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Examining the Impact of Online Math Games on Student Performance and Attitudes

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Low mathematics scores in the U.S. have been pressing educators to find engaging strategies and effective tools to promote math performance. While emerging technologies, such as digital math games, show promises in improving mathematical education, existing studies have garnered mixed findings and thereby necessitating further investigation. This study aims to examine the impact of skill-based online math games on students' math performance and attitudes, as well as students' perceptions of the games. Thirty-eight students ranging from fifth to eighth grade participated in the study. The results showed a mixed picture of the impact of the online games on math performance and attitude. Implications and recommendations for future research are also discussed.

Keywords: math games, math performance, learning engagement, math attitude, game-based learning

INTRODUCTION

Mathematics (math) scores have been reported low across the U.S. For example, the math scores on the National Assessment of Educational Progress (NAEP) have decreased for the past six years (Rebarber, 2020). Data from Trends in International Mathematics and Science Study (TIMSS) in 2015 displayed that there was only 10 percent of students in the U.S. who achieved the competency for mastering the foundation in math (Rebarber, 2020; "National Center for Education Statistics," n.d.), which also showed no improvement from the 2011 TIMS results (Carnoy & Rothstein, 2015). As of 2015, the U.S. students are ranked closer to the bottom group of countries than the top group in the mathematical competency (Rebarber, 2020).

Students often perceive math as a difficult and tedious subject, thereby causing disengagement and anxiety (Demirbilek & Tamer, 2010; Heyder, Weidinger, Cimpian, & Steinmayr, 2020; Leon, Nunez, & Liew, 2015). As student interest in math and STEM-related careers has waned, it has been challenging for educators to find motivating, engaging strategies and tools for math education (Chand, Chaudhary, Prasad, & Chand, 2021; Okita & Jamalian, 2011). With the increased accessibility of the internet, the use of digital technologies has been increasingly popular to keep students engaged in mathematical learning (Akugizibwe & Ahn, 2020; Crompton & Burke, 2015; Fabian, Topping, & Barron, 2018; Li & Ma, 2010). For example, college students using mobile devices over three months in a remedial math program were able to complete the program successfully and became eligible to take college-level math courses (Foshee, Elliott, & Atkinson, 2016). Many interactive mobile apps can provide repetitive exercises and drills that are used for low-achieving math students to promote learning retention (Outhwaite, Gilliford, & Pitchford, 2017). Technological tools such as online digital games can be designed and used as supplemental materials for classrooms (Callaghan, Long, van Es, Reich, & Rutherford, 2016). Digital games have interactivity characteristics that can potentially improve learning engagement (Abdul Jabbar & Felicia, 2015; Chang et al., 2016), enhance student performance (Masek, Boston, Lam, & Corcoran, 2017) and influence attitude towards learning math (Ke & Grabowski, 2007).

Despite the abovementioned evidence showing the potential of digital technology and games to support student learning of math, extant research has also presented controversial findings. For example, Ke (2008) did not find a significant effect on math achievement and metacognitive awareness when the use of games was integrated into a summer math program for 4th and 5th graders. Carr (2012) investigated the effects of iPads and game-based learning on fifth graders' math achievement. This study failed to find a significant difference in the pre-test and post-test scores of the experimental group that utilized digital technology. A meta-analysis found that among studies examining the effect of reading and mathematics software products, only a small number of rigorous studies existed that compared the conventional and technology-supported learning environments in a K-12 setting (Dynarski et al., 2007). Also, several studies discovered that integrating games into learning activities did not significantly change students' attitudes towards math (Çankaya & Karamete, 2009; Doğan & Sönmez, 2019; Vankúš, 2021). These inconclusive research findings call for additional empirical evidence demonstrating the impact of technology on student learning from various aspects.

REVIEW OF RESEARCH

Learning Engagement

Using digital games can potentially improve math learning engagement when the utilization is aligned with the instructional goal (Akman & Çakir, 2020; Fadda et al., 2022; Shelton & Scoresby, 2010). Games that include entertainment features can promote challenge, interest, play, and mastery to enhance engagement (Chang et al., 2016). While the benefits of digital games related to learning engagement are well documented, further investigations regarding game elements that lead to engagement still deserve more exploration (Masek et al., 2017; Pan, Ke, & Xu, 2022; Shin, Sutherland, Norris, & Soloway, 2012).

