

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

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)



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

■ To help students stay on track ...

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

To help students stay on track...

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

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)

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But some studies reported a **tradeoff** between learning and enjoyment: students enjoyed games more but learned less from them.
(Pittman, 2013; Plass et al., 2015; Greipl et al., 2019)

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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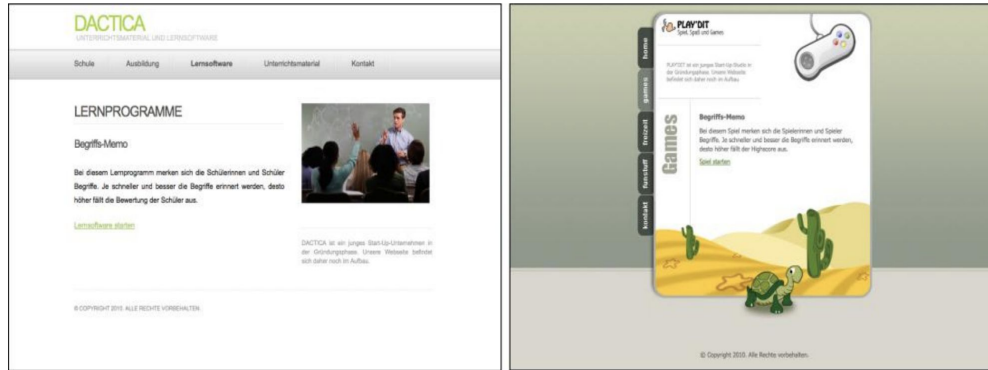


Figure 2: Screenshots of both websites (serious condition left, playful condition right) leading to one and the same serious game.

(Wechselberger, 2013)

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

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Learning instruction



Consigne 1 : consigne module

Bienvenue dans ASTRA, le module d'apprentissage qui vous aide à appréhender par la simulation les troubles des personnes âgées.

Au cours de ce module, vous serez amené à répondre à des quiz. Pour chacun de ces quiz, vous pourrez cumuler des points.

Pour commencer le module, vous allez devoir cliquer sur le bouton « commencez » ci dessus.

Entertainment instruction



Consigne 2 : consigne jeu

Bienvenue dans ASTRA, le jeu qui vous aide à appréhender par la simulation les troubles des personnes âgées.

Au cours de ce jeu, vous serez amené à répondre à des quiz. Pour chacun de ces quiz, vous pourrez cumuler des points.

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

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






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(Erhel & Jamet, 2013; Wechselberger, 2013)

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.

Emphasis through student-facing dashboards






Learning Condition

How well you learned each skill	
Skill A	
Skill B	
Skill C	
Skill D	
Skill E	
We recommend more practicing on skills A and B (least learned skills).	



Enjoyment Condition

Emphasis through student-facing dashboards

Learning Condition

How well you learned each skill	
Skill A	
Skill B	
Skill C	
Skill D	
Skill E	
We recommend more practicing on skills A and B (least learned skills)	

Enjoyment Condition

How much you enjoyed each game type	
Game Type A	
Game Type B	
Game Type C	
Game Type D	
Game Type E	
We recommend more playing more game types A and B (most enjoyed game types).	

Measuring in-game learning

Suppose a student has six opportunities to practice a skill, and emits the following sequence of correct (1) and incorrect (0) responses:

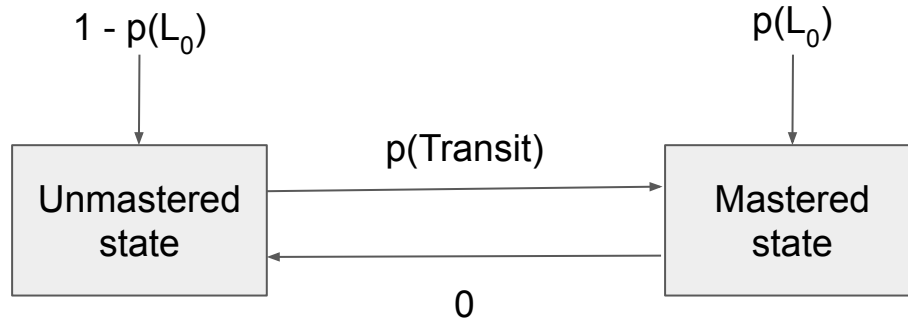
1 0 1 0 1 1

Did the student master this skill?

Output sequence → Learning state (latent)

