Designing Math Games for Learning: CATS Project

Rebecca E. Buschang

Warp Speed, Mr. Sulu: Integrating Games, Technology, and Assessment to Accelerate Learning in the 21st Century

Redondo Beach, CA– April 29, 2014

cats
center for advanced technology in schools

National Center for Research
on Evaluation, Standards, & Student Testing
Graduate School of Education & Information Studies | cresst.org

CRESST

Talk Overview

- Project studies overview and studies
- Design process #1: Review log data during game design process to identify common successes and errors
- Design Process #2: Modify game based on log data findings
- Design Process #3: Involve teachers in studies with professional development

Center for Advanced Technology in Schools (CATS)

- 5-year research and development Center funded by the US Department of Education (IES)
  - ✓ *National Center for Instructional Technology*
- Led by CRESST, multiple partners nationally
- How can games and other technology tools be designed and implemented to optimally improve student learning?
  - ✓ *Initial focus: middle school math/algebra readiness*

Overall Project Research Questions

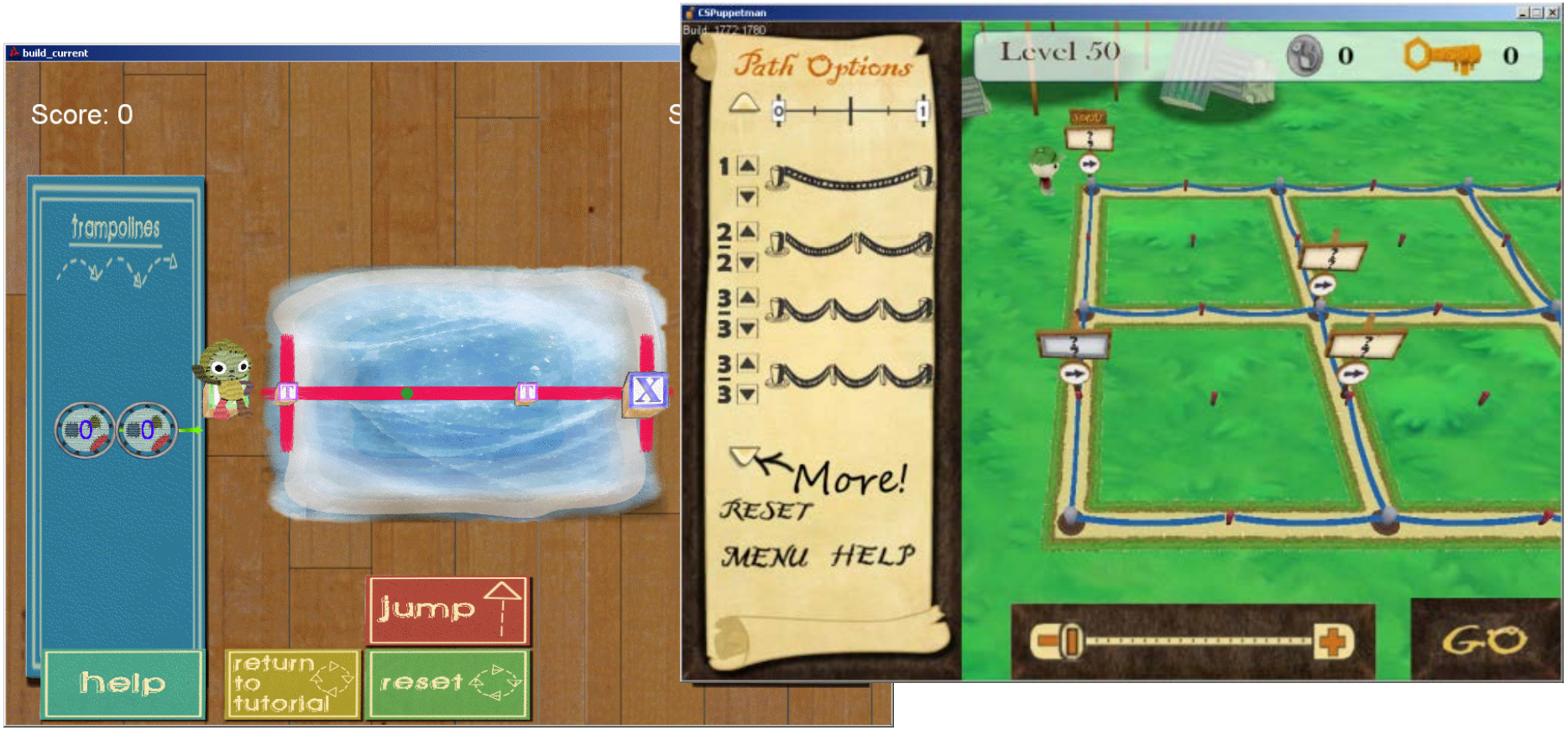
- To what extent do different game design features affect student outcomes?
- To what extent do environments that vary in structure and degree of supervision (e.g., classrooms, after school, homework) affect student outcomes?
- To what extent do student background characteristics interact with effects of the game on student outcomes?