Games are an attractive mechanism to children (Bassiouni & Hackley, 2016; Marange & Adendorff, 2021) that teachers often consider incorporating as a means to increase students' desire to learn (Beserra, Nussbaim, & Oteo, 2019; Sampayo-Vargas, Cope, He, & Byrne, 2013; Schaaf, 2012; Usart, Romero, & Barbera`, 2013). Teachers believe that games can be an effective teaching and learning mechanism because they can often encourage time on task (Kebritchi, Hirumi, & Bai, 2010; Russo, Bragg, & Russo, 2021). Bragg (2012) has validated this belief by comparing fifth-grade students' behavior in game-playing and non-game-playing learning activities. Students conducting game-playing learning activities demonstrated a higher percentage of on-task behaviors than those who were conducting non-game-playing learning activities.

Increased Opportunities to Practice

Teachers incorporate games in math lessons because they can encourage students to practice more (Lim-Teo, 1991). Having opportunities to practice is crucial in yielding math competence (Kanive, Nelson, Burns, & Ysseldyke, 2014; Stacy, Cartwright, Arwood, Candield, & Kloos, 2017). The use of drill-and-practice math games that feature interactive elements such as graphics, animation, narration, and game mechanics can motivate students, provide them with immediate feedback, as well as serve as a function for teachers to monitor their learning progress (Beserra et al., 2019; Lim, Tang, & Kor, 2012; Kuiper & de Pater-Sneep, 2014). Unsurprisingly, a recent systematic review found that teachers frequently utilize math games as a practice tool to enhance in-class instruction (Pan et al., 2022).

Several studies have shown positive findings regarding the use of games to promote practice. Shin, Sutherland, Norris, and Soloway (2012) found that students who practiced arithmetic problems on a digital game outperformed those who used a paper-based game. Students who spent more time practicing with the digital game outperformed those who spent less time with it. By facilitating students to use a math game app installed on touch-screen tablets to practice math, Stacy, Cartwright, Arwood, Canfield, & Kloos (2017) discovered that (a) students enjoyed practicing, (b) playing math games on the app decreased math anxiety, (c) students perceived an increase in their math competence, and (d) it increased their standardized math scores.

Attitudes

Research literature has suggested that students may have a more positive attitude toward mathematics after using technology-based learning options (Barros, Varvalho, & Salgueiro, 2020; Bouzid, Kaddari, Darhmaoui, & Bouzid, 2021; Gao, Li, & Sun, 2020). Students learning arithmetic operations on polynomials reported that learning was more interesting when using a digital game and recommended a game integration in math classes (Barros et al., 2020). Riconscente, Peng, and Alhabash (2013) revealed that students liked learning fractions more after using a fraction-based video game available on iPads. Students also noted an increase in perceived math abilities after participating in technology-enhanced learning (Foshee et al., 2016). Stacy et al. (2017) found that students, who initially reported negative attitudes toward math, enjoyed practicing math using a math game app installed on a tablet. Studies also found that providing learner control promotes students' ability to regulate learning activities (Quintana, Shin, Norris & Soloway, 2006; Shin et al., 2012). In games, learner control enables an individualized learning environment where students can decide on the topics and difficulty level of the tasks according to their abilities, goals, and strategies (Kinzie & Joseph, 2008), which in turn prompts learners to have a positive attitude towards learning activities (Blumenfeld, Kempler & Krajcik, 2006; Bouzid et al., 2021; Kahveci & Imamoglu, 2007).

Challenges in Incorporating Games

The selection of the games should be aligned with the learning and curriculum objectives in order to be effective (Demirbilek & Tamer, 2010; Mayer, 2016). Therefore, the integration will only likely occur when teachers perceive the clear link between the learning goals within the games and the state or federally mandated standards (Norris, Shin, & Soloway, 2007; Shin et al., 2012). The use of gaming will also require teachers to find additional time to search and locate the appropriate games; teachers sometimes encounter issues finding a suitable game (Demirbilek & Tamer, 2010), and therefore, the integration is still rare (Rutherford, Long, & Farkas, 2014). In addition, incorporating digital games or any type of digital technology warrants caution because it can result in distraction and deviation from the original learning content as students may be tempted to browse irrelevant content on the internet during web-based lesson time (Demirbilek & Tamer, 2010; Nguyen & Kulm, 2005). Notably, teachers have to find strategies to allow enjoyment and ensure learning while integrating math games (Deng, Wu, Chen, & Peng, 2020)

PURPOSE OF THE STUDY

The primary goal of this study was to examine the impact of a skill-based online games website on students' mathematical learning and attitude. This study also aimed to investigate student perceptions of this website and their experience via open-ended questions and qualitative interviews. We hoypothsized that engagement in the skills-based online games would positively infludenced students's math performance and attitudes. Three quantitative research questions and one qualitative question guided this study:

1. To what extent did engagement in the skills-based online games as evidenced by numbers of questions practiced influence students' math performance?

