Carnegie Mellon University

Human-Computer Interaction Institute

Exploring How Gender and Enjoyment Impact Learning in a Digital Learning Game

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Presented by:

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Digital learning games are…

Instructional tools that can both engage students and promote learning through learning activities embedded in game environments

(Gee, 2003; Harp et al, 1998)

https://apps.apple.com/us/app/math-vs-zombies-educational/id687283022

https://play.google.com/store/apps/details?id=com.rvappstudios.abc.spelling.toddler.spell.phonics

However, students may be distracted from learning by the engaging game features.

- To help students stay on track ...

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To help students stay on track...

> Learning-oriented mechanics:
> **collaborative problem-solving**, **instructional feedback** and **open learner models**.
> **(Chen et al., 2007; Moreno & Mayer, 2004; Sung & Hwang, 2013)**

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To help students stay on track...

Learning-oriented mechanics
collaborative problem-solving, instructional feedback and open learner models.
(Chen et al, 2007; Moreno & Mayer, 2004; Sung & Hwang, 2013)

And more **general frameworks** about **game feature design** that **optimize learning**
(e.g., Kiili et al., 2013; 2014; Chen et al., 2014)

On the other hand, students' enjoyment in the game is also an important factor

> Students' enjoyment can serve as a catalyst for their **learning motivation** and is **positively correlated with learning outcomes**.
> **(Anderman & Dawson, 2011; Fu et al., 2009; Liu et al., 2011)**

Comparing the effects of **enjoyment-focused** and **learning-focused** game environments

Some prior studies have explicitly compared the **learning and enjoyment constructs** in the same game context.

(Erhel & Jamet, 2013; Wechselberger, 2013)

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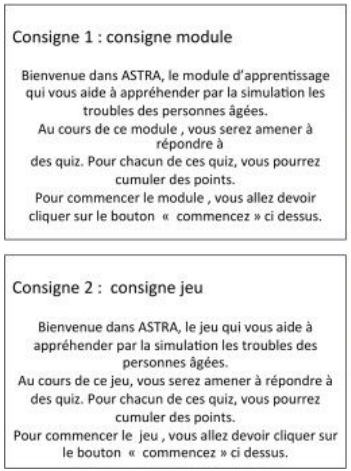

(Erhel & Jamet, 2013)

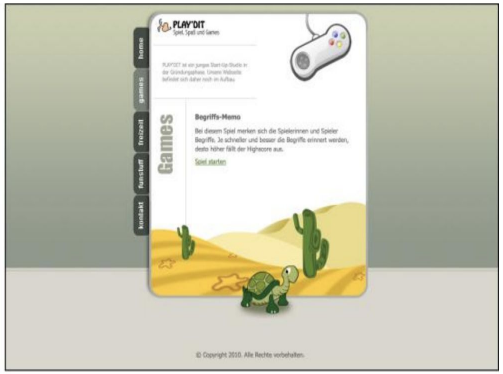

Figure 2: Screenshots of both websites (serious condition left, playful condition right) leading to one and the same serious game.

(Wechselberger, 2013)

Therefore, we focus on the double-topic in digital learning games: Learning-Enjoyment Balance

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We believe a more authentic comparison should

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We believe a more authentic comparison should

➔ take place **during students' actual gameplay**

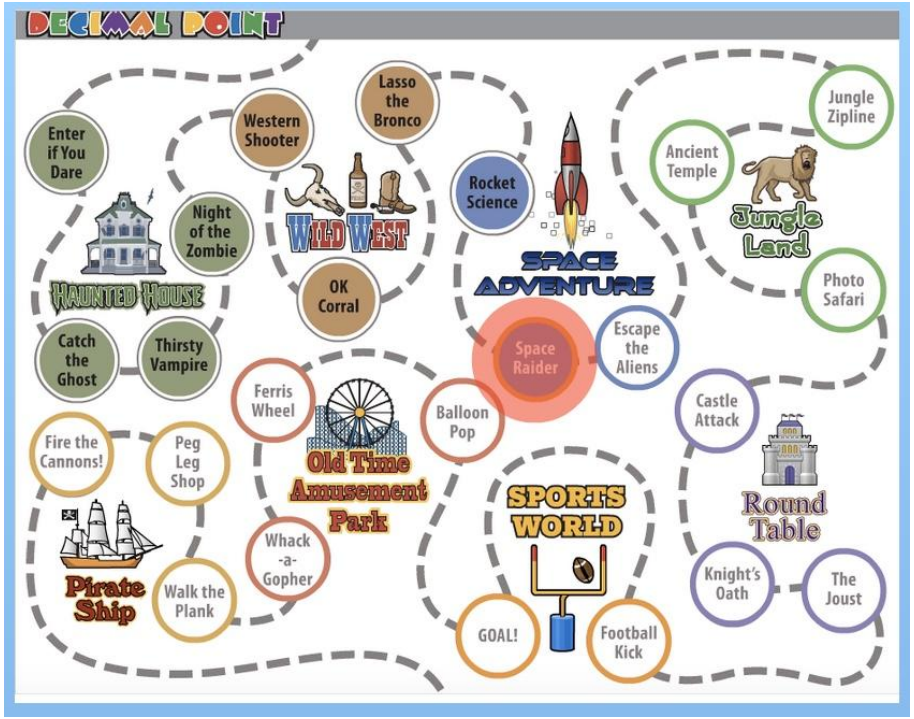
➔ with **different game mechanics** designed to **emphasize either the learning or enjoyment aspect** of the game.

Decimal Point: A math digital learning game for middle-school students

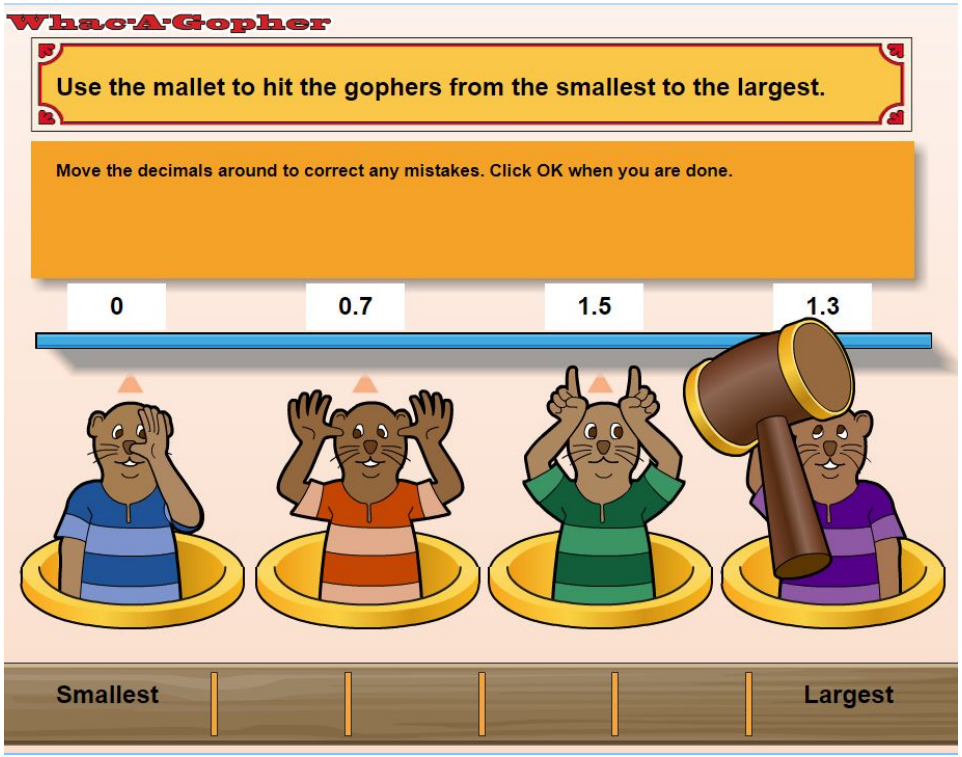
Decimal numbers and operations

Amusement park metaphor

8 theme areas
24 mini-games



An example mini-game: Whac-A-Gopher



Round 1:

