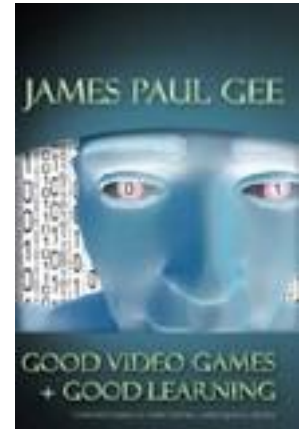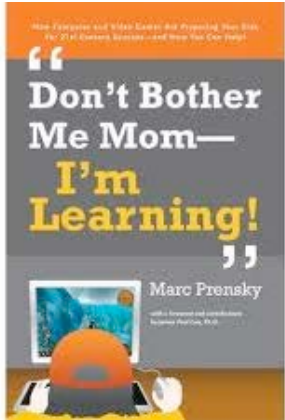# Decimal Point: An Educational Game for Learning Mathematics

Dr. J. Elizabeth Richey
Dr. Bruce M. McLaren
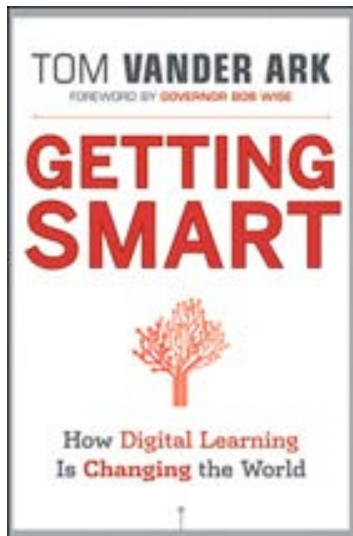**Carnegie Mellon University**

November 13, 2019

Educational Games – The Hype

- Games teach 21st-century skills (Prensky, 2006)

- Good games create deep learning, learning that is better than what we often see in schools (Gee, 2007)

- Learning Games ... are ready for implementation across the land .... (Vander Ark, 2012)

- Game-based learning has the opportunity to really challenge our assumptions about linear modes of educational interaction. (EdSurge, Lorenzo, 2016)

Educational Games – The Scientific Reality

"… there is considerably more enthusiasm for describing the affordance of games and their motivating properties than for conducting research to demonstrate that these affordances are used to attain instructional aims…"

Tobias & Fletcher, 2011

"All of the studies that have been published in reputable journals have reached a negative conclusion about learning from games."
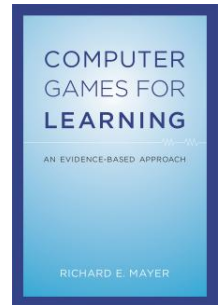
Clark, Yates, Early, & Moulton, 2011, p. 269

"Methodological rigor needs to be increased in research on games for learning."

Clark, Tanner-Smith, & Killingsworth, 2016, p. 35

Educational Games – The Scientific Reality

Mayer, R. E. (2014). *Computer games for learning: An evidence-based approach.* Cambridge, MA: MIT Press.

- Relatively few rigorous studies in each genre; Very small number of rigorous *Media Comparison studies* (32), with varying effect sizes across content areas

Table 7.1
Research using the media comparison approach by content area

Type	Number	Effect size
Content area		
Science	12 out of 16	0.69
Second-language learning	4 out of 5	0.96
Math	3 out of 5	0.03
Language arts	3 out of 3	0.32
Social studies	2 out of 3	0.62

"Promising"

"Unpromising"

"Not-yet Promising"

Educational Games – The Scientific Reality

- ## In summary …

  - There are many, many publications about the benefits of games that are based either on (a) hype or (b) flawed and/or non-rigorous study designs

  - On the one hand, there *have* been rigorous studies that have shown the learning benefits of games over more conventional instructional approaches

  - On the other hand, there have been a *limited* number of such rigorous studies

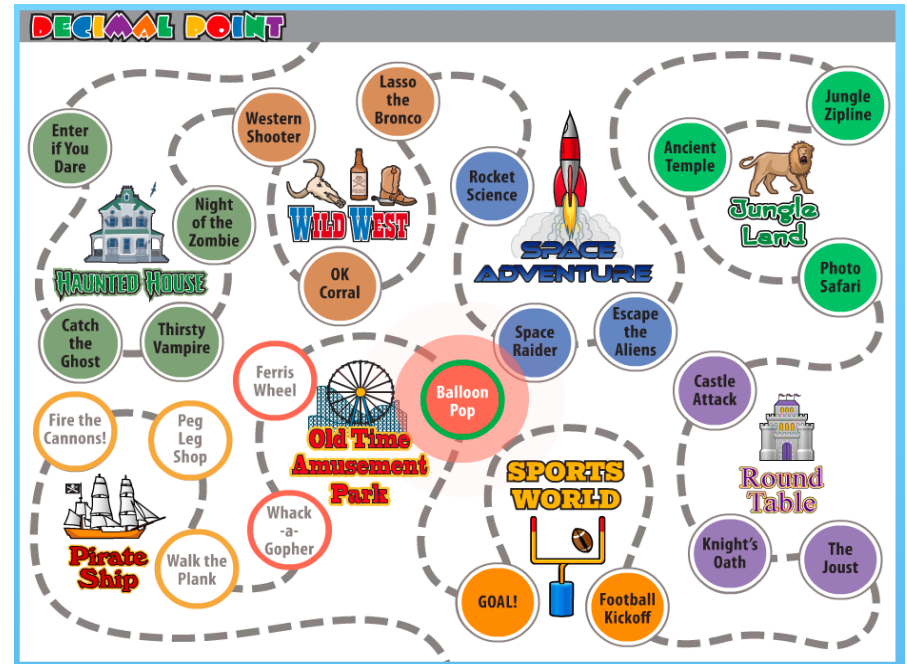 - Evidence of learning mathematics with games has been particularly lacking