CATS Games


Divide each whole unit into 4 equal pieces. Click the Divide button to start.
0
1
2
Path Options
Level1
RESET
MENU
Hello! I'll give you helpful tips from time to time. Use the A and D keys to walk left and right, and press W to jump!
3/2 Units
X
Y
change in Y = Y2 - Y1
change in X = X2 - X1
next Y = last Y + change in Y
next X = last X + change in X
For educational use only


Score: 900
Reset
26
FIRE
2
49
HOW DO YOU SOLVE
x+6 = 13
x+6 = 13
ADD
MULTIPLY BY
uses 2

Save Patch


build_current
Score: 0
trampolines
help
return to tutorial
reset
jump
CSPuppetman
Path Options
More!
RESET
MENU HELP
Level 50
0
0
GO

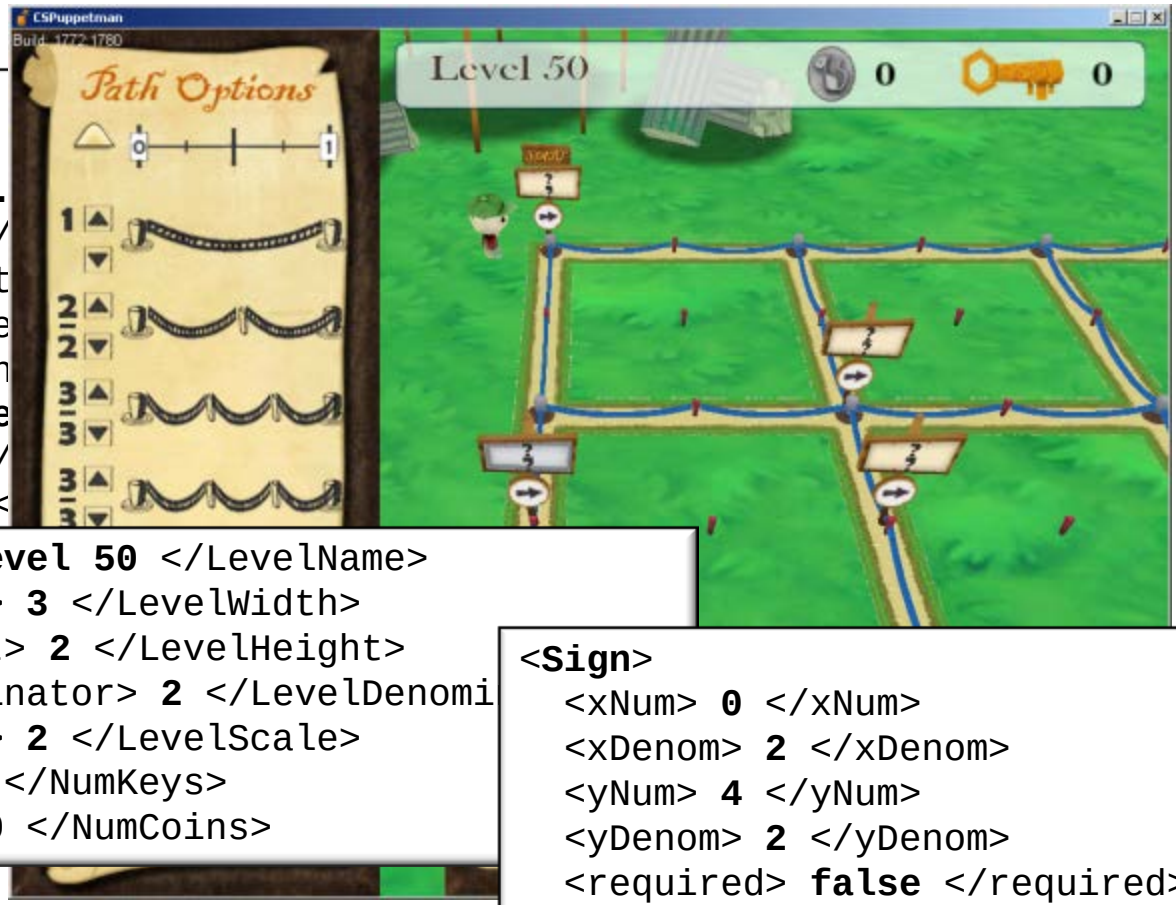
Instructional Design Studies

Study	*N*
Pilot test of the effects of in-game instruction and feedback on math and game performance	119
Effect of type of tutorial on math and game performance	142
Effect of feedback on math and game performance	184
Effect of format of tutorial and feedback on math and game performance	363
Effect of self-assessment on math and game performance	114
Effect of narrative on math and game performance	177
Exploratory study of the effect of collaboration on math and game outcome	137
Effect of scoring information as feedback, for motivation, and as rewards on math and game performance	128
Pilot test of in-game checkpoint problems	29
Aligning instruction and assessment with game and simulation design	34
Efficacy Study	1664

