Decimal Point: An Educational Game for Learning Mathematics

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• 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)
“... 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

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

<table>
<thead>
<tr>
<th>Content area</th>
<th>Number</th>
<th>Effect size</th>
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</thead>
<tbody>
<tr>
<td>Science</td>
<td>12 out of 16</td>
<td>0.69</td>
</tr>
<tr>
<td>Second-language learning</td>
<td>4 out of 5</td>
<td>0.96</td>
</tr>
<tr>
<td>Math</td>
<td>3 out of 5</td>
<td>0.03</td>
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<tr>
<td>Language arts</td>
<td>3 out of 3</td>
<td>0.32</td>
</tr>
<tr>
<td>Social studies</td>
<td>2 out of 3</td>
<td>0.62</td>
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</tbody>
</table>
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


- 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

<table>
<thead>
<tr>
<th>Game (Experimental Condition)</th>
<th>Non-Game (Control Condition)</th>
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<tbody>
<tr>
<td>Pretest (A, B, or C)</td>
<td>Pretest (A, B, or C)</td>
</tr>
<tr>
<td>Demographic Questionnaire</td>
<td>Demographic Questionnaire</td>
</tr>
<tr>
<td>Intervention - Game</td>
<td>Intervention – Non-Game</td>
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<td>Game-Item-1a</td>
<td>Non-Game-Item-1a</td>
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<tr>
<td>Game-Item-1b</td>
<td>Non-Game-Item-1b</td>
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<td>Game-Item-24a</td>
<td>Non-Game-Item-24a</td>
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<tr>
<td>Game-Item-24b</td>
<td>Non-Game-Item-24b</td>
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<tr>
<td>Evaluation Questionnaire</td>
<td>Evaluation Questionnaire</td>
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<tr>
<td>Posttest (A, B, or C)</td>
<td>Posttest (A, B, or C)</td>
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<tr>
<td>Delayed Posttest (A, B, or C)</td>
<td>Delayed Posttest (A, B, or C)</td>
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Decimal Point Media Comparison Study: Results

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

YES. The Game Group significantly outperformed the Non-Game Group on both the Posttest and Delayed Posttest.
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?*

  Low prior knowledge students benefitted more than high prior knowledge students from the Decimal Point game.
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?

The differences in learning from the game, favoring females over males, are statistically significant on both the immediate posttest (females: $d = .59$, males: $d = .39$) and the delayed posttest (females: $d = .71$, males: $d = .17$).

While the females learned significantly less than the males on the delayed posttest in the non-game condition ($d = .37$), they learned significantly more than the males in the game condition ($d = .12$).
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

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

How well you have mastered each skill

Addition
Sequence
Bucket
Number Line
Sorting

Recommended mini-games
Peg Leg Shop
Thirsty Vampire
Fire The Cannon

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

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
Contact bmclaren@andrew.cmu.edu

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