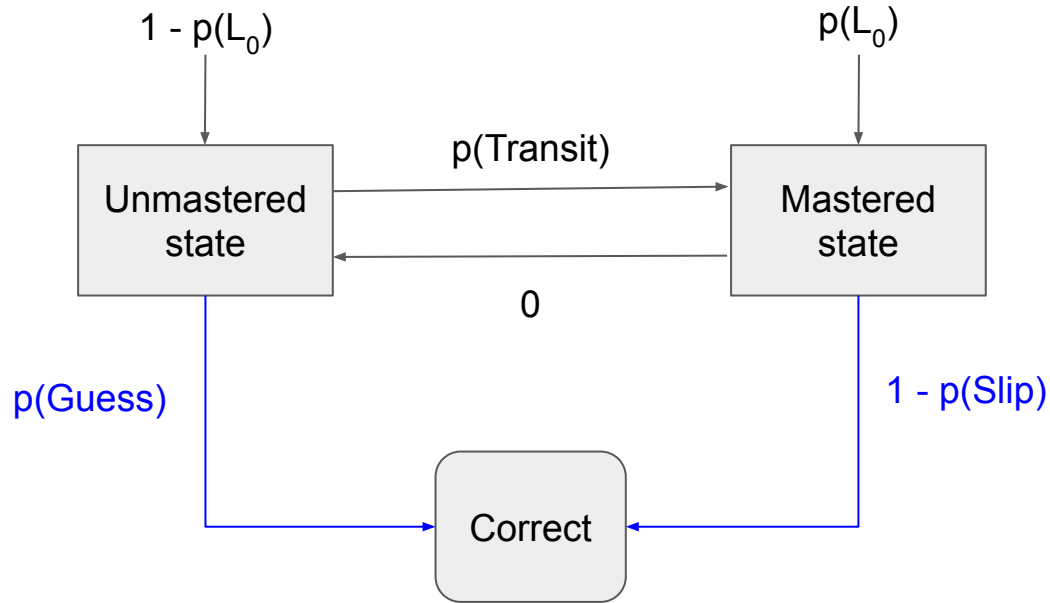
Measuring in-game learning

Bayesian Knowledge Tracing (Corbett & Anderson, 1995)



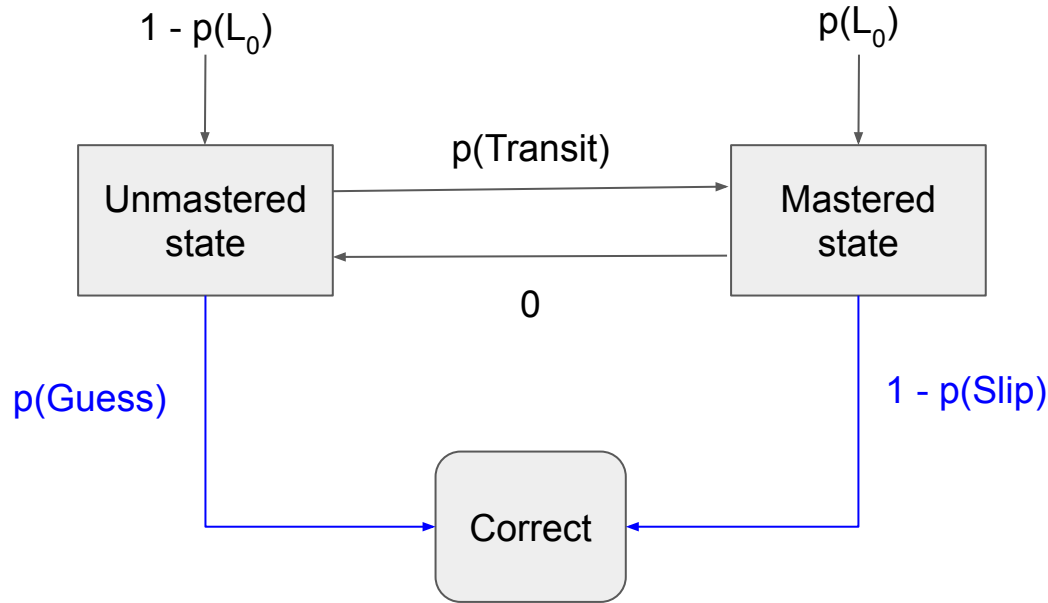
Measuring in-game learning

Bayesian Knowledge Tracing (Corbett & Anderson, 1995)



Measuring in-game learning

Bayesian Knowledge Tracing (Corbett & Anderson, 1995)



Parameter	Value
$p(L_0)$	0.4
$p(\text{Transit})$	0.05
$p(\text{Guess})$	0.299
$p(\text{Slip})$	0.299

Measuring in-game learning

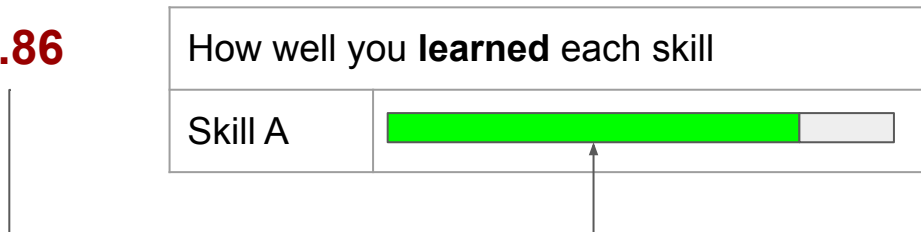
Suppose a student has six opportunities to practice a skill, and emits the following sequence of correct (1) and incorrect (0) responses:

1 0 1 0 1 1

Did the student master this skill?

$p(L_0) = 0.4$, $p(T) = 0.05$, $p(G) = p(S) = 0.299$

→ **HMM Inference: $p(L_6 \mid 101011) = 0.86$**



Measuring in-game enjoyment

Survey after the student completes each game round.