Important Design Process #1: Reviewing Log Data During Game Design

Log Data

```
<root>
  <verifylogins> false
  <loginfile> RNLogins.
  <hidescroll> false </
  <cheats> true </cheat
  <newFormat> true </ne
  <showbuild> true </sh
  <lockcharacters> true
  <levelselect> true </
  <onlyvisited> false <
</root>
```




```
<LevelName> Level 50 </LevelName>
  <LevelWidth> 3 </LevelWidth>
  <LevelHeight> 2 </LevelHeight>
  <LevelDenominator> 2 </LevelDenomi
  <LevelScale> 2 </LevelScale>
  <NumKeys> 0 </NumKeys>
  <NumCoins> 0 </NumCoins>
```

```
<Sign>
  <xNum> 0 </xNum>
  <xDenom> 2 </xDenom>
  <yNum> 4 </yNum>
  <yDenom> 2 </yDenom>
  <required> false </required>
  <optional> false </optional>
  <goal> false </goal>
  <start> true </start>
</Sign>
```

Error Identification in *Save Patch*

- Errors were identified through cluster analysis
  - ✓ *Cluster analysis is a type of data mining*
  - ✓ *Cluster analysis groups actions into action sets*
  - ✓ *One set of actions is done by one group of people, another set of actions is done by another group of people*
- Cluster analysis identified a majority of action sets performed in the game
- Cluster analysis identified two major mathematical errors: partitioning & unitizing

Log Data Study Example

- 244 students (115 males, 115 females, 14 not reported) played *Save Patch* for 40 minutes
- Computed average number of unitizing and partitioning errors made per level
- Multinomial logistic regression
  - ✓ *Dependent variables: learning and confusion*
  - ✓ *Independent variables: pretest score, low self-belief in math, positive game experience*
  - ✓ *Independent variables broken out into Algebra and Pre-algebra students*

Study Conclusion

- For Algebra students:
  - ✓ *Positive game experience, Partitioning errors = opportunity*
  - ✓ *Low self-belief in math, Unitizing errors = obstacle*
- For Pre-algebra students:
  - ✓ *Unitizing errors = obstacle*
- Students who can't identify the unit, can't learn from the game
- Students with sufficient math knowledge broaden their schema through partitioning errors

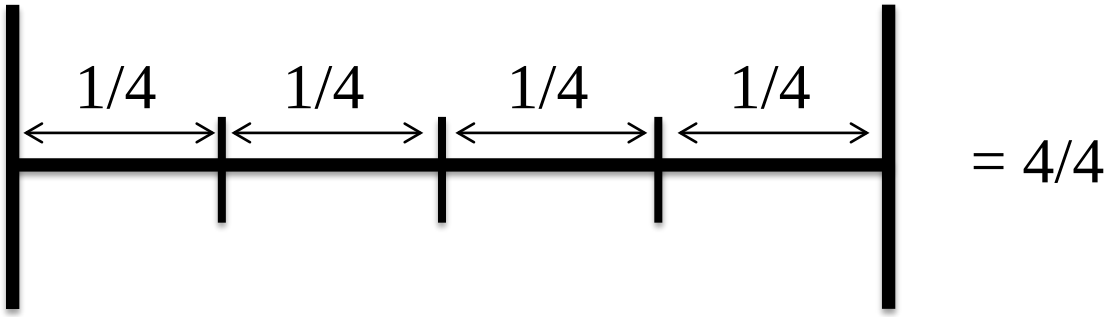
Important Design Process #2: Modify Game Based on Log Data Findings

Identifying Misconceptions

- Logged every action each student took
- Cluster analysis identified actions that occurred together
- Groups of co-occurring actions were examined by content experts
- Student strategies were identified

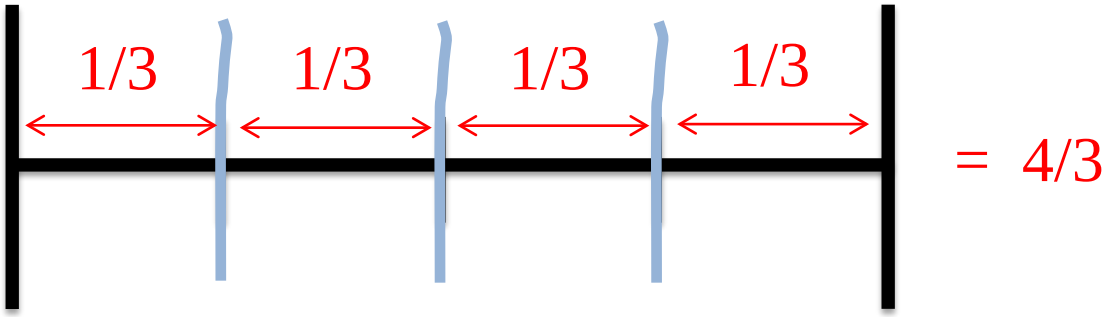
Partitioning Misconception

- Students believe the denominator is the number of dividing lines rather than the spaces between



