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Uncovering Gender and Problem Difficulty Effects in Learning with an Educational Game

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Abstract: A prior study showed that middle school students who used the educational game *Decimal Point* achieved significantly higher gain scores on immediate and delayed posttests of decimal understanding than students who learned with a more conventional computer-based learning tool. This paper reports on new analyses of the data from that study, providing new insights into the benefits of the game. First, females benefited more than males from the game. Second, students in the game condition performed better on the more difficult intervention problems. This paper presents these new analyses and discusses why the educational game might have led to these results.

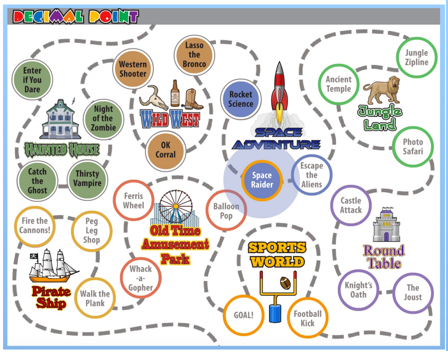
Keywords: educational games, mathematics learning, educational data mining

1 Introduction

Research is still needed to determine the conditions under which game-based learning can be effective [1]. A meta-review of over 1000 educational game studies advises that more *value-added studies* of educational games be conducted, that is, research that carefully identifies the features and conditions that lead to the successes and failures of educational games [2]. This paper is a step in this direction. Using a successful educational game, *Decimal Point*, we investigate under what conditions learning occurs. In a prior study *Decimal Point* was shown to lead to more learning and was more enjoyable to students than a more conventional computer-based learning tool [3]. In this paper, we report on new analyses that shed light on who benefitted from the game and under what conditions.

Decimal Point (Figure 1) is a single-player game based on an amusement park metaphor, targeted at middle-school students learning decimals. Students play a series of *mini-games* in different theme areas that are targeted at decimal misconceptions. There is no scoring and no leader board; students simply make their way through the park and are congratulated upon finishing.

The "Space Raider" mini-game of Figure 2 is targeted at the common misconception in which students think longer decimals are larger than shorter decimals (e.g., 0.634 > 0.82). The student tries to shoot the alien ships in the requested order (i.e., smallest to largest). If they make mistakes, they are prompted to correct their solution by dragging and dropping the decimals to the correct sequence. The various mini-games challenge students with other types of decimal problems, as well, including placing a point on a number line and adding decimals. After playing a mini-game and correctly solving the problem, the student is prompted to explain his or her solution [4], by choosing possible self-explanations from a multiple-choice list.



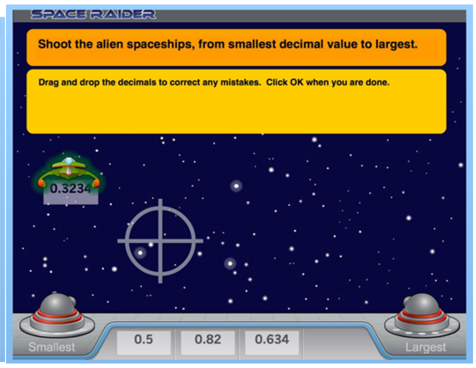


Figure 1: Map of the *Decimal Point* Game **Figure 2:** The "Space Raider" mini-game

As a comparison to the game, a more conventional, non-game version of the decimal instructional materials uses a more standard user interface, prompting students to solve decimal problems. As with the mini-games, after solving a problem the student is prompted to explain his or her solution in the same way that the mini-games prompt students for self-explanation.

A classroom study of *Decimal Point* is presented in [3]. The study involved more than 150 sixth grade students at two schools, comparing students who played the *Decimal Point* game to learn decimals with students who learned decimals with the more conventional computer-based learning tool. The same 48 decimal problems were presented to students in the same order across the conditions, except that students in the game condition solved problems using the mini-games, while students in the non-game condition solved the problems using the conventional instructional software. Students in both conditions took a pretest, posttest, and delayed posttest (comprising 61 items). A survey, completed after the intervention, had 11 5-point Likert scale questions ("Strongly agree" (1) to "Strongly disagree" (5)) related to the categories of Lesson Enjoyment, Ease of Interface, and Feelings of Math Efficacy. Summary of the results [3]: students in the game condition learned significantly more and had significantly more positive feelings about their experience. Also, low prior knowledge learners benefited significantly more from the game.

2 Exploring Gender and Problem Difficulty Effects

In this work, we raised new research questions and conducted new analyses of the data from our prior study. ***RQ1***: *Is the learning benefit of playing the Decimal Point* game more, less, or the same for female students as for male students? ***RQ2***: *Did the Decimal Point game lead to students performing better, and potentially learning more, from the more difficult problems in the intervention?* We wondered whether females, in particular, might benefit from the game. One could argue that games are more likely to benefit males who more frequently identify themselves as gamers and are more frequent game players [5]. Yet, there is evidence that gender does not play a role, especially when games rely on fostering intrinsic motivation [6]. It is also important to understand how games facilitate learning of more complicated materials. As the difficulty level grows, engagement with the materials might drop. Thus, engagement might be more important for difficult problems. Games could help by providing a more engaging way to grapple with difficult problems.