Measuring in-game enjoyment

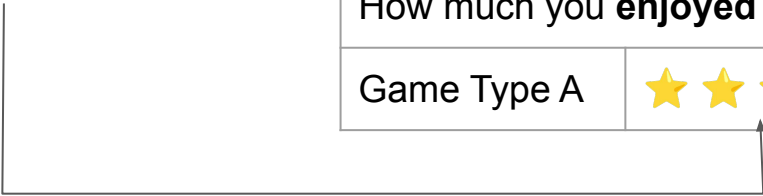
Average enjoyment ratings of all game rounds in each type.

Example: game type A with 3 rounds.

- Round 1 rated 5 stars
- Round 2 rated 1 stars
- Round 3 rated 3 stars

→ **Rating of game type A: 3 stars**

How much you enjoyed each game type	
Game Type A	 



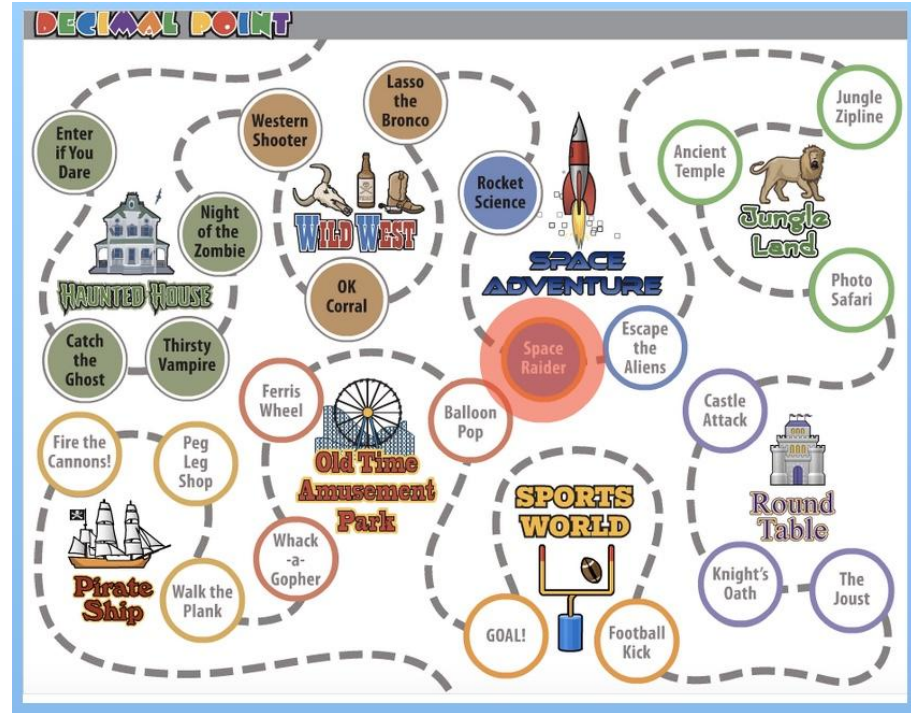
Decimal Point: A math digital learning game for middle-school students

(McLaren et al., 2017; Forlizzi et al., 2017)

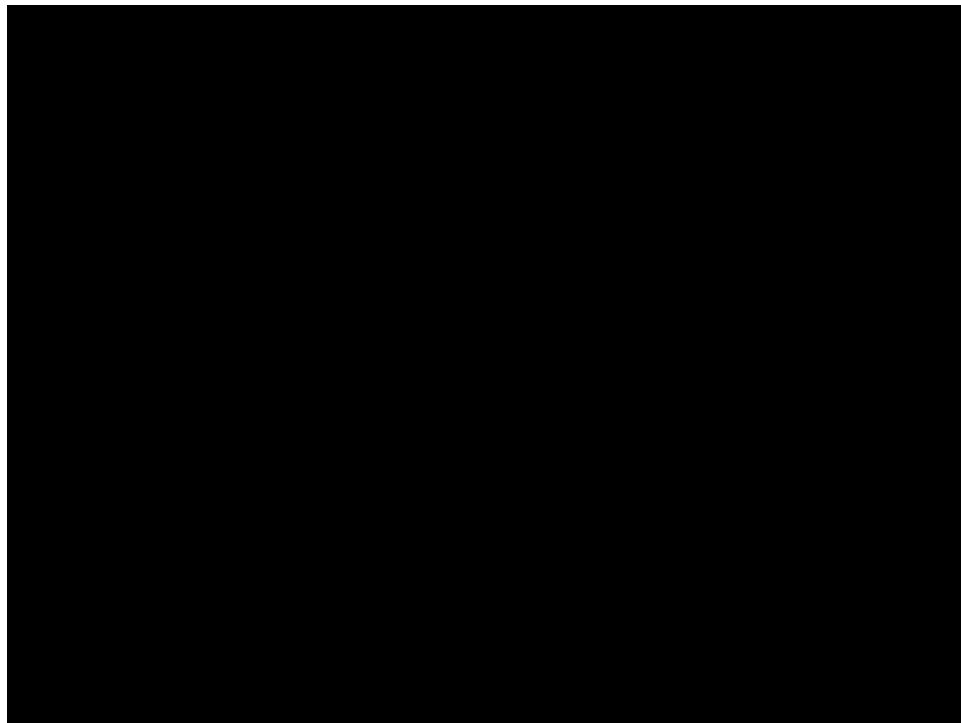
Decimal numbers
and operations

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

Learning-focused

Enjoyment-focused

Control

Enter If You Dare

Help the ghost into the haunted house.
Correctly place a decimal number on a number line.