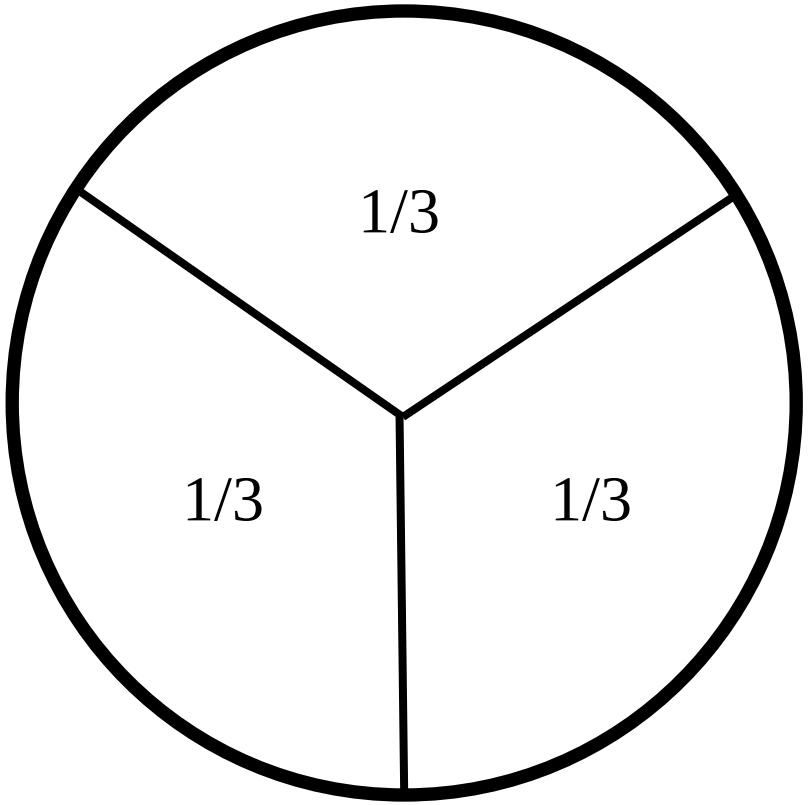
Partitioning Misconception

- Students believe the denominator is the number of dividing lines rather than the spaces between



Partitioning Misconception

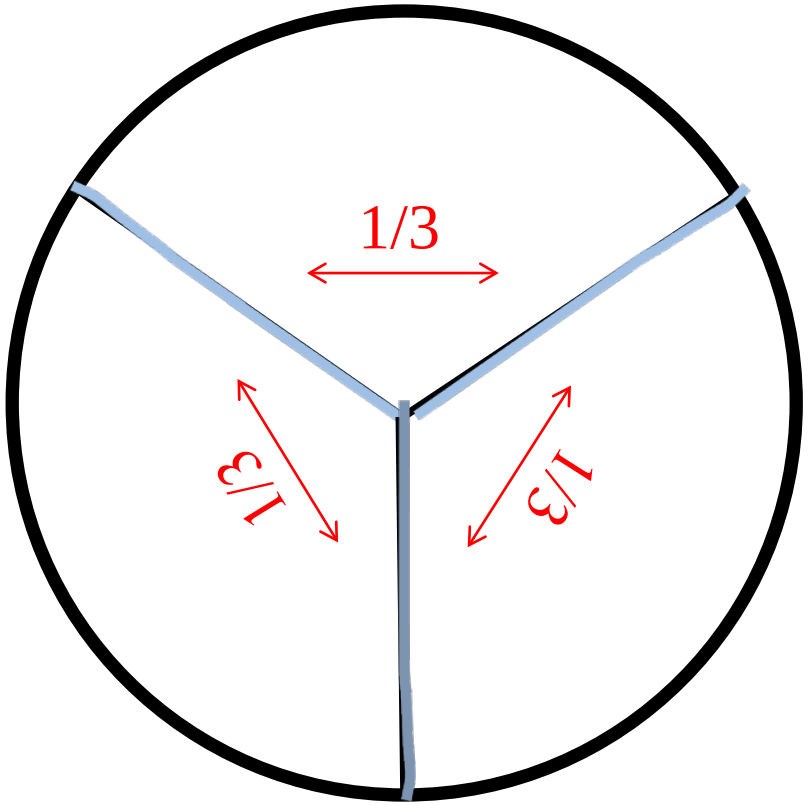
- True when the representation is a circle