0, 0.7, 1.5, 1.3

Round 2:

0.6, 0, -0.5, -0.9

Round 3:

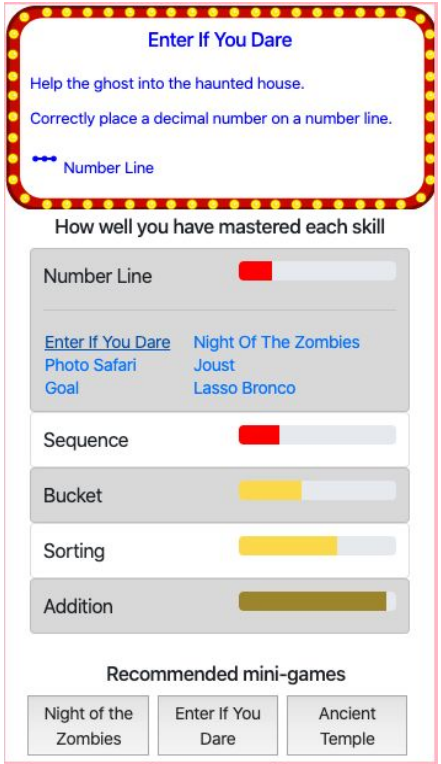
1.2, 2.11, 1.1211, 1.221

Conditions

Learning-focused

Enjoyment-focused

Control



Conditions

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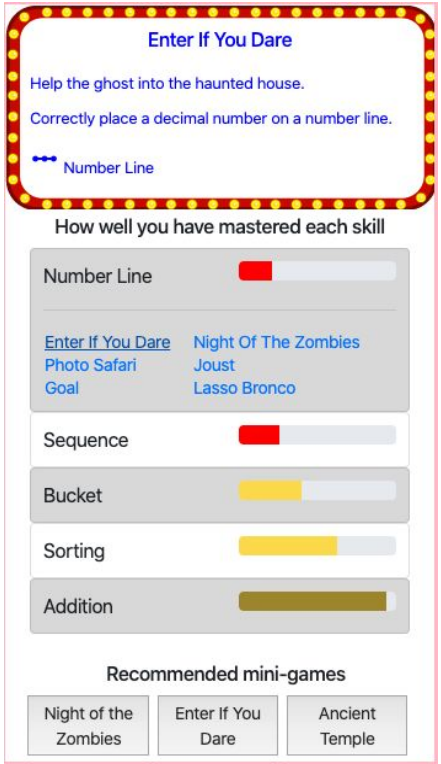
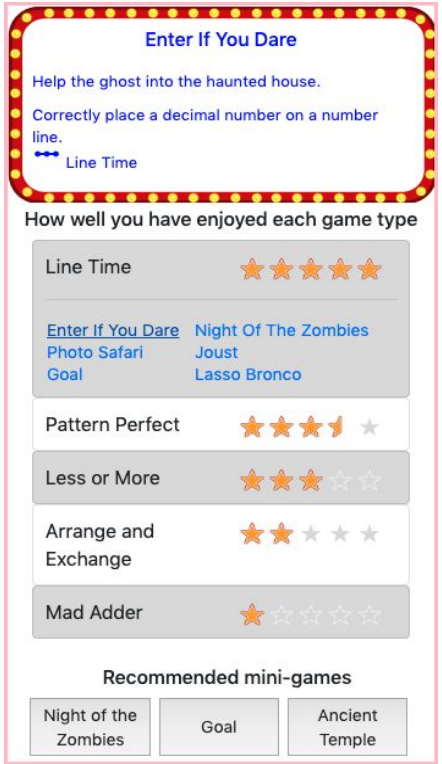