2. To what extent did engagement in the skills-based online games as evidenced by practice scores earned influence students' math performance?
3. To what extent did engagement in the skills-based online games influence students' attitudes towards math?
4. How did students perceive the skills-based online games?

METHODS

Research Design

This research study was a mixed method study that included quantitative data gathered from standardized tests, skills-based online practice, attitude surveys, and qualitative data gathered from open-ended questions and interviews (Creswell & Guetterman, 2019). Quantitative data were evaluated to determine the impact of an online games website on standardized test scores and student attitude towards math. Qualitative data were examined to further understand students' perceptions of their learning experience.

Participants

The study included 38 students from Grade 5 to 8 attending a private elementary school. One-third of the students at this school had scored below the National Percentile Rank of 50% on the fall performance series test. The participants included in the study had a wide range in abilities from below grade level to above grade level. Participants in the study ranged in age from 10-13. The student population included the following: Caucasian, Hispanic, African American, and Asian. The study included nine fifth-graders, 13 sixth-graders, eight seventh-graders and eight eighth-graders consisting of 22 girls and 16 boys. Caucasian students totaled 75% of the school's population, 23% were Black, and 2% were Hispanic.

Materials

The website utilized in the study, *mathgames.com*, provided individual math skill practice for pre-kindergarten through 8th grade (see Figure 1). The math skills included on the website range from counting numbers to advanced algebra skills. Each practice session has the number of questions selected by the teacher (10 to 50 questions), providing additional practice of each skill for students. The teacher assigned practice sessions for individuals or entire classes. Students were assigned practice sessions based on information they had previously learned in class, offering a cumulative, sequential component. The website also provided immediate feedback for correct and incorrect responses. The skills-based website provided data that logged each student's practice activities, including the number of sessions completed and the percentage correct for the completed practice sessions (see Figure 2).

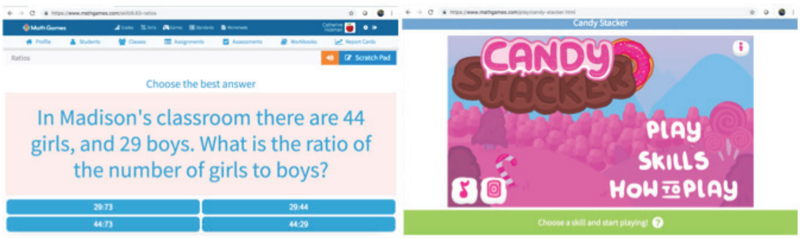
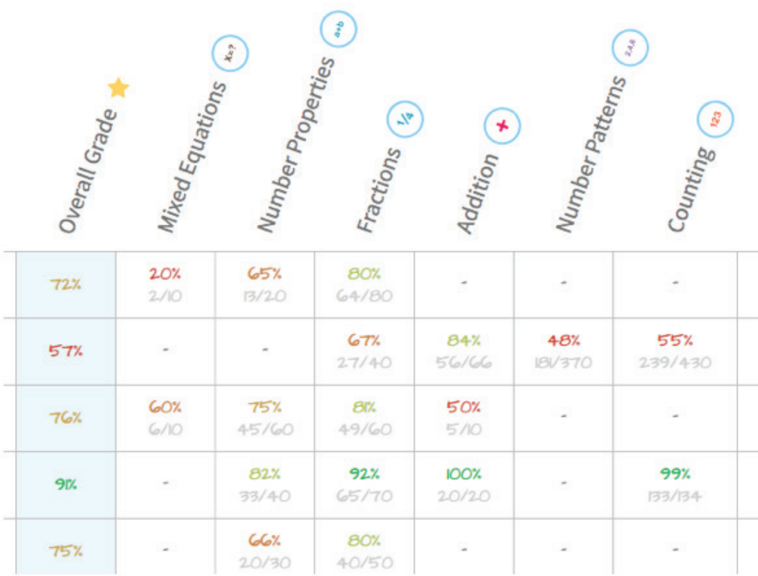


Figure 1. Mathgames.com Skill Practice Screen (left), Mathgames.com Game Screen (right).



Overall Grade	Mixed Equations	Number Properties	Fractions	Addition	Number Patterns	Counting
72%	20% 2/10	65% 13/20	80% 64/80	-	-	-
57%	-	-	67% 27/40	84% 56/66	48% 181/370	55% 239/430
76%	60% 6/10	75% 45/60	81% 49/60	50% 5/10	-	-
91%	-	82% 33/40	92% 65/70	100% 20/20	-	99% 133/134
75%	-	66% 20/30	80% 40/50	-	-	-

Figure 2. Mathgames.com Score Data page showing the percent correct on various skills.