= 3/3

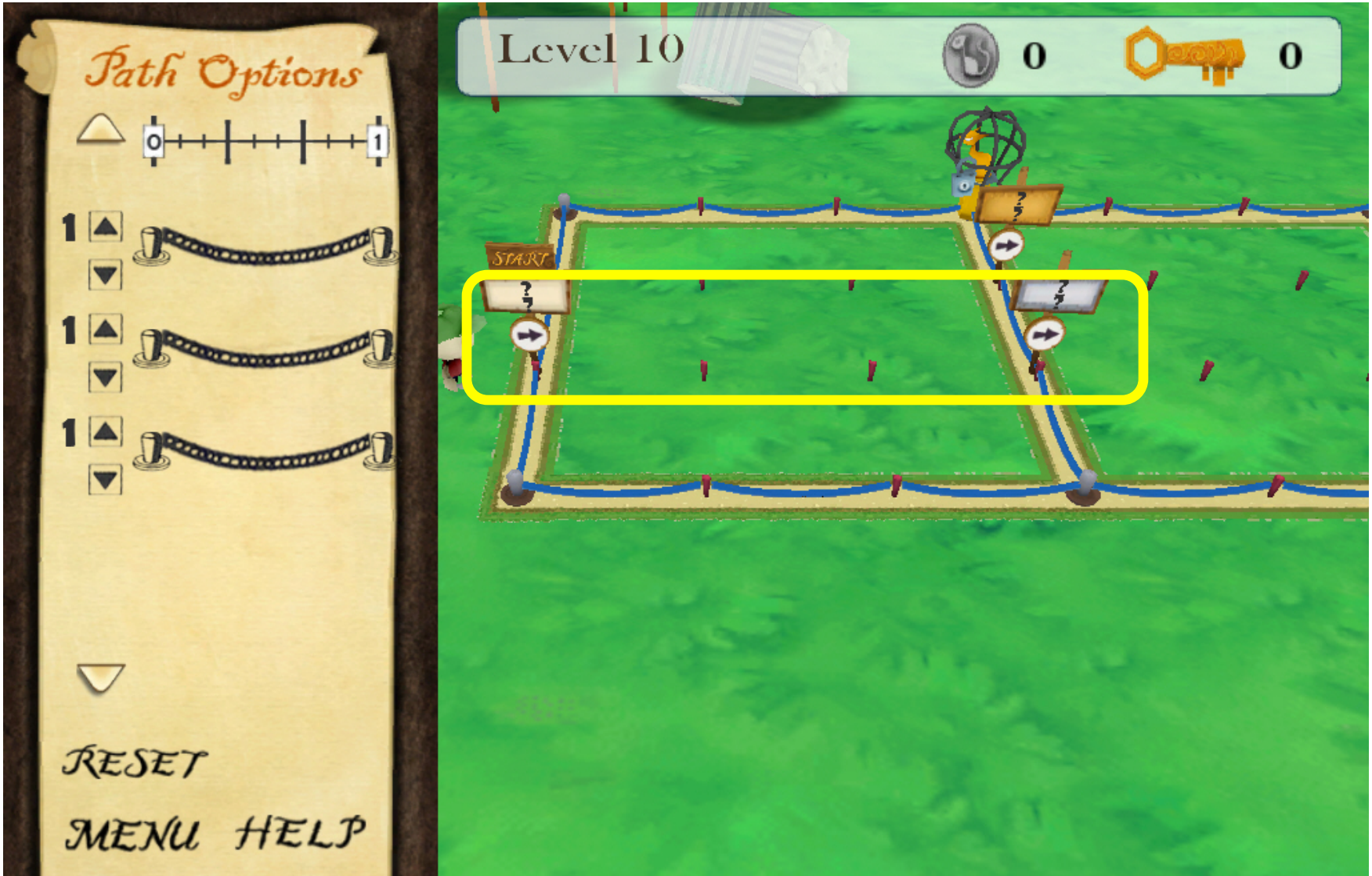
Partitioning Misconception

- True when the representation is a circle



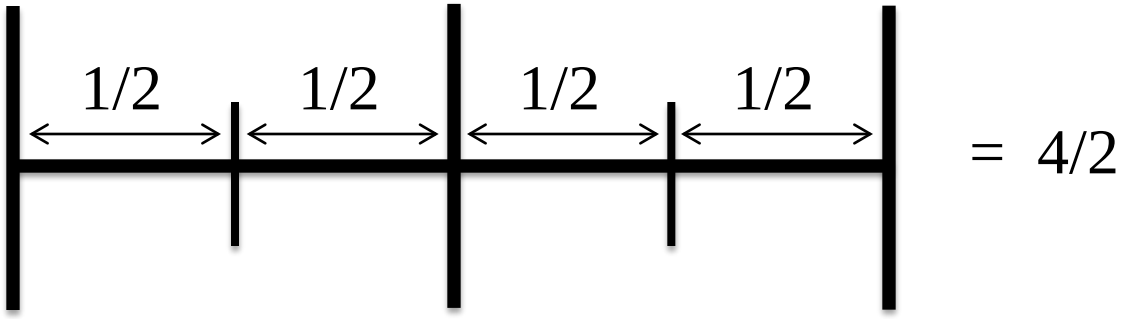
= 3/3

Incorporation of Misconception in Game



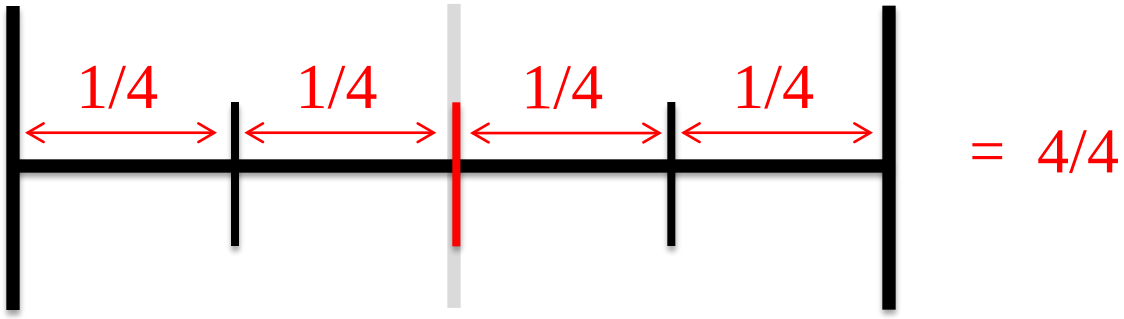
Unitizing Misconceptions

- Students believe there is always one unit in the representation

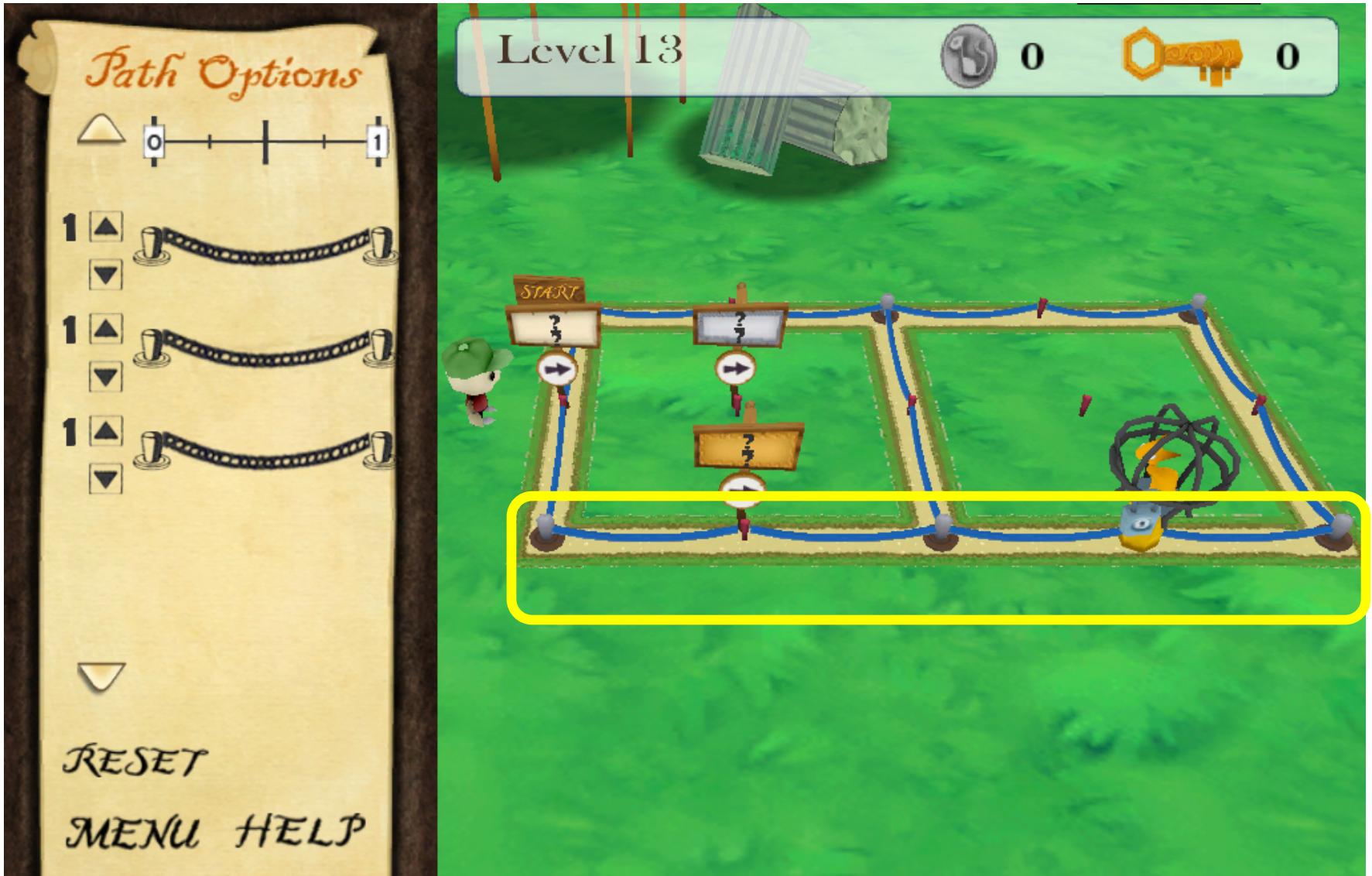


Unitizing Misconceptions

- Students believe there is always one unit in the representation