Number Line

How well you have mastered each skill

Number Line	<div><div></div></div>
Enter If You Dare	Night Of The Zombies
Photo Safari	Joust
Goal	Lasso Bronco

Sequence	<div><div></div></div>
Bucket	<div><div></div></div>
Sorting	<div><div></div></div>
Addition	<div><div></div></div>

Recommended mini-games

Night of the
Zombies

Enter If You
Dare

Ancient
Temple

Learning-focused

Enjoyment-focused

Control

Enter If You Dare

Help the ghost into the haunted house.
Correctly place a decimal number on a number line.

Number Line

How well you have mastered each skill

Skill	Progress
Number Line	<div><div></div></div>
Enter If You Dare	<div><div></div></div>
Night Of The Zombies	<div><div></div></div>
Photo Safari	<div><div></div></div>
Goal	<div><div></div></div>
Joust	<div><div></div></div>
Lasso Bronco	<div><div></div></div>
Sequence	<div><div></div></div>
Bucket	<div><div></div></div>
Sorting	<div><div></div></div>
Addition	<div><div></div></div>

Recommended mini-games

Night of the Zombies	Enter If You Dare	Ancient Temple
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Learning-focused

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Sequence

Bucket

Sorting

Addition

Recommended mini-games

Night of the Zombies

Enter If You Dare

Ancient Temple

Enjoyment-focused

Enter If You Dare

Help the ghost into the haunted house.

Correctly place a decimal number on a number line.

Line Time

How well you have enjoyed each game type

Line Time

[Enter If You Dare](#) [Night Of The Zombies](#)

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Pattern Perfect

Less or More

Arrange and Exchange

Mad Adder

Recommended mini-games

Night of the Zombies

Goal

Ancient Temple

Control

Learning-focused

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Recommended mini-games

Night of the Zombies	Enter If You Dare	Ancient Temple
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Recommended mini-games

Night of the Zombies	Goal	Ancient Temple
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Control

Learning-focused

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Number Line

How well you have mastered each skill

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Recommended mini-games

Night of the Zombies

Enter If You Dare

Ancient Temple

Enjoyment-focused

Enter If You Dare

Help the ghost into the haunted house.
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Line Time

How well you have enjoyed each game type

Line Time	★★★★★★
Enter If You Dare Night Of The Zombies Photo Safari Joust Goal Lasso Bronco	
Pattern Perfect	★★★★★
Less or More	★★★★★
Arrange and Exchange	★★★☆☆
Mad Adder	★☆☆☆☆

Recommended mini-games

Night of the Zombies

Goal

Ancient Temple

Control

Enter If You Dare

Help the ghost into the haunted house.
Correctly place a decimal number on a number line.

Number Line

Below are all of the mini-games in Decimal Point, organized by game type. Games you have already played are in **red font**.

<h4>Addition</h4> <p>+ Add decimals</p> <p>Thirsty Vampire Peg Leg Shop</p> <h4>Bucket</h4> <p>■ Compare decimals</p> <p>Catch The Ghost OK Corral Walk The Plank Fire The Cannon</p> <h4>Sequence</h4> <p>▶▶ Complete a decimal sequence</p> <p>Alien Escape Ancient Temple Knights Oath Ferris Wheel</p>	<h4>Number Line</h4> <p>↔ Place point on numberline</p> <p>Enter If You Dare Night Of The Zombies Lasso Bronco Photo Safari Joust Goal</p> <h4>Sorting</h4> <p>↑ Order decimals</p> <p>Western Shooter Rocket Science Space Raider Jungle Zipline Castle Attack Football Balloon Pop Whac A Gopher</p>
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Research Questions

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**?

Research Questions

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?

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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Before
game play

Pretest, Demographic, Game survey



Intervention

Game play

Procedure: Classroom Experiment

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

Before
game play

Pretest, Demographic, Game survey



Intervention

Game play



Immediately after
game play

Evaluation survey, Posttest

Procedure: Classroom Experiment

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

Before
game play

Pretest, Demographic, Game survey



Game play

Game play



Immediately after
game play

Evaluation survey, Posttest



One week after
posttest

Delayed posttest

Post-intervention Measures

Learning:

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?”

Post-intervention Measures

Learning:

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?”