Instrumentation

Engagement in online games. Students' engagement in mathgames.com consisted of mandatory class sessions and in-home voluntary practice. The website automatically recorded each user's engagement with the website by the number of questions practiced and practice scores earned based on the percentage of correct answers to the questions that students completed. A median split technique was applied to split the students into three groups based on their levels of practice: low, middle, and high. Students in the low group answered between 0 – 330 questions using the skills-based website; students in the medium group answered 331 – 750 questions; students in the highest group answered between 751 – 7914 questions. They were also split into three groups of similar size according to practice scores earned: (1) 13 students scored between 57%-79%, (2) 13 students who scored between 80%-89%, and (3) 12 students who scored between 90%-100%.

Students' math performance. Students' mathematical performance was measured using two indicators from their standardized test performance shown on their Performance Series Report (see Figure 3). All students in the school were required to take the Scantron Performance Series standardized test, which provided data concerning individual achievement over time. This test was administered three times a year (i.e., fall, winter, and spring) to gauge where a student stands amongst the pool of all students taking the test on multiple numerical measures. We selected these two types of data, which may have reflected students' performance from different perspectives: (a) changes in the scaled scores and (b) National Percentile Ranking (NPR) as measures for the mathematics performance variable. *Changes in the scaled scores* used the winter semester scaled score (prior to intervention) as baseline data and subtracted with the spring score, which was administered end-of-intervention spring semester score. The Scaled Score included a student ability rating based on the Rasch single-parameter computer adaptive model. It is a relative score representing how much improvement one student has made over the course of the intervention. *NPR* was a static score measured at the end of the intervention based on the individual's national percentile ranking, which compared the student with the national norm group based on the student's grade in school and his/her scaled score within the same grade level. This absolute score represents a student's math performance at the time, irrespective of where they stood prior to the intervention.

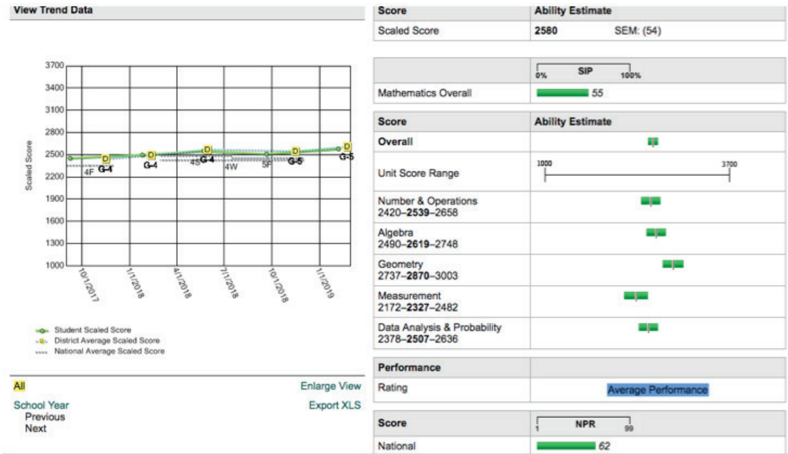


Figure 3. Performance Series Report (scaled score over time, SIP score, score by unit, & NPR).

Math attitudes survey. Students' attitudes toward math were measured by a 19-item Likert-scale attitude survey adopted from Yaşar (2014). The attitude survey consisted of four dimensions, respectively, a) enjoyment, b) anxiety and distress, c) use of mathematics in everyday life, and d) perceived mathematical achievement. Cronbach's alpha reliability coefficient for the overall scale was calculated as 0.956, according to Yaşar (2014). One change was made to question 3. "I enjoy fiddling with maths in my free times" was changed to "I enjoy exploring math in my free time" to match the reading level of the students. Student attitude towards math was compared to the number of questions answered on the skills-based online website and the score students received on the practice. The Cronbach's alpha reliability coefficient in the present study was calculated as .75 for the 19 items. Each sub-scale has higher reliability: enjoyment (α=.87), b) anxiety and distress (α=.75), c) use of Mathematics in everyday life (α=.72), and d) perceived mathematics achievement. (α=.70). Two additional open-ended questions were asked at the end of the attitude survey to prompt students' views on the design of the game and their overall learning experience.

Procedures

Students began the study with the winter Scantron Performance Series test. All scores were used to determine what impact the online games website had on these scores. The Changes in Scaled Score and NPR were compared to the three groups of students, low, medium, and high number of questions answered and the percentage of correct scores answered during the practice sessions. The participants in the study took the winter scantron performance series test at the beginning of February. Afterward, the test students were assigned practice sessions during the next 12 weeks. The spring test was given in May of the same year. Following the spring test, students were invited to complete an attitude survey questionnaire along with open-ended questions asking about their interest in the skills-based website and how the website could be improved via Qualtrics. Thirty-seven students completed the questionnaire. Nineteen out of 37 students also participated in a five-to-ten-minute interview where they were asked to share more details about their perceptions of their experience using the online games website.