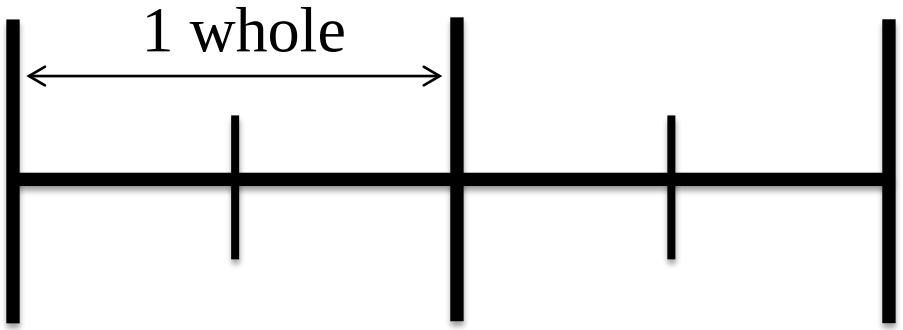


Incorporation of Misconception in Game



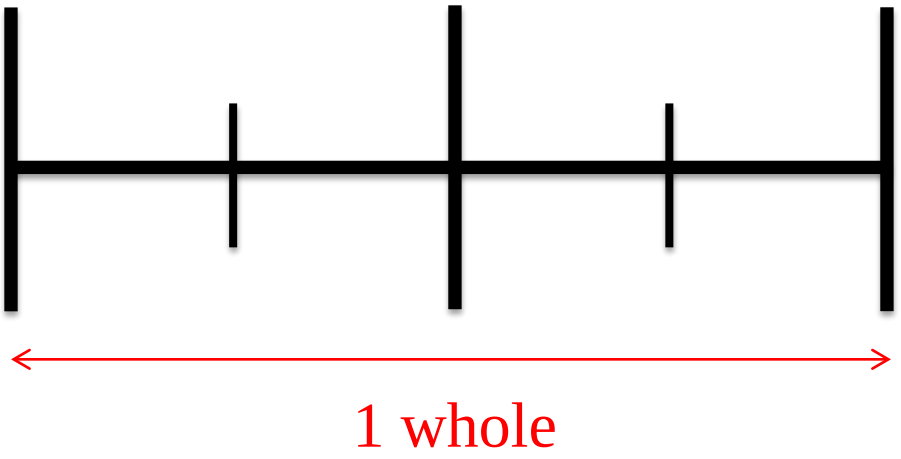
Other Misconceptions

- Students think a whole always has to start at zero and end at one

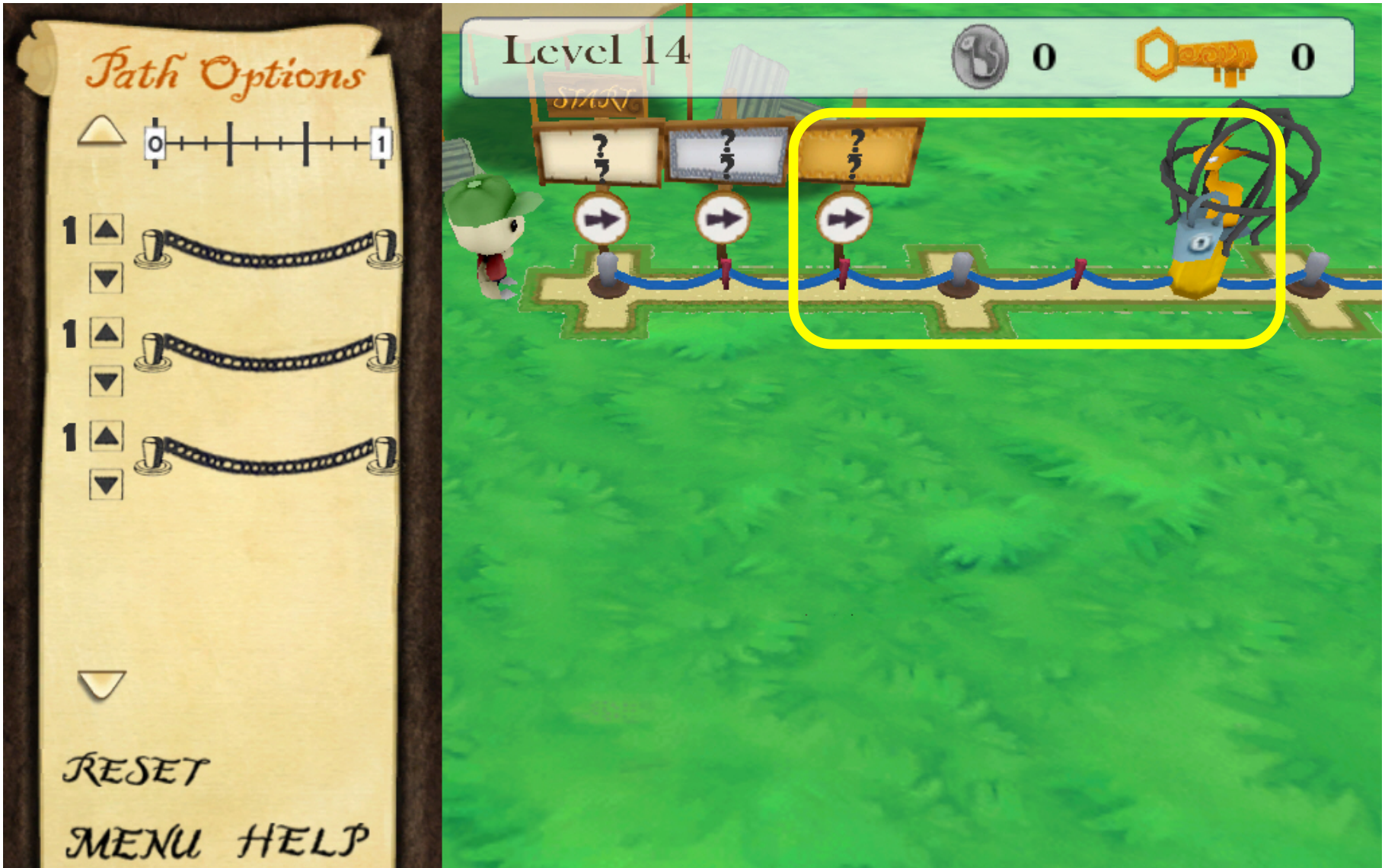


Other Misconceptions

- Students think a whole always has to start at zero and end at one

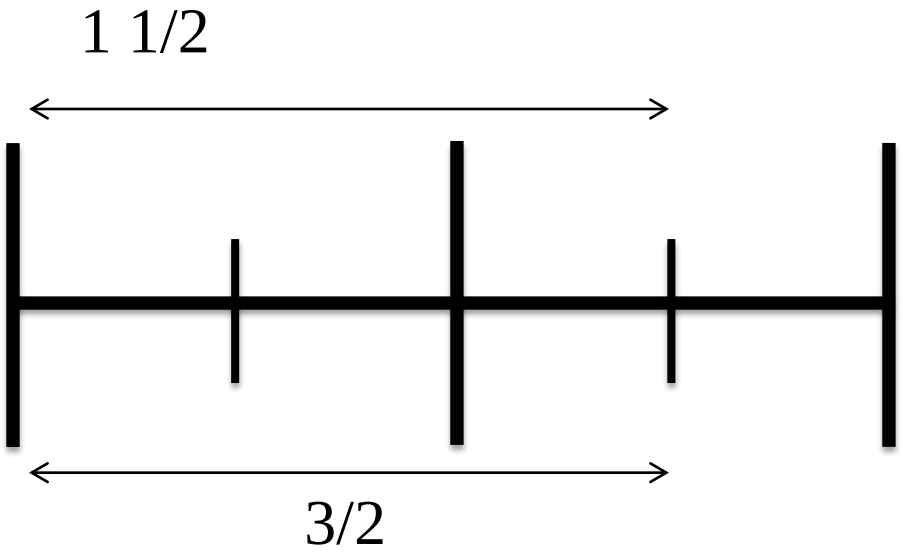


Incorporation of Misconception in Game



Other Misconceptions

- Students think a fraction must be a mixed number instead of an improper fraction.



Incorporation of Misconception in Game

Save Patch

- Identifying Fractions Stages:
  - ✓ *Identifying Whole Numbers*
  - ✓ *Identifying Unit Fractions*
  - ✓ *Identifying Unit Fractions and Whole Numbers*
  - ✓ *Identifying Whole Numbers That Cross the Unit Marker*
  - ✓ *Identifying Proper Fractions*
  - ✓ *Identifying Improper Fractions*

Important Design Process #3: Involve Teachers in Studies Through Professional Development

Professional Development in Efficacy Study 1

- 62 teachers
  - ✓ *32 rational numbers*
  - ✓ *30 control (solving equations)*
- 25 schools in 9 districts
- California and Nevada

Professional Development Design

- Teachers pre-assigned to condition
- Evenings and weekends
- One four-hour session
  - ✓ *Teachers given binder with PD content*
  - ✓ *Facilitators demonstrated how to introduce games to students*
  - ✓ *Teachers played all games/discussion*
  - ✓ *Administered survey*

Professional Development Survey: Self-report