Enjoyment:

Self-reported Likert ratings in the evaluation survey (1-5)

- Achievement emotion, 6 items (Pekrun, 2005)
- Game engagement, 5 items (Brockmyer et al., 2009)
- Affective engagement, 3 items (Ben-Eliyahu et al., 2018)
- Per-student **average Likert scores**

Results

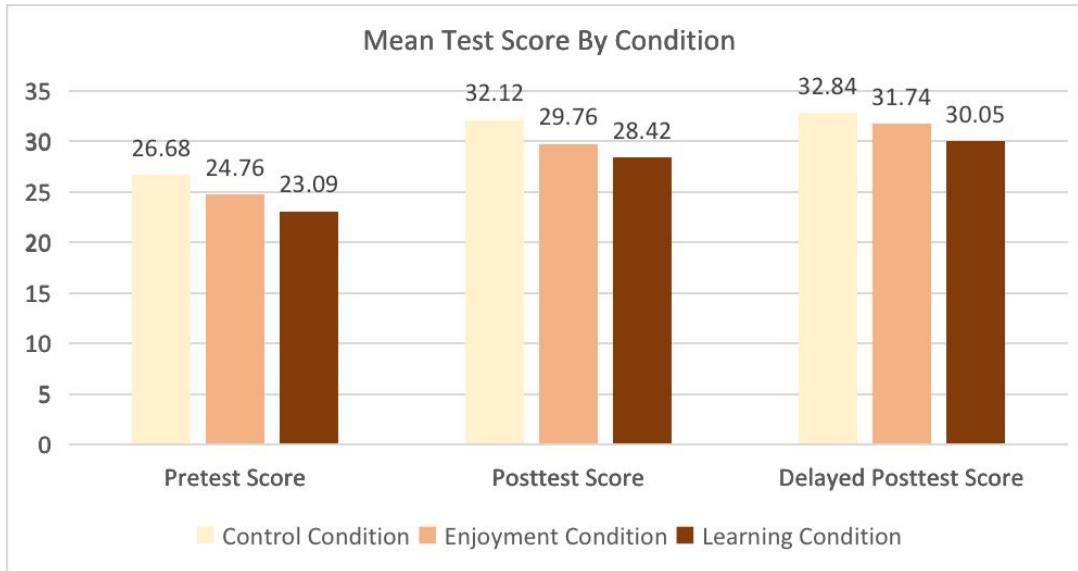
RQ1: Is there a difference in learning outcomes among students in the three conditions?

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?

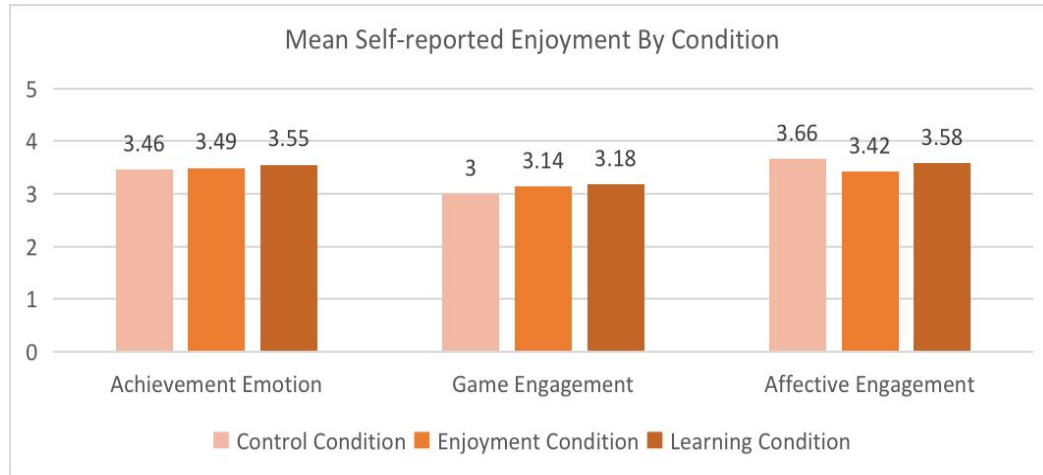
RQ1 - Is there a difference in learning outcomes among students in the three conditions?



No significant differences across conditions in

- Pretest scores (ANOVA)
- Posttest scores (ANCOVA)
- Delayed posttest scores (ANCOVA)

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



No significant differences
across conditions in

- 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?

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



No condition effect on learning or enjoyment

Results

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

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

No condition effect on learning or enjoyment

Number of mini-game rounds played

Replay rate

Mini-game rounds comparison by condition

Kruskal-Wallis test:

Significant differences across conditions in the number of mini-game rounds played.

Dunn's post hoc:

Control $(M = 45.08, SD = 18.40)$ $>$ **Learning** $(M = 33.20, SD = 9.86)$ $>$ **Enjoyment** $(M = 26.65, SD = 4.59)$

Replay Rate Comparison by Condition

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

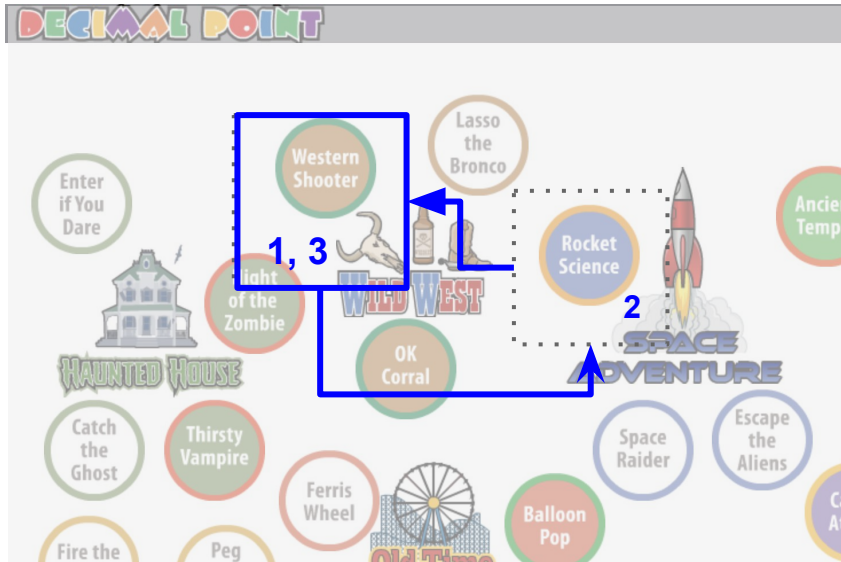


High: play more rounds of certain mini-games

Low: play a wider variety of mini-games

Replay Rate Comparison by Condition

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



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:

