanic group) may not generalize to a different context. With a larger or more purposeful sample, future work could compare a variety of ethnicities and gender. A broader examination could provide a more precise understanding of the influence of ethnicity and gender on physics learning and in-game performance.

Although significant differences within ethnic groups and gender groups were discovered, the regression analyses on the relationships among perceived competence, learning, and in-game performance revealed that these differences become less important once perceived competence and incoming knowledge are accounted for. The results highlight the important role of perceived competence in game-based learning and illuminate opportunities for removal of barriers in STEM education for underrepresented groups. After all, "self-belief does not necessarily ensure success, but self-disbelief assuredly spawns failure" (Bandura, 1997, p. 77). By purposely designing STEM learning games to enhance students' perceived competence, the doors to STEM may be opened to many students who once saw only barriers.

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Ginny Smith is an educator, designer, and researcher with a Ph.D. in Instructional Systems and Learning Technologies from Florida State University. Her research interests center around the design, development and evaluation of learning games and interactive learning experiences for STEM based competencies in both secondary and higher education. Before her doctorate, she developed and led the secondary math program at a nationally recognized charter school. She believes that math is power and desires to encourage learners to discover for themselves the wonder and excitement she has found in the STEM fields.

Curt Fulwider lives in Tallahassee and is a doctoral candidate in the Instructional Systems and Learning Technology program at Florida State University. His research interests are focused on competition within game-based learning and how it can affect various non-cognitive constructs such as self-efficacy and persistence.

Zhichun Liu is a postdoctoral fellow at Kaput Center for Research and Innovation in STEM Education, University of Massachusetts Dartmouth. Dr. Liu's current work aims at promoting the development and learning transfer of computational thinking among K-12 students and teachers. His research interests also include using quantitative analytics methods to understand learners' behavior, competence, discourse, and interactions.

Xi Lu graduated from Florida State University in 2021 with a Ph.D. in Instructional Systems and Learning Technologies. Her research interest focuses on designing and developing optimal learning supports to facilitate learning in digital interactive environments.

Val Shute is the Mack & Effie Campbell Tyner Endowed Professor in Education in the Department of Educational Psychology and Learning Systems at Florida State University. Her current research involves using games with stealth assessment to support learning—of cognitive and non-cognitive knowledge, skills, and dispositions. Her research has resulted in numerous grants, journal articles, books, chapters in edited books, a patent, and a couple of recent books (e.g., Shute & Ventura [2013], Measuring and supporting learning in games: Stealth assessment, the MIT Press; and Shute & Becker [Eds.] [2010], Innovative assessment for the 21st century: Supporting educational needs, Springer-Verlag).

Jiawei Li is a Ph.D. candidate in the Department of Instructional Systems and Learning Technologies, Florida State University.