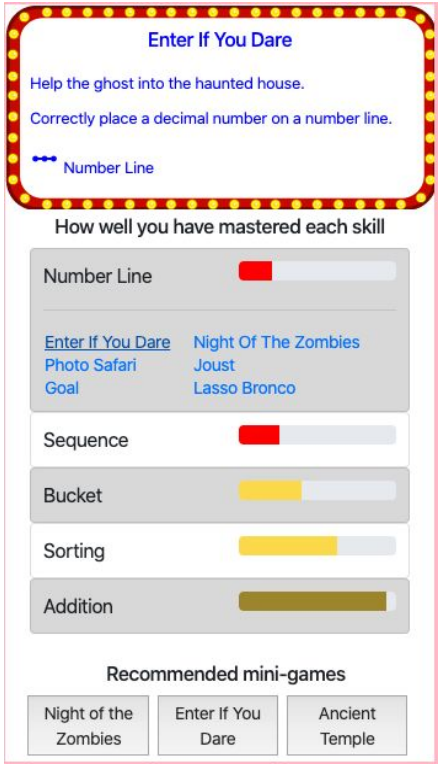
Enjoyment-focused



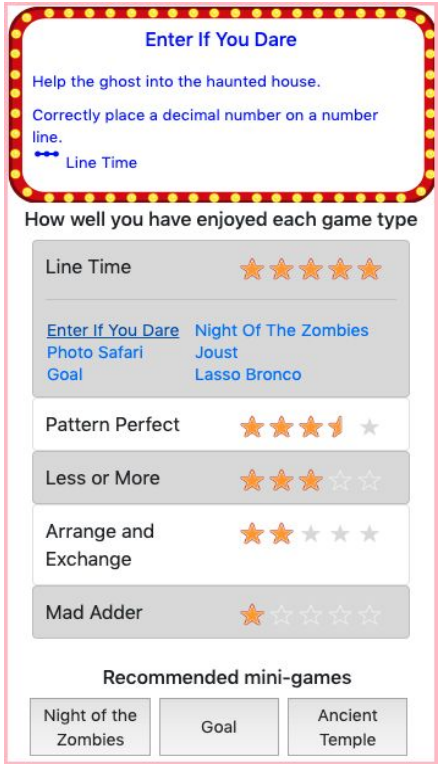
Control

Conditions

Learning-focused



Enjoyment-focused



Control

Procedure: Classroom Experiment

159 fifth and sixth grade students from **3** middle schools

Before game play

Pretest, Demographic, Game survey

Procedure: Classroom Experiment

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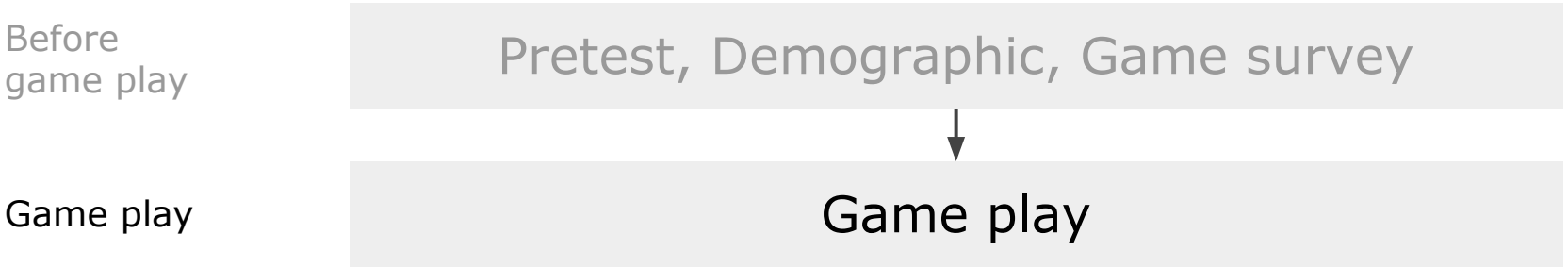

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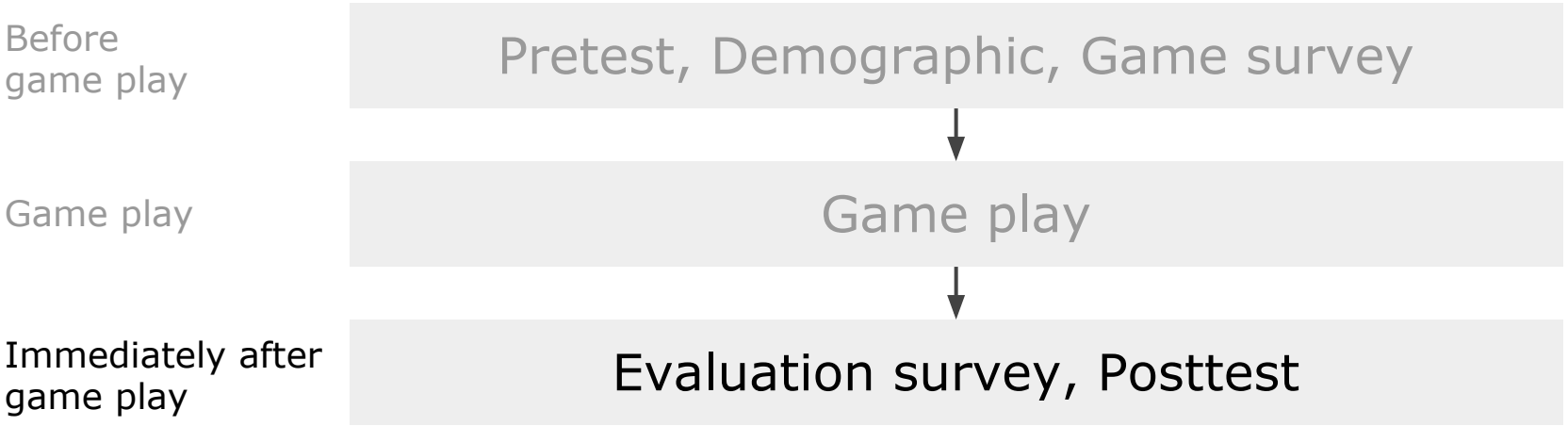

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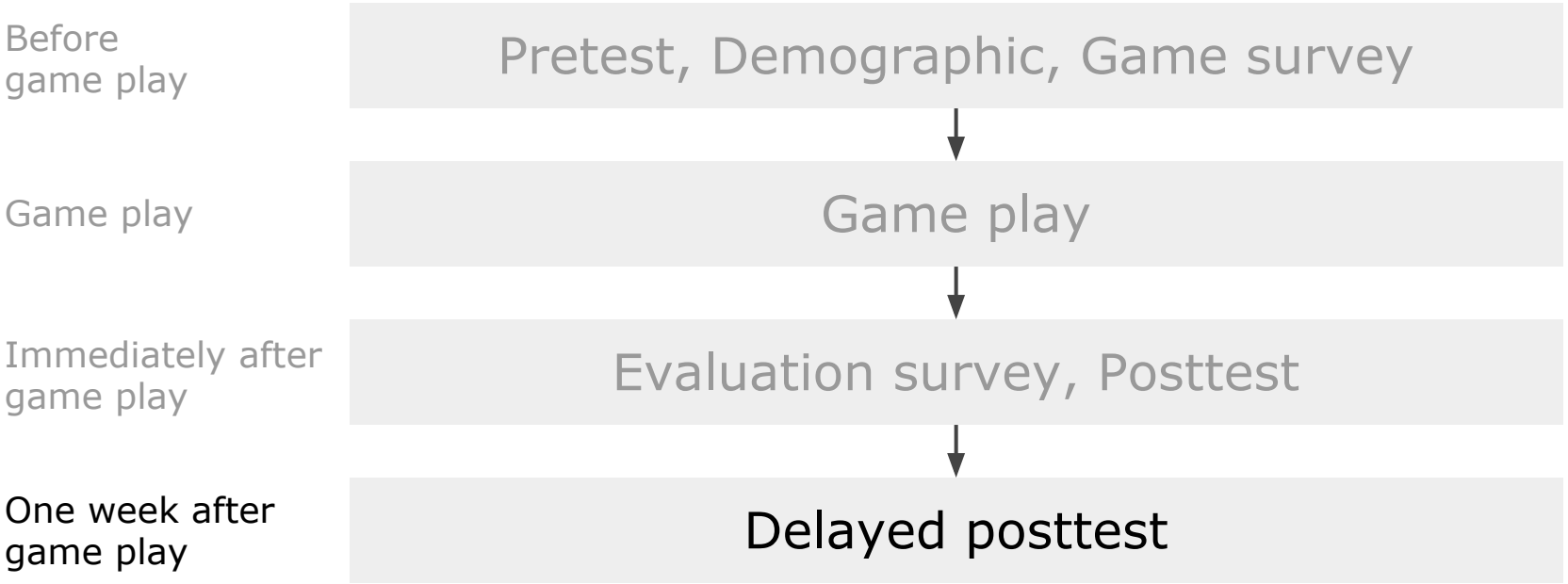

Key Measures

Learning:

Learning outcome: Test performance

Posttest and Delayed posttest scores

- Each test consisted of 43 items, for a total of 52 points.
- e.g., “is a longer decimal larger than a shorter decimal?”

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Enjoyment:

Self-reported Enjoyment in evaluation survey (1-5)

- Achievement emotion
- Game engagement
- Affective engagement
- Per-student **average Likert scores**

Results

RQ1: Is there a difference in learning outcomes among students in the three conditions?

RQ2: Is there a difference in self-reported enjoyment among students in the three conditions?