Students in the Learning Condition ($M = 0.44$, $SD = 0.20$) had **significantly higher** replay rates than those in the Enjoyment Condition ($M = 0.15$, $SD = 0.17$).

Replay Rate Comparison by Condition

Kruskal-Wallis test:

Students in the Learning Condition ($M = 0.44$, $SD = 0.20$) had **significantly higher** replay rates than those in the Enjoyment Condition ($M = 0.15$, $SD = 0.17$).

- 25/54 students the Enjoyment Condition: **trying out every available mini-game.**
 - “I really wanted to finish the whole map and see all the things filled in with color.”
- 17/55 students in the Learning Condition: **re-practicing until mastery.**
 - “I was trying to get all the decimal category skill bars full.”

Replay Rate Comparison by Condition

Kruskal-Wallis test:

Students in the Learning Condition ($M = 0.44$, $SD = 0.20$) had **significantly higher** replay rates than those in the Enjoyment Condition ($M = 0.15$, $SD = 0.17$).

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?

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

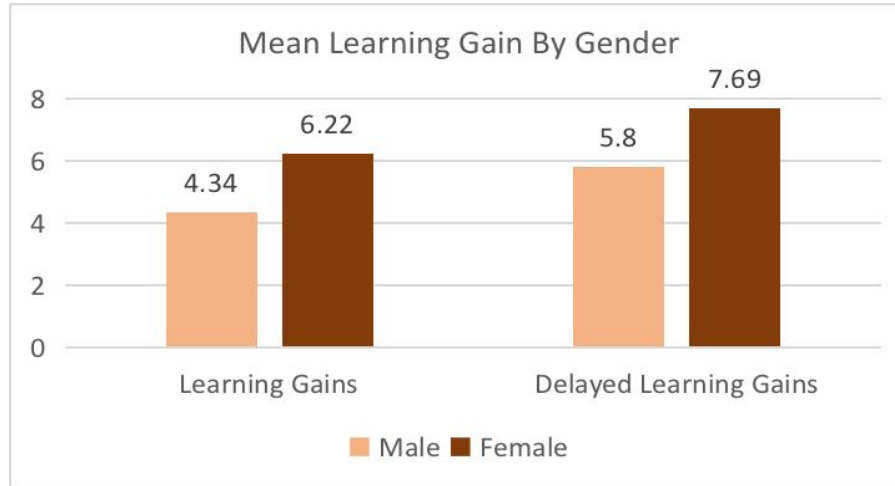
RQ4: Is there a difference in self-reported enjoyment between male and female students?

No condition effect on learning or enjoyment

Number of mini-game rounds played

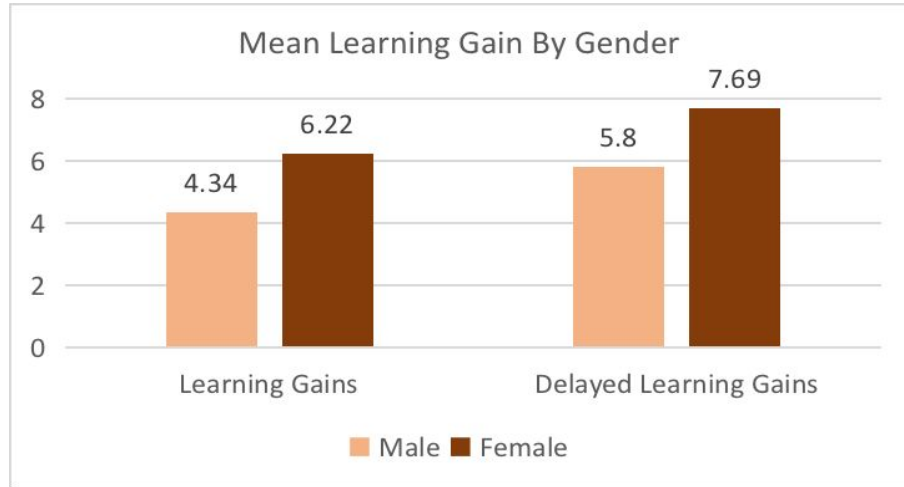
Replay rate

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 <ul style="list-style-type: none">• Learning gains• Delayed learning gains
Gender x Condition interaction effect	No significant gender x condition interaction effect <ul style="list-style-type: none">• Learning gains• Delayed learning gains