Data Analysis

Prior to performing the independent ANOVAs, a test of normality and Levene's test of homogeneity of variances were conducted for all the tests. Assumptions were met across all tests.

Student engagement in the online games impacting test scores and math performance. An ANOVA test was performed to determine if the level of practice impacted students' changes in their scaled scores from the winter to the spring standardized test. An ANOVA test was run to determine the three levels of practice compared to each student's NPR for the spring test. The same two ANOVA tests were conducted using students' practice scores earned based on the percentage of correct answers to determine the three levels as a categorical variable.

Skills-based online practice and math attitude. An ANOVA test was performed to determine the relationship between a student's math attitude and their level of practice (low, medium, or high). This test was intended to determine if their level of practice in the online games impacted a student's attitude toward math. The negatively phrased items in the attitude survey were recoded to be consistent with the remaining items. An ANOVA test was also run to analyze a relationship between a student's attitude toward math and the mean practice score earned on the skills-based online website.

Student perception of the online games website. The three open-ended questions from the survey questionnaire provided ample information about students' interest level in the skills-based online games website and what improvements would make the website more appealing to them. The interview protocol included seven questions where students were asked to describe their experience with mathgames.com, features of the website that they liked or disliked, whether or not they felt they learned using the website, issues or challenges of using the skills-based software for math practice, and any improvements that they may suggest if they were to redesign the online games. Data from open-ended questions were analyzed in combination with transcribed interview data. We used open coding (Merriam, 2009; Patton, 2002) to analyze the qualitative data. One researcher was involved in the initial qualitative coding; an additional researcher served as a second coder verifying the initial codes. Consensus on the coding was reached through discussion.

RESULTS

RQ1: Impact of Online Games Engagement Evidenced by Numbers of Questions Practiced on Math Performance

Level of practice to changes in scaled score. A one-way ANOVA was performed on the changes in scaled score to determine whether students scored differently based on their level of practice (M_{lowest} = 62.69, SD = 68.89; M_{medium} = 26.85, SD = 94.15; $M_{highest}$ = 107.177, SD = 62.13). There was a significant difference in the changes in scaled scores among practice levels, $F(2, 35) = 2.621$, $p = .044$. Students with a medium level of practice in the online games website revealed the slimmest changes in their scale score.

Level of practice to NPR. A one-way ANOVA was also performed on the NPR to determine whether students scored differently across the three practice levels (M_{lowest} = 50.08, SD = 21.20, M_{medium} = 77.15, SD = 22.17, $M_{highest}$ = 72.08, SD = 15.99). There was a significant difference on NPR among practice levels, $F(2, 35) = 5.9$, $p = .003$. The middle and high groups mean NPR scores were within 5 points of each other. Generally speaking, students in the middle and high groups had higher NPR scores compared to the lowest group.

RQ2: Impact of Online Games Engagement Evidenced by Practice Score Earned on Math Performance

Percent correct on practice to changes in scaled score. A one-way ANOVA was performed on the changes in scaled score to determine whether students scored differently based on the levels of correct answers (M_{lowest} = 49.85, *SD* = 85.78, M_{medium} = 84.15, *SD* = 69.95, $M_{highest}$ = 59.00, *SD* = 90.91). There was no significant difference in the scaled score among levels of correct answers $F(2, 35) = .601$, $p = .554$. However, it is worth noting that students with a medium level of practice scored the highest based on NPR.

Percent correct on practice to NPR. A one-way ANOVA was performed on the NPR to determine whether students scored differently based on the levels of correct answers (M_{lowest} = 54.08, *SD* = 23.67, M_{medium} = 64.46, *SD* = 18.63; $M_{highest}$ = 81.50, *SD* = 17.31). There was a significant difference on the NPR among score levels, $F(2, 35) = 5.871$, $p = .006$. This test shows that students who earned more correct answers on the online games websites were likely to score higher in NPR.

RQ3: Engagement in Online Games and Math Attitude

Table 1 presents the descriptive statistics showing the means and standard deviations of student ratings of the 19 items in the math attitude survey. Overall, students in this class perceived math favorably.