RQ3: Is there a difference in learning outcomes between male and female students?

RQ4: Is there a difference in self-reported enjoyment between male and female students?

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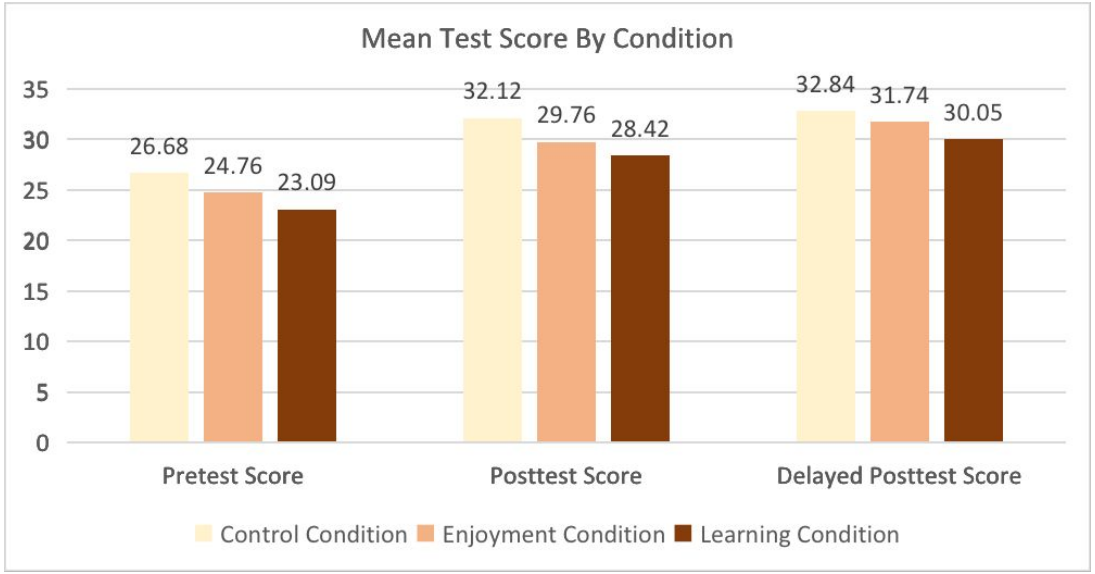
RQ4: Is there a difference in self-reported enjoyment between male and female students?

Hypothesis: Learning Condition students would achieve the highest learning outcome.
(Bodily et al., 2018; Bull & Nghiem, 2002)

RQ1 - Is there a difference in learning outcomes among students in the three conditions?



No significant differences across conditions in pretest scores.

No significant differences across conditions in

- Posttest scores
- Delayed posttest scores

No condition effect on learning outcomes

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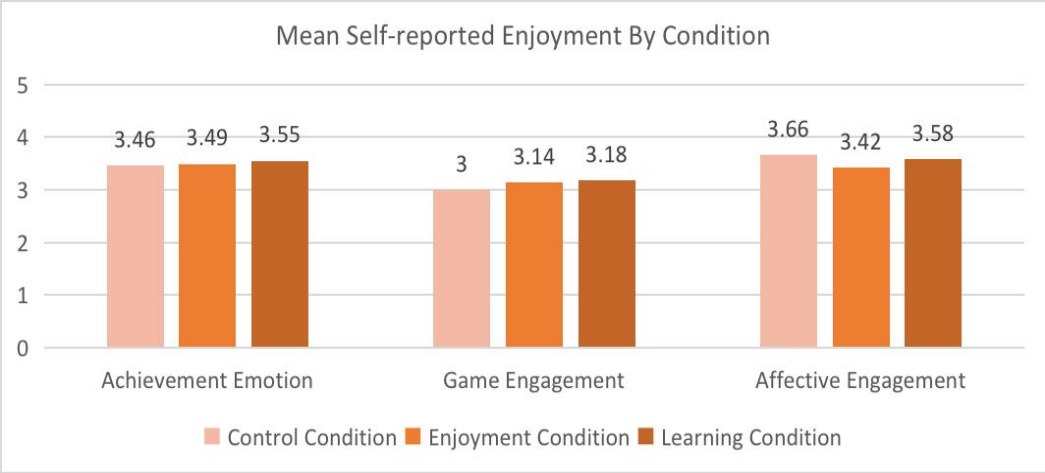

No significant differences across conditions in

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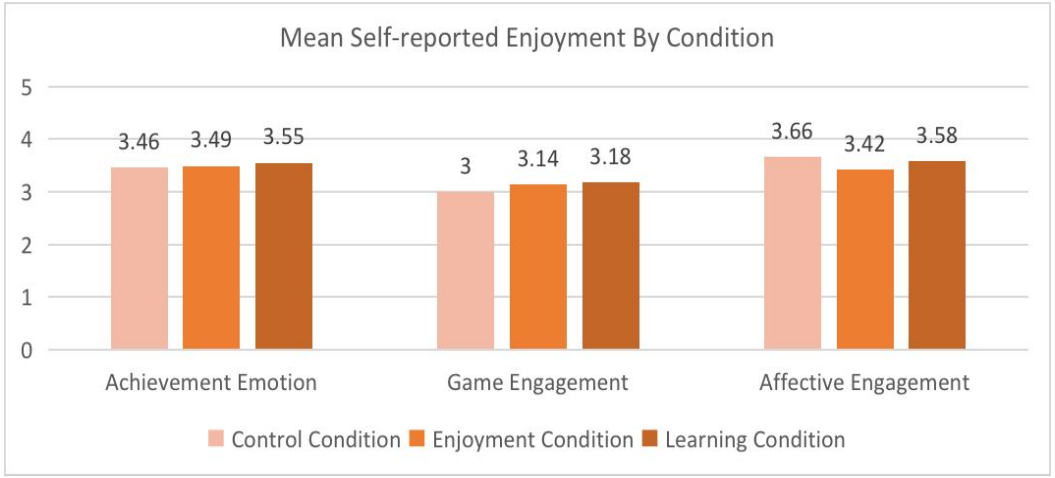

No significant differences across conditions in

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No condition effect on self-reported enjoyment

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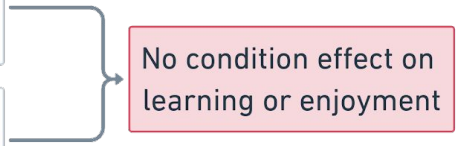