Decimal Point – McLaren, Mayer, Forlizzi, Adams

- *Students Learn –*
  - ➢ Decimal place value
  - ➢ Comparing decimal magnitude
  - ➢ Ordering decimals
  - ➢ Placing decimals on a number line
  - ➢ Adding decimals

- *Students Play –*
  - ➢ A series of amusement park "mini-games"
  - ➢ The next game in sequence
  - ➢ With fantasy characters

Decimal Point – McLaren, Mayer, Forlizzi, Adams

- 5th and 6th grade students

- Single player

- No points or competition

- No "levels"

A relatively simple, straightforward game

Decimal Point Media Comparison Study

- McLaren, B. M., Adams, D. M., Mayer, R. E., & Forlizzi, J. (2017). A Computer-based Game that Promotes Mathematics Learning More than a Conventional Approach. *International Journal of Game-Based Learning (IJGBL), 7*(1), 36-56.

- Participants (153 students, 11 classes, across two schools)
  - Game: n=70
  - Non-Game: n=83

- Students assigned to condition by class (but classes randomly assigned)

- Pre, Post, Delayed Test: Three isomorphic, 61-point tests
  - Items designed to probe for specific decimal misconceptions, e.g.,
    - Choosing the largest of a given set of decimals (e.g., "Choose the largest of the following three numbers: 5.413, 5.75, 5.6")
    - Placing a given decimal number on a number line
    - Answering conceptual questions (e.g., "Is 786 / 987 less than zero, zero, or greater than zero?")
    - Completing decimal sequences (e.g., "Write down the next item in the following sequence: 0.201, 0.401, 0.601, 0.801", _____)

Decimal Point Media Comparison Study: Method

- Demographic Questionnaire

- Evaluation Questionnaire: Questions grouped according to -
  - Lesson Enjoyment (2 items)
  - Ease of Interface Use (4 items)
  - Feelings of Math Efficacy (2 items)

- Intervention: 48 items

Game (Experimental Condition)	*Non-Game (Control Condition)*
Pretest (A, B, or C)	Pretest (A, B, or C)
Demographic Questionnaire	Demographic Questionnaire
Intervention - Game	Intervention – Non-Game
Game-Item-1a	*Non-Game-Item-1a*
Game-Item-1b	*Non-Game-Item-1b*
…	…
Game-Item-24a	*Non-Game-Item-24a*
Game-Item-24b	*Non-Game-Item-24b*
Evaluation Questionnaire	Evaluation Questionnaire
Posttest (A, B, or C)	Posttest (A, B, or C)
Delayed Posttest (A, B, or C)	Delayed Posttest (A, B, or C)

Decimal Point Media Comparison Study: Results

- RQ1: *Does the game lead to better decimal learning than a more conventional instructional approach?*

Decimal Point Media Comparison Study: Results

- RQ2: *Do students in the game group enjoy their learning experience more than the students in the non-game group?*

Decimal Point Media Comparison Study: Results

- RQ3: *Was the Game more beneficial to low or high prior knowledge students?*

Decimal Point Media Comparison Study: Results

- RQ4: *Is the learning benefit of playing the Decimal Point game more, less, or the same for female students as for male students?*

Decimal Point Media Comparison Study: Conclusions

- Results reveal a clear benefit to learning with an educational game
  - *Game students learned more*
  - *Game students enjoyed their experience more*

- Lower prior knowledge students benefited more
  - Perhaps the best audience, as they tend to lack motivation and/or interest

- Females benefited more
  - Simple game; Young females tend to be less "gamers" than young males
  - Math in a game context may reduce stereotype threat

- An example of a rigorous media comparison study that shows the benefit of learning mathematics with an educational game!

High agency with line vs without line

Explore the effects of indirect control in Decimal Point.

High agency with line
(HAL)

High agency without
line (HANL)

[Harpstead et al., 2019]

Learning vs fun recommendations

Left panel:

Game Information

Click on one of the game types below to select mini-games to play.

↓

Stop Playing

How well you have mastered each skill

| Addition |
| Sequence |
| Bucket |
| Number Line |
| Sorting |

Recommended mini-games

Peg Leg Shop | Thirsty Vampire | Fire The Cannon

Right panel:

Game Information

Click on one of the game types below to select mini-games to play.

↓

Stop Playing

How well you have enjoyed each game type

Mad Adder	★★★★★
Pattern Perfect	★★★★☆
Less or More	★★★★☆
Line Time	★★☆☆☆
Arrange and Exchange	★☆☆☆☆

Recommended mini-games

Thirsty Vampire | Peg Leg Shop | Ferris Wheel

Questions?

http://www.cs.cmu.edu/~bmclaren/publications.html
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