157 students participated in the study with the gender distribution as follows:

Game (70) – 39 females, 31 males; *Non-Game* (87) – 49 females, 38 males.

To address ***RQ1*** we conducted a regression analysis to predict the relationship between the intervention and learning outcomes for female vs. male students. The results of the main effect in the regression model confirmed the prior learning results cited above. The results for immediate and delayed posttests by gender are summarized in Figure 3 (a) and (b). In terms of both immediate posttest and delayed posttest, there is a significant interaction effect of game condition with gender.

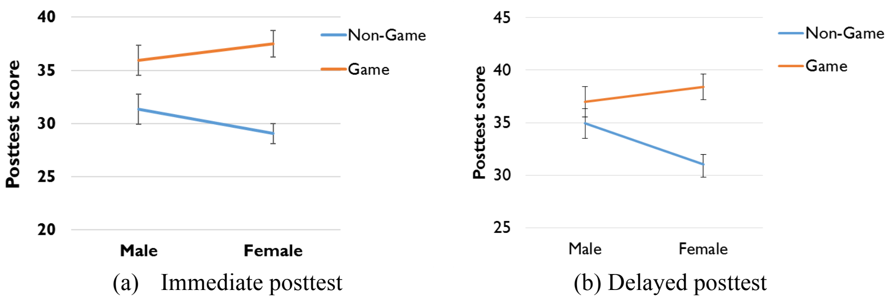


Figure 3: Interaction effect of game with gender on learning outcomes

Even though both male and female students performed significantly better under the game condition on the immediate posttest, the effect size for the female students is higher (d = .59 vs. d = .39). For the delayed posttest, while male students did not perform differently with or without game, female students performed significantly better under the game condition (d = .71).

To address ***RQ2***, we first conducted a subjective evaluation with 3 middle school math teachers of problem difficulty. The teachers rated the 48 intervention problems on a 5-point Likert scale: 1 - "Very Easy"; 5 - "Very Difficult". Using this data, we judged a problem as difficult if the average rating of the 3 teachers was above 3, and easy if the average rating was less than or equal 3. 27 of the problems were judged as easy, 21 as difficult. To then assess the impact of the game on difficult vs. easy problems, we conducted a regression analysis of the relationship between the intervention conditions on the number of errors students made on each problem.

There is a significant interaction of the game condition and the difficulty level of the problem on the number of errors students make at the problem level. The interaction effect is presented in Figure 4. For the easy problems, the game does not influence the number of errors the students make; however, for difficult problems, the game leads to students making significantly fewer errors (*d* = .09).

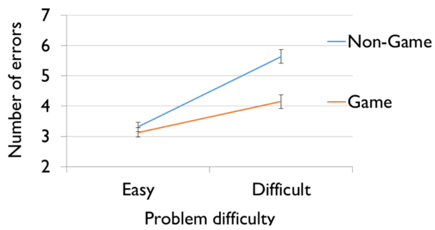


Figure 4: Interaction of difficulty level of problem with number of errors on each problem

Our new data analyses answered our two new research questions. First, females benefited more from the game than males. This result may be related to the fact that game achievement is not a focus of *Decimal Point*. Prior research suggests that male players can be particularly attracted to games of achievement, while achievement does not appear to be a key factor in engaging female players [7]. Second, the game appears to have made difficult problems more tractable, as the game group made significantly fewer errors on the difficult problems in the intervention than the non-game group. Better performance on the difficult problems may be a result of students' higher level of engagement with the game. Games may be a way to engage students in continuing to higher levels of mastery, even in the face of difficult problems.

3 References

1. Mayer, R. E.: *Computer games for learning: An evidence-based approach.* Cambridge, MA: MIT Press. (2014)
2. Clark, D.B., Tanner-Smith, E.E., & Killingsworth, S.S.: Digital games, design, and learning: A systematic review and meta-analysis. *Rev of Ed.Res. 86*(1), pp. 79–122 (2016)
3. McLaren, B. M., Adams, D. M., Mayer, R. E., & Forlizzi, J.: A computer-based game that promotes mathematics learning more than a conventional approach. *International Journal of Game-Based Learning (IJGBL), 7*(1), 36-56. doi:10.4018/IJGBL.2017010103 (2017)
4. Chi, M.T.H.: Self-explaining expository texts: The dual processes of generating inferences and repairing mental models. In R. Glaser (Ed.), *Advances in instructional psychology* (pp. 161-238). Mahwah, NJ: Lawrence Erlbaum Associates, Inc. (2000)
5. Lenhart, A., Smith, A., Anderson, M., Duggan, M., & Perrin, A.: Teens, Technology and Friendships. Pew Research Center. (2015)
6. Habgood, M.P.J., & Ainsworth, S.: Motivating children to learn effectively: Exploring the value of intrinsic integration in educational games. *J. Learning Sci, 20*/2, 169-206. (2011)
7. Inkpen, K.: Three important research agendas for educational multimedia: Learning, children, and gender. In *AACE World Conference on Educational Multimedia and Hypermedia* (Vol. 97, pp. 521-526). (1997)