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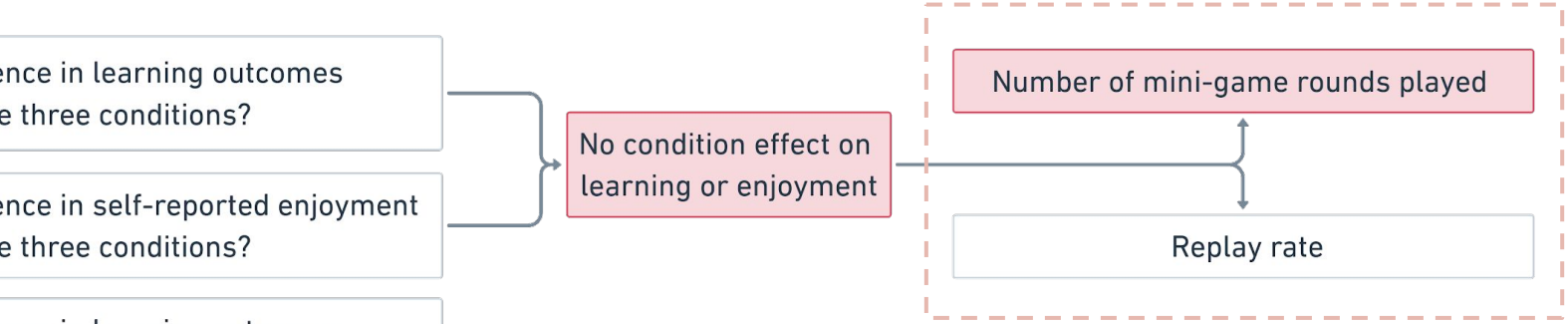

Mini-game rounds comparison by condition

Kruskal-Wallis test:
Significant differences across conditions ($H = 38.08$, $p < .001$)

Dunn's post hoc:

- **Control Condition > Learning Condition** ($p < .001$, $d = 0.44$)
- **Learning Condition > Enjoyment Condition** ($p = .007$, $d = 0.33$)

> **Control Condition > Learning Condition > Enjoyment Condition in number of mini-game rounds**

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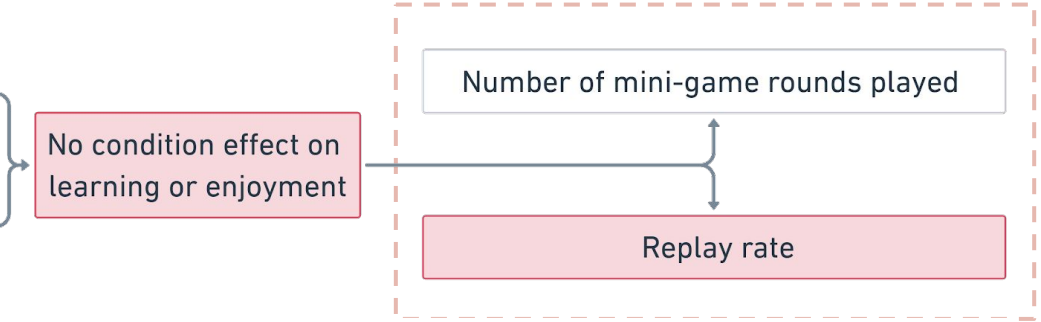
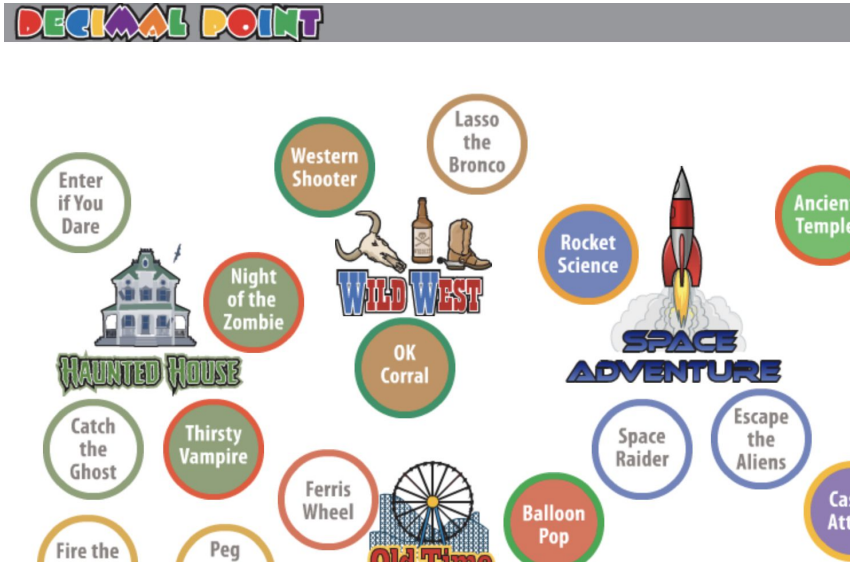


Replay Rate Comparison by Condition

$$\textbf{Replay Rate} = \frac{\#\text{ of } \textbf{reselected} \text{ a mini-game beyond the first try}}{\text{Total \# of mini-game selections}}$$



High: play more rounds of certain mini-games
Low: play a wider variety of mini-games

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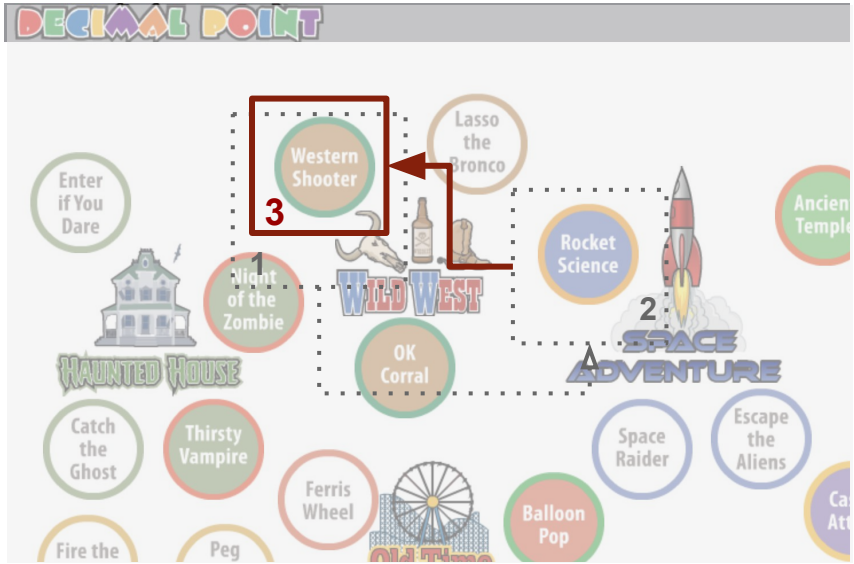


High: play more rounds of certain mini-games
Low: play a wider variety of mini-games

Western Shooter -> **Rocket Science** -> **Western Shooter**

$$\text{Replay Rate (current)} = \frac{1}{3}$$

Focused comparison on the **Learning Condition** and **Enjoyment Condition**

Replay Rate Comparison by Condition

Kruskal-Wallis test:

Significant difference in replay rates between the students in Learning Condition and Enjoyment Condition($H = 42.41$, $p < .001$)

Replay Rate Comparison by Condition

Kruskal-Wallis test:
Significant difference in replay rates between the students in Learning Condition and Enjoyment Condition($H = 42.41$, $p < .001$)

- Students in Enjoyment Condition (25/54) and Control Condition (20/50) mentioned more about **trying out every available mini-game → interleaved practice**
  e.g., "I really wanted to finish the whole map and see all the things filled in with color."

- Students in Learning Condition (17/55) mentioned more about **re-practicing until mastery → blocked practice**
  e.g., "I was trying to get all the decimal category skill bars full."