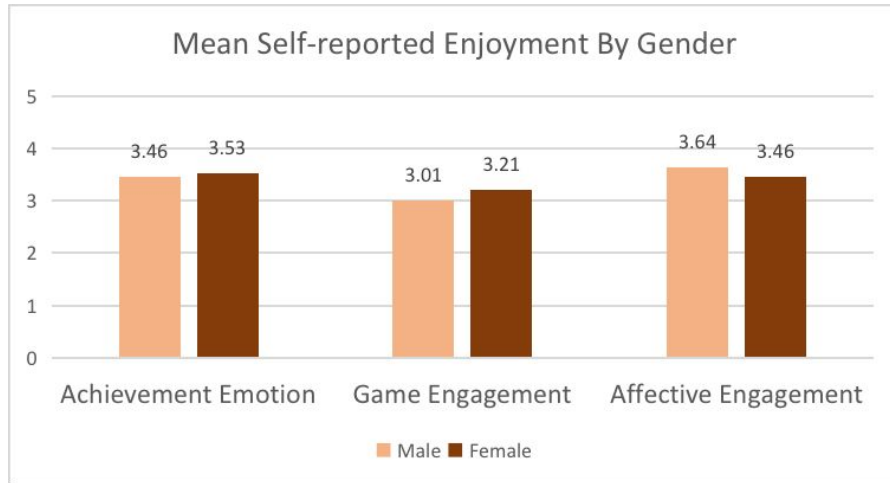
RQ3 - Is there a difference in learning outcomes between male and female students?



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

	Learning Gain (Two-way ANOVA)
Gender effect	Significant main effect of gender: Female > Male <ul style="list-style-type: none">• Learning gains• Delayed learning gains
Gender x Condition interaction effect	No significant gender x condition interaction effect <ul style="list-style-type: none">• Learning gains• Delayed learning gains

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

Results Summary

Across conditions:

- No condition differences in post-intervention learning or enjoyment.
- Number of mini-game rounds: **Control > Learning > Enjoyment**.
- Replay rate: **Learning > Enjoyment**.

Between genders:

- Females **learned more** than males across all conditions.
- No gender differences in enjoyment.

Discussion: 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**.

Discussion: 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**.
- **Real classroom environment** may have negated the playful atmosphere that the Enjoyment condition focused on. (Osman & Baker, 2012; Rice, 2007)

Discussion: Distinct gameplay patterns

Learning Condition

The screenshot shows a game interface with a red and yellow dotted border. The title is "Enter If You Dare". Below the title, there are instructions: "Help the ghost into the haunted house." and "Correctly place a decimal number on a number line." A link "Number Line" is provided. Below this, a section titled "How well you have mastered each skill" shows progress bars for "Number Line", "Sequence", "Bucket", "Sorting", and "Addition". The "Number Line" bar is red, while the others are yellow. Below this, a section titled "Recommended mini-games" shows three buttons: "Night of the Zombies", "Enter If You Dare", and "Ancient Temple".

Enter If You Dare

Help the ghost into the haunted house.
Correctly place a decimal number on a number line.

*** Number Line

How well you have mastered each skill

Number Line

Enter If You Dare Night Of The Zombies
Photo Safari Joust
Goal Lasso Bronco

Sequence

Bucket

Sorting

Addition

Recommended mini-games

Night of the Zombies Enter If You Dare Ancient Temple

Higher # of rounds and replay rates
Focused on **repeated practice** in each game type

Discussion: Distinct gameplay patterns

Learning Condition

Enter If You Dare

Help the ghost into the haunted house.

Correctly place a decimal number on a number line.

*** Number Line

How well you have mastered each skill

Number Line

Enter If You Dare Night Of The Zombies
Photo Safari Joust
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Sequence

Bucket

Sorting

Addition

Recommended mini-games

Night of the Zombies Enter If You Dare Ancient Temple

Higher # of rounds and replay rates
Focused on **repeated practice** in each game type

Enjoyment Condition

Enter If You Dare

Help the ghost into the haunted house.

Correctly place a decimal number on a number line.

*** Line Time

How well you have enjoyed each game type

Line Time

Enter If You Dare Night Of The Zombies
Photo Safari Joust
Goal Lasso Bronco

Pattern Perfect

Less or More

Arrange and Exchange

Mad Adder

Recommended mini-games

Night of the Zombies Goal Ancient Temple

Lower # of rounds and replay rates
Focus on **exploration** of different game types

Discussion: Distinct gameplay patterns

Learning Condition

Enter If You Dare

Help the ghost into the haunted house.
Correctly place a decimal number on a number line.

*** Number Line

How well you have mastered each skill

Number Line

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Sequence

Bucket

Sorting

Addition

Recommended mini-games

Night of the Zombies Enter If You Dare Ancient Temple

Higher # of rounds and replay rates
Focused on **repeated practice** in each game type

Blocked practice

Enjoyment Condition

Enter If You Dare

Help the ghost into the haunted house.
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How well you have enjoyed each game type

Line Time

Enter If You Dare Night Of The Zombies
Photo Safari Joust
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Pattern Perfect

Less or More

Arrange and Exchange

Mad Adder

Recommended mini-games

Night of the Zombies Goal Ancient Temple

Lower # of rounds and replay rates
Focus on **exploration** of different game types

Interleaved practice

Discussion: Gender effect in learning gains but not in enjoyment

Similar result from a prior study of *Decimal Point*.
(McLaren & Farzan et al., 2017)

- *Decimal Point* can help bridge the gender gap in math education.
- Next step: find out which feature of the game led to the gender effect.