Table 1
Attitude Survey Questions Results

	Question	Mean	SD
Enjoyment			
1	I enjoy solving math problems whenever I see them.	2.84	1.10
2	I feel happy when dealing with mathematics.	2.95	1.11
3	I enjoy exploring math in my free time.	3.89	0.87
4	I like math topics so much that I've started thinking about everything mathematically.	3.84	1.24
5	I like to practice math.	3.00	1.23
6	I think math courses are very enjoyable and fun.	2.54	1.15
Fear, Anxiety, and Distress			
7	I'm so bored in math class.	4.00	0.94
8	I think math is a very boring class.	4.32	0.96
9	I study math only to pass the course.	3.46	1.39
10	Math is the course I fear most.	4.08	1.30
11	I am annoyed by the fact that math is a course consisting of symbols and formulas.	3.95	1.29

	Question	Mean	SD
The use of Mathematics in everyday life			
12	I believe that the knowledge I get in math class will be useful in life.	2.08	1.24
13	I believe what I learn in math will work for me.	2.03	1.07
14	I think I will need math in my work life in the future.	1.81	0.94
15	I think that math has an important place in my daily life.	2.47	1.26
Perceived Mathematics Achievement			
16	My friends think that I am successful at math.	2.67	1.18
17	I see myself as a successful student in math.	2.30	1.14
18	I am not a model student in math.	3.69	1.17
19	I think I am a good student in math.	2.35	1.17

Note. 1= Always, 2= Most of the time, 3= About half of the time, 4= Sometimes, 5=Never

Level of practice to attitude toward math. A one-way ANOVA was performed to determine whether students scored differently on the attitude survey based on level of practice (M_{lowest} = 48.08, *SD* = 14.69, M_{medium} = 48.15, *SD* = 12.57, $M_{highest}$ = 43.83, *SD* = 11.74). There was not a significant difference on the math attitude among levels of practice, $F(2, 35) = .44$, $p = .65$. In this study, the number of questions completed on the skills-based online website did not significantly impact student attitude toward math. A student who completed high number of practice sessions did not always have the best math attitude.

Percent correct on practice to attitude toward math. An ANOVA test was run to determine whether students scored differently on the attitude survey based on level of correct answers earned on their practice (M_{lowest} = 54.75, *SD* = 12.50, M_{medium} = 45.62, *SD* = 12.61, $M_{highest}$ = 39.91, *SD* = 12.83). There was a significant difference in the math attitude among levels of practice $F(2, 35) = 4.98$, $p = .0.01$. However, this test showed an opposite relationship between their math scores earned from the online practice and their math attitude. Students who scored highest on their practice sessions did not have a better attitude toward math.

RQ4. Student Perceptions

The qualitative data has been coded into three overall categories showing their perceptions of their experience with the mathgames.com skill-based practice activities. The benefits and helpful means category focused on what students liked about the website or how the website helped them. The dislikes, challenges, or drawbacks were components of the website that were not helpful to students. The recommendations section gathered information concerning student-suggested improvements to the website.

Benefits and means that help students. According to the open-ended questions and interview data, a vast majority of students (31 students from surveys and 17 from interviews) held a positive view of the online math games. Students reported several benefits, suggesting that the website was helpful to students. Eleven students described the experience as "fun" and "enjoyable." They enjoyed the site because it offered a voluminous amount of practices across various difficulty levels. As one student commented, "I learned a lot from the practices on math games, and it was a lot of fun playing in the sessions. On some of them, I didn't understand what to do, but when I looked closer, I understood what to do. I enjoyed playing and doing practice; it was a good way to learn." The brevity of the practice sessions (10 questions at a time) was a positive attribute for many students. Student 5 says, "I like that there are a good amount of questions, it's not too little that you could do in 5 minutes, and it's not too much that it overwhelms you." Students also liked the characters on the website. "I like how the characters are cute and friendly, and I like how it is not put into a real scenario," Student 3 related. Student 14 commented, "I liked the characters because they made me feel better when I got a question right." Many students said that the website helped them learn math concepts because the practice in the game helped to reinforce what they had already learned in class. For example, Student 3 stated, "Yes, I do think it was helpful if I was struggling with a skill, it really helped me learn that skill more, progress in skill." Student 2 replied, "I think it's more practice, it won't teach you a lesson. I [It] will get you better at it."

Dislikes, challenges, or drawbacks. Overall, several students wished that the online games could provide more elaborate feedback highlighting why they got a problem wrong, as well as contain a greater variety of questions. Nine students commented that the practice was boring at times. Over one-third of students (*N* = 15) expressed frustration of not being able to see the correct answer or know how to work the problem correctly. Student 6 commented, "I kind of want to see what I did wrong. It just tells you what it is wrong and does not tell you why it is wrong." Another student commented, "I wish the practice sessions would have little lessons on what you did wrong. Sometimes I would get something wrong, but I would not understand exactly what." Some students found that the game was too sensitive.