Replay Rate Comparison by Condition

Kruskal-Wallis test:
Significant difference in replay rates between the students in Learning Condition and Enjoyment Condition($H = 42.41$, $p < .001$)

> **Students in Learning Condition tended to replay more rounds of the mini-games they had already played than those in Enjoyment Condition.**

Results

RQ1: Is there a difference in learning outcomes among students in the three conditions?

RQ2: Is there a difference in self-reported enjoyment among students in the three conditions?

No condition effect on learning or enjoyment

Number of mini-game rounds played

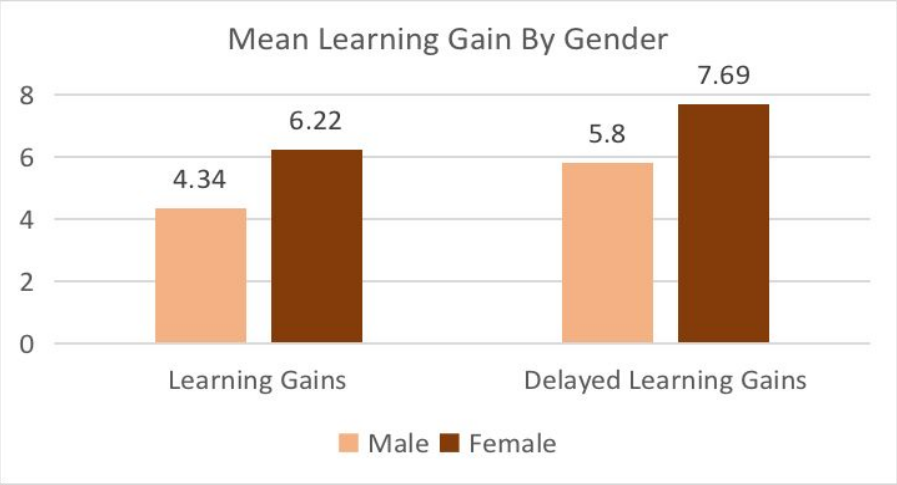
Replay rate

RQ3: Is there a difference in learning outcomes between male and female students?

RQ4: Is there a difference in self-reported enjoyment between male and female students?

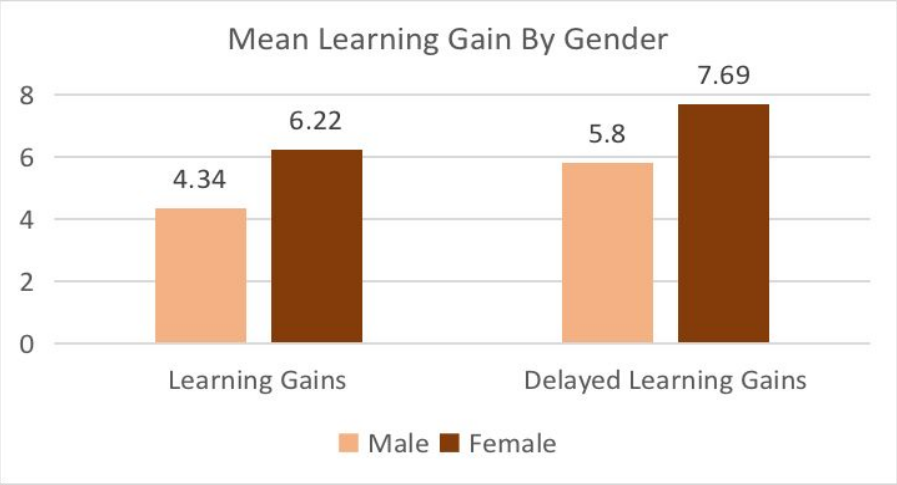
Hypothesis: Female students would learn more from the game across all three conditions. (Klisch et al., 2012; McLaren et al., 2017)

RQ3 - Is there a difference in learning outcomes between male and female students?



	Learning Gain (Two-way ANOVA)
Gender effect	**Significant main effect of gender: Female > Male** • Learning gains • Delayed learning gains
Gender x Condition interaction effect	No significant gender x condition interaction effect • Learning gains • Delayed learning gains

RQ3 - Is there a difference in learning outcomes between male and female students?



	Learning Gain (Two-way ANOVA)
Gender effect	**Significant main effect of gender: Female > Male** • Learning gains • Delayed learning gains
Gender x Condition interaction effect	No significant gender x condition interaction effect • Learning gains • Delayed learning gains

Gender effect on learning gain: Females learned more than males across all conditions was confirmed.

Results

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RQ2: Is there a difference in self-reported enjoyment among students in the three conditions?

No condition effect on learning or enjoyment

Number of mini-game rounds played

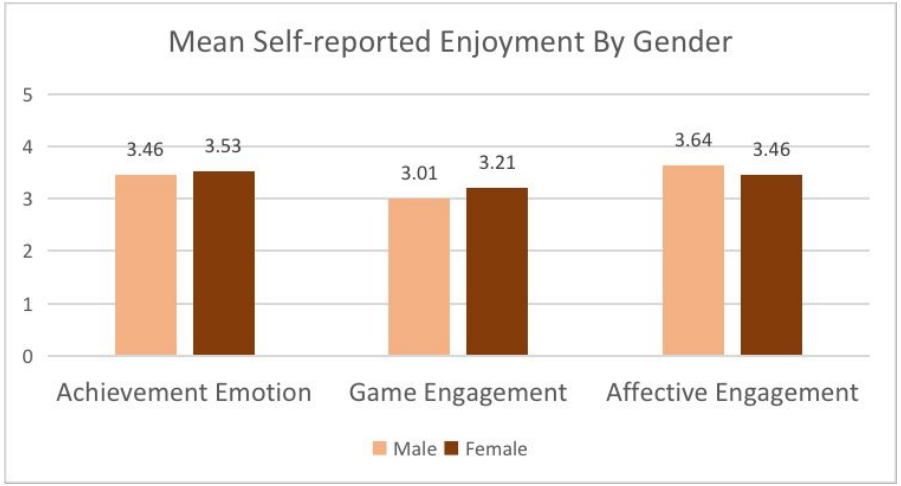
Replay rate

RQ3: Is there a difference in learning outcomes between male and female students?

RQ4: Is there a difference in self-reported enjoyment between male and female students?

Hypothesis: Females would report higher enjoyment than males across all three conditions.
(Bammel & Burrus-Bammel, 1982; Paraskeva et al, 2010; Griffiths & Hunt, 1995; Subrahmanyam & Greenfield, 1998)

RQ4 - Is there a difference in self-reported enjoyment between male and female students?