Future Work

Learning:

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

Enjoyment:

- More **in-game measures and survey** questions to understand students' perception of game play in the classroom.

Generalizability:

- See if the same findings can be **replicated in a remote setting** without classroom pressure → relevant in the current COVID situation.

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!

Carnegie
Mellon
University



Human-
Computer
Interaction
Institute

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

Collaborators:

Xinying Hou, J. Elizabeth Richey, Bruce M. McLaren

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Related Publications

Hou, X., Nguyen, H.A., Richey, J.E., & McLaren, B.M. (2020). Exploring how gender and enjoyment impact learning in a digital learning game. In *Proceedings of the International Conference on Artificial Intelligence in Education*, pp. 255-268. [\[pdf\]](#)

Hou, X., Nguyen, H.A., Stamper, J, & McLaren, B.M. (2020). Moving beyond Test Scores: Analyzing the Effectiveness of a Digital Learning Game through Learning Analytics. In *Proceedings of the International Conference on Educational Data Mining*, pp. 487-495. [\[pdf\]](#)

Appendix: Follow-up analyses

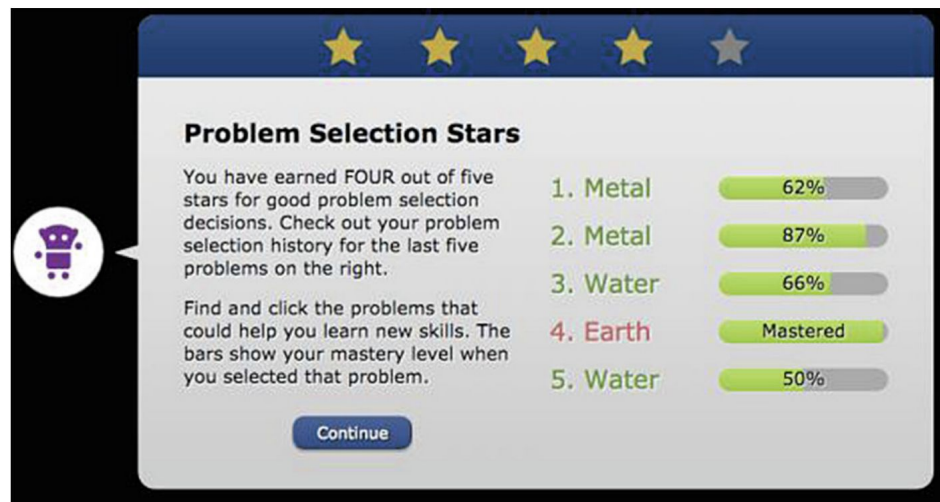
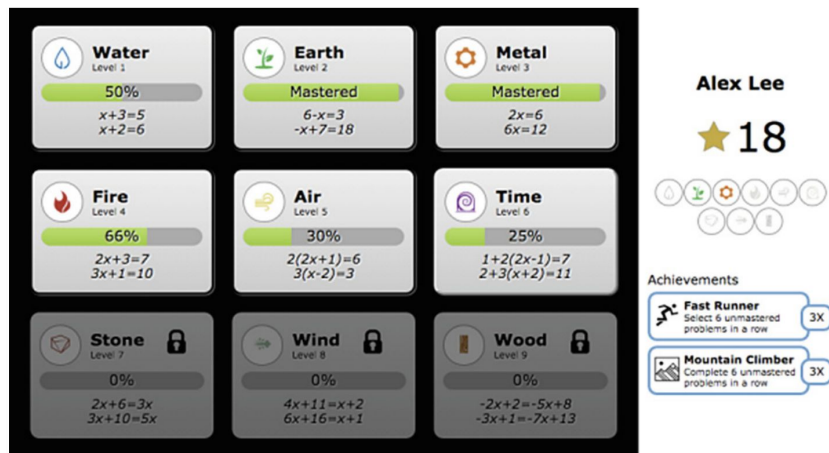
Females learned more than males in the test items that have **similar format** to the in-game exercises. (Hou, Nguyen, Richey, & McLaren, 2020)

Students' mastery in Number Line and Sorting are most predictive of their test performance. (Nguyen, Hou, Stamper, & McLaren, 2020)

Following the Learning Condition's recommendations led to **better in-game learning and test performance**. Following the Enjoyment Condition's recommendations did not lead to more enjoyment. (Hou et al., Under Review)

Q: Other ways to emphasize learning/enjoyment

Provide feedback on students' mini-game selection (Long & Aleven, 2016)



Q: 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

Q: Design rationale for open enjoyment model?

Our open enjoyment model analysis was motivated by whether optimizing for enjoyment would positively or negatively impact learning, given that enjoyment is often posed as a trade-off to learning (Greipl et al., 2018), but in some cases can be a conducive factor (Giannakos, 2013). This question is especially relevant for in-class studies, where players' sense of enjoyment may be offset by the classroom environment and teacher expectation

Q: 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.