"It doesn't let you say submit. If you click on something by accident, it just goes as your answer," said Student 11. Some students also preferred to be presented with a wide variety of questions focusing on various skills instead of repeatedly being presented with one type of question. Other students preferred to have more learner control on the website. As Student 7 commented, "So the questions are kind of easy, and sometimes they are hard. For the questions, […] there might be like a skip button and there is no help. […] there should be something that will let you skip that question and move on to like an easier question."

Recommended changes. Students made several recommendations for changes to the website. Students were interested in a pause between questions. Student 7 commented, "If I were making a game I would give a pause so you could actually see what is going on in the game so you could pay attention to the game too. So, a small pause so you can actually think about it." Students also expressed that they would like to see more gaming elements on the website, such as an avatar, more role-play, use of advanced animation, use of currency, use of a storyline, and more customization options. As Student 8 said, "I would give you points, and I would give you your own character, and how many points you get from doing it correct you could use your points to change your avatar." Student 5 stated, "Mathgames.com doesn't have a lot of games on it. It has 16, and most of the games are straightforward, without a storyline." Student 12 commented, "I liked the games where there were armies and stuff and castle games. I didn't like that there weren't enough characters." Many students suggested a help button, hints, or instructional videos that can offer more assistance. "Maybe put hints so that students can learn more," commented Student 14. When asked about technical issues or challenges, Student 11 suggested, "Just the submit button."

DISCUSSION

The data showed a multifaceted relationship between student engagement in online games and their performance determined by performance tests. It is apparent that in the study, student engagement in the online games did not directly lead to an increase in their math performance. When using the *changes in scale score* as a dependent variable which accounted for students' individual prior knowledge, the data shows that students that practiced the most volume according to their level of practice did not necessarily have a higher score in changes in scale score (M_{lowest} = 62.69, M_{medium}

= 26.85, $M_{highest}$ = 107.18). Likewise, students who practiced more questions correctly in the games did not necessarily progress more (M_{lowest} = 50.08, M_{medium} = 77.15, $M_{highest}$ = 72.08). When using NPR, a more objective indicator of students' math performance level as a dependent variable, it is suggested that students' *quantity* of practice as evidenced by the numbers of questions practiced did not positively relate to NPR (M_{lowest} = 49.85, M_{medium} = 84.15, $M_{highest}$ = 59.00, p = .55), but the *quality* of practice represented by practice scores earned may have correlated with a better score in NPR (M_{lowest} = 54.08, M_{medium} = 64.46, $M_{highest}$ = 81.50, p = .006). In examining the medium group per *quantity* of practice, we speculated that the medium group who scored very low (M_{medium} = 26.85) in the changes in scale score might have included a number of high achievers whose math skills were at a higher starting point and became bored with the practice. They might have included part of the same group who scored highest in terms of NPR (M_{medium} = 77.15). Likewise, there might also have been students who repeatedly practiced on the same skills in the online games website because they were fun, but they were not necessarily advancing their math skills. In examining the medium group per *quality* of practice, the medium group obtained a large change in scale score, which represented a considerable improvement when accounting for their baseline level (M_{medium} = 84.15). Only when using NPR as a dependent variable, the relationship between the quality of engagement and performance is simultaneously positive and significant.

Meanwhile, these results reveal a complex picture of the potential relationship between students' online games engagement and their math performance. First and foremost, it is clear that a high engagement level in online math games cannot be equated to higher performance in standardized tests. There must have existed groups of students who practiced more for enjoyment rather than learning, as well as students who practiced less merely because they were not attracted to games or had already mastered the assigned skill level. While engagement is one of the benefits offered by the use of digital games, the type of engagement that can more significantly influence mathematical learning is engagement associated with learning motivation (Abdul Jabbar & Felicia, 2015; Denham, 2019; Middleton & Spanias, 1999). Therefore, it requires a more fine-grained look at the performance data in mathgames.com to further separate those groups and identify the subtle relationships amongst them. These results further point to the pivotal role of instructional guidance that can ensure the relevance of games and clarify the learning goals of gaming incorporation (Callaghan et al., 2014; Es-Sajjade & Paas, 2020; Denham, 2015; Mayer, 2016).

Additionally, the assessment measures chosen might have impacted the results. The scaled score was a personal individual score based on each student's previous test and their improvement on the next test. The performance series started students where they left off at the last test and increased the level of ability as long as students got the answers correct. They could have been tested on topics they had never seen before or never practiced in the games. The NPR was based on a student's level using their scaled score, their grade, and the average pool of students in that same grouping. The difference in the type of assessment data might have explained the two different results.