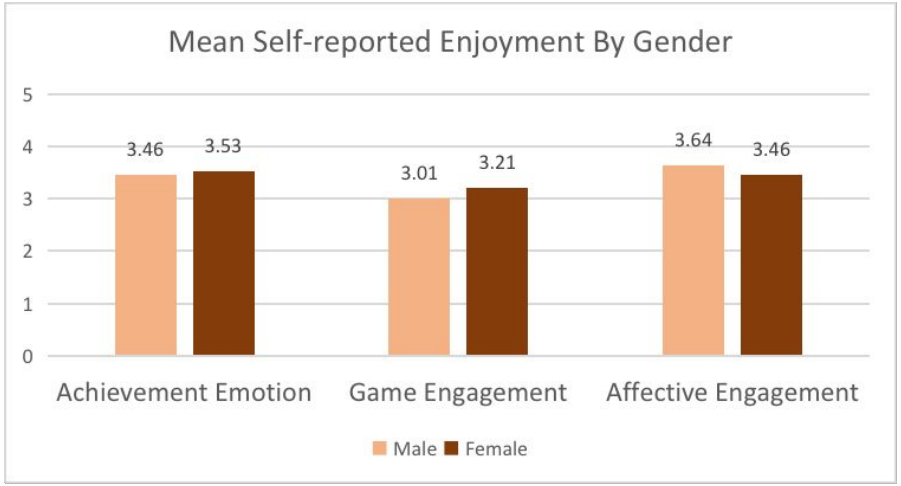


No significant main gender effect

No significant gender x condition interaction effects

- achievement emotions
- game engagement
- affective engagement

RQ4 - Is there a difference in self-reported enjoyment between male and female students?



No significant main gender effect

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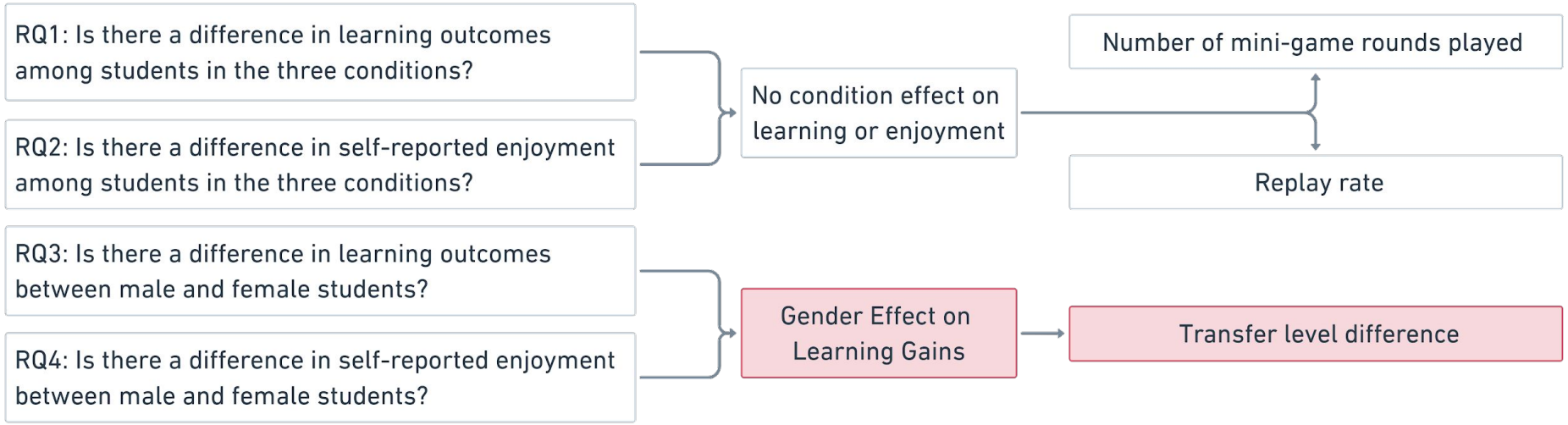
Our hypothesis that females would enjoy the game more than males was not confirmed.

Results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No condition effect on learning or enjoyment
Gender Effect on Learning Gains
Number of mini-game rounds played
Replay rate
Transfer level difference

Transfer Level Difference

We assigned a level of learning transfer to each of the 43 test items:
20 near, 8 middle, 15 far

Near transfer questions

Use **identical procedures** to those practiced in the game to complete
(Novick, 1990; Barnett & Ceci, 2002)

- E.g., "Place the following list of decimals in order, smallest to largest: 0.7, 0, 1.0, 0.35"

Transfer Level Difference

We assigned a level of learning transfer to each of the 43 test items:
20 near, 8 middle, 15 far

Middle transfer questions

Rely on **practiced representations** but required **modification of procedures** (Novick, 1990; Barnett & Ceci, 2002)

- E.g., "Which number is closest to 2.8? 2.88888, 2.91, 2.6, or 2.78"

Transfer Level Difference

We assigned a level of learning transfer to each of the 43 test items:
20 near, 8 middle, 15 far

Far transfer questions

Understand **underlying principles** of practiced problems (Novick, 1990; Barnett & Ceci, 2002)

- E.g., "Is a longer decimal number larger than a shorter decimal number?"

Transfer Level Difference

Near and Middle transfer items

Pretest: Female < Male

Learning Gain: Female > Male

Transfer Level Difference

Near and Middle transfer items

Pretest: Female < Male

Learning Gain: Female > Male

Far transfer items

No significant gender differences

Discussion 1: No condition effect on learning or enjoyment

Possible Reasons:

- Students still spend **most of the game time** in the actual mini-games, which are **identical across conditions**

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- Students were likely **not exposed to** this "**open enjoyment model**" before and did not use it effectively.

Discussion 1: No condition effect on learning or enjoyment

Possible Reasons:

- Students still spend **most of the game time** in the actual mini-games, which are **identical across conditions**
- Students were likely **not exposed to** this "**open enjoyment model**" before and did not use it effectively.
- **Real classroom environment** may have negated the playful atmosphere that the Enjoyment condition focused **(Osman & Baker, 2012; Rice, 2007)**

Discussion 2: Gender effect in learning gains but not in enjoyment

Females **outperformed males** in learning gains at the **near and middle** transfer level but not on far transfer level problems.

Possible Reason:

- Improving procedural knowledge but not necessarily for abstract knowledge or far transfer
  (Richey & Nokes-Malach, 2015; Singley & Anderson, 1989)

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Possible Reason:

- Improving procedural knowledge but not necessarily for abstract knowledge or far transfer
  (Richey & Nokes-Malach, 2015; Singley & Anderson, 1989)

No gender differences in self-reported enjoyment

Possible Reason:

- The variety of mini-game themes and activities appeal to both genders

Future Work

Learning perspective:

Experiment with different skill mappings or model representation
(Bodily et al., 2018; Nguyen et al., 2019)

Enjoyment perspective:

- More in-game measures and survey questions to understand students' perception of game play in the classroom
- Optimize enjoyment in this game

General Future Direction:

- Which game features are conducive to the observed gender effects
- How to extend the game's knowledge content to better support far transfer learning

Conclusion

Two distinct gameplay patterns:

- Learning Condition: Repeated practice
- Enjoyment Condition: Exploration

Females > Males in learning from the game

- Explore the effect of emphasizing **game-based learning or enjoyment** in **a classroom environment**
- The game's potential in **bridging the gender gap** in math education

Thank you!