The data in this study did not show a significant relationship between skills-based online practice and attitude towards math, contradicting previous studies that showed a positive change in student attitude towards math (Bouzid et al., 2021; Fabian et al., 2018; Divjak & Tomiğ 2011; Howard & Crotty, 2017; Shin et al., 2012). Findings in this study suggested that students who scored the highest on the practice sessions and who completed the greatest number of questions were not necessarily those with the highest math attitude as one might expect. This finding is similar to previous studies, which also revealed that playing educational computer games did not significantly change students' attitudes towards math (Çankaya & Karamete, 2009; Doğan & Sönmez, 2019; Vankúš, 2021). Again, students may practice continually for the sake of fun rather than learning. Besides, a person's attitude towards math is not likely to change after a short-term intervention as used in this study (Çankaya & Karamete, 2009).

The qualitative data suggested that students had a positive learning experience using mathgames.com. This result concurs with extant literature, suggesting that students tend to favor game-based and game-like components integration into traditional math learning (Beserra et al., 2019; Chen et al., 2012; Ediger & Rao, 2000; Marange & Adendorff, 2021; Reimer & Moyer, 2005; Shin et al., 2012). Students perceived gaming techniques as fun and enjoyable (Bragg, 2012). Additionally, they wished to see the practice games integrate more game-like features, including storylines, characters, rewards, challenges, and more (Abdul Jabbar & Felicia, 2015; Barros et al., 2020). They also demanded the necessity for the game to show them how to solve the problem if their answers were wrong. Providing explanatory and constructive feedback was invaluable to students, which is not always in place for traditional games. The importance of including appropriate feedback is aligned with prior literature (Killi, 2005; Ke, 2013; Mayer, 2016; Vanbecelaere et al., 2020; Tan, Goh, Ang, & Huan, 2013).

IMPLICATIONS FOR PRACTITIONERS

Although online practice games hold potential to enhance students' learning engagement and performance, the incorporation is not always seamless. Teachers need to ensure the alignment between the game content and learning objectives that will ultimately assist teachers in providing relevant math practices to students, thus promoting students' math mastery (Demirbilek & Tamer, 2010). Also, teachers may want to balance promoting enjoyment and enhancing learning when integrating math games (Deng et al., 2020). At the same time, teachers should be aware that searching and locating the appropriate games, as well as ensuring the alignment between the learning objectives and game content, require extensive time and effort (Callaghan et al., 2018; Demirbilek & Tamer, 2010). Arguably, it was often a challenge for math teachers to locate an online resource with a sufficient blend of content, engagement, and affordability.

When evaluating the success of a technological platform or application to improve student learning, teachers should be reminded that other factors may have contributed to the success of the students who completed more questions (Li & Ma, 2010; Shin et al., 2012). Some additional components that may have impacted results were: students who studied more during the second semester, students who completed all of their homework assignments during the in-class session, and the impact of parents on a student's efforts, among others. Finding an assessment instrument that accurately reflects student performance and removing possible confounding variables would be a goal for any evaluation efforts aiming to objectively measure the impact of an educational technology program or initiative.

Students in this study shared their views of what was considered an engaging educational game. The level of engagement needed to keep students practicing differed for each student, but most were looking for a practice with fun components that encouraged them with rewards. Mathgames.com was a reasonable choice given that it offered practice for most math skills from Kindergarten through 8^{th} grade with minimal cost. The website did not provide help screens or video lessons when students did not understand the problems; this was desired by students. Students also wanted to be recognized for their accomplishments, and this website kept a running total of their percentage scores. Students recommended providing an avatar they could name, configure, and provide with customization. Future practitioners may consider these features when choosing a skills-based online games website.

LIMITATIONS AND RECOMMENDATIONS

Several limitations were encountered in this study. The limited sample size ($N = 38$) may have impacted the results. The sample was drawn from a private, religious school in the U.S.; therefore, the results may not be generalized to a different population. Future studies using a larger, and more diverse sample group may yield different results. While the Scantron Performance Series testing was a handy test to use as a performance test, it was not necessarily aligned with student learning from the practice games. An alternative testing indicator that directly assesses student learning of the targeted math skills learned over the intervention period other than the Scantron Performance Series test would allow the researchers to reach a more definitive result judging the impact of the skills-based online website. Additionally, in this study, students had the flexibility to control how much they would like to practice on the online games website. The medium split technique provided levels for determining data, but a different result could have been discovered if the amount of gaming practice as a variable had been held constant. Conducting an experimental design using a control group versus a treatment group would help eliminate some of these confounding variables and come to a more definitive result of the impact. The attitude survey could have been given before and after the intervention to measure changes in students' attitudes. Lastly, a more in-depth qualitative study interviewing teachers, students, and parents could also bring more insights into the role of online practice games from different stakeholders.

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