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For more information: http://tiny.cc/DecimalPoint

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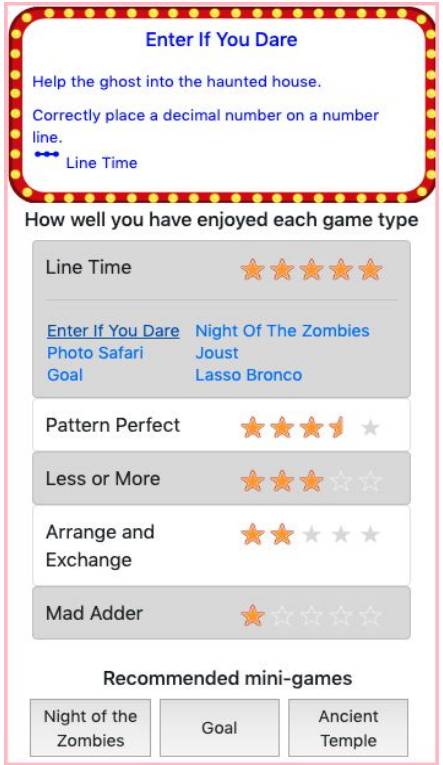
Q1: How were enjoyment rating collected?



Q2: Why comparing test score by condition but learning gains by gender?

Given that gender is not a randomly assigned variable and males tend to outperform females in math performance by the end of elementary school [46], we did not expect students to be equivalent across genders at pretest. For this reason, we focused our gender analyses on gain scores [18]. In contrast, because the conditions (CC, LC and EC) were randomly assigned, we expected students to perform equally well on pretest across conditions; therefore, we used analyses of covariance (ANCOVA) to assess condition effects on posttest and delayed posttest.

Q3: Why did differences in gameplay pattern not lead to differences in learning outcomes or enjoyment?

Learning:

- Interleaving vs blocking: the skills may be sufficiently distinct from one another and each was embedded in a unique interface, so interleaving and blocking, if present, were unlikely to yield differences in learning outcomes

Enjoyment:

- As we mentioned, students still spent most of their game play in the actual mini-games, which are identical across conditions
- Classroom atmosphere negated the enjoyment condition's effect

Discussion 1: The condition effect on learning efficiency

Control Condition has higher number of rounds, but similar average time per round and test scores compared with EC, which led to lower learning efficiency

Possible Reason:

- Control Condition students' higher number of rounds
- Students in Control Condition had to play two rounds per mini-game selection.

Learning Condition had significantly more game rounds and replay rate than EC

Possible Reason:

- EC students: chose to stop playing after trying most of the 24 mini-games once

On the other hand, students' enjoyment in the game is also an important factor

Students' enjoyment can serve as a catalyst for their **learning motivation** and is **positively correlated with learning outcomes**
(Anderman & Dawson, 2011; Fu et al., 2009; Liu et al., 2011)

> But have also been posted as a trade-off to learning
> **(Greipl et al., 2018)**

Key Measures

Learning:

Condition Analysis

Learning outcome: Test performance

Posttest and Delayed posttest scores

- Each test consisted of 43 items, for a total of 52 points.
- e.g., “is a longer decimal larger than a shorter decimal?”

Gender Analysis

Learning outcome: Learning gain during the gameplay

Pre-post: **Posttest score - Pretest score**

Pre-delayed: **Delayed posttest score - Pretest score**

Key Measures

Enjoyment:

Self-reported Enjoyment in post-intervention surveys (1-5)

- Per-student **average Likert scores**
- Achievement emotion
- Game engagement
- Affective engagement

Results

RQ1: Is there a difference in learning outcomes among students in the three conditions?

RQ2: Is there a difference in self-reported enjoyment among students in the three conditions?

Post hoc Analysis

RQ3: Is there a difference in learning outcomes between male and female students?

RQ4: Is there a difference in self-reported enjoyment between male and female students?

Research Questions

RQ1: Is there a difference in **learning outcomes** among students in the **three conditions**?

Hypothesis: Learning Condition students would achieve the highest learning outcome. **(Bodily et al, 2018; Bull & Nghiem, 2002)**

RQ2: Is there a difference in **self-reported enjoyment** between students in the **three conditions**?

Hypothesis: the Enjoyment Condition group would report the highest enjoyment.

Research Questions

RQ3: Is there a difference in **learning outcomes** between **male and female students**?

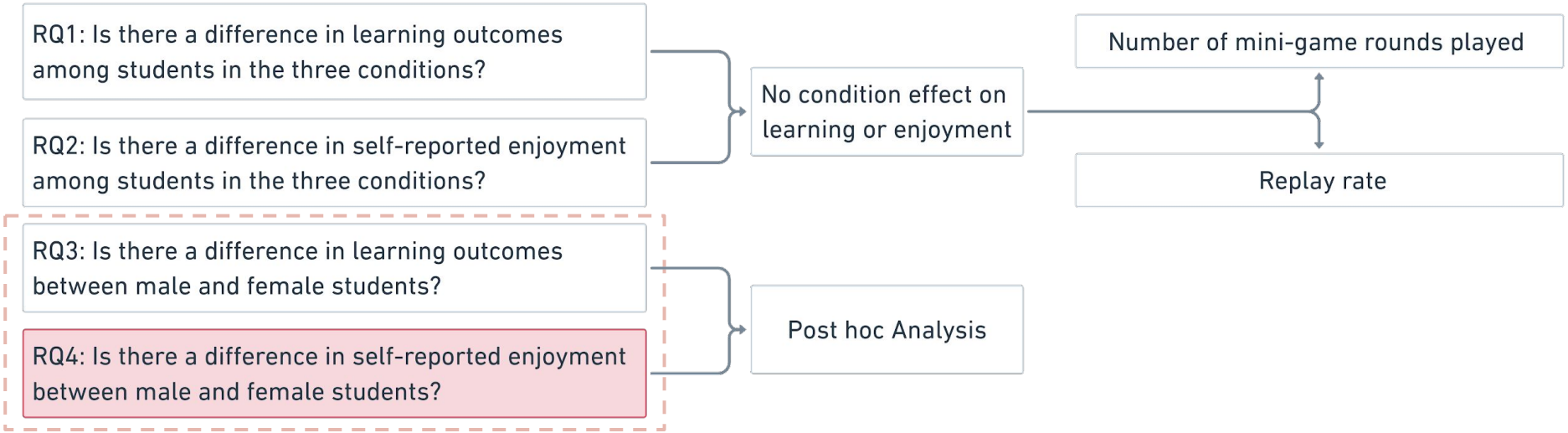
Hypothesis: female students would have better learning outcomes than males in our game across all three conditions. **(Klisch et al., 2012; McLaren et al., 2017)**

RQ4: Is there a difference in **self-reported enjoyment** between **male and female students**?

Hypothesis: females would report higher enjoyment than males across all three conditions.

(Bammel & Burrus-Bammel, 1982; Paraskeva et al, 2010; Griffiths & Hunt, 1995; Subrahmanyam & Greenfield, 1998)

Results


RQ1: Is there a difference in learning outcomes among students in the three conditions?
RQ2: Is there a difference in self-reported enjoyment among students in the three conditions?
RQ3: Is there a difference in learning outcomes between male and female students?
RQ4: Is there a difference in self-reported enjoyment between male and female students?
No condition effect on learning or enjoyment
Post hoc Analysis
Number of mini-game rounds played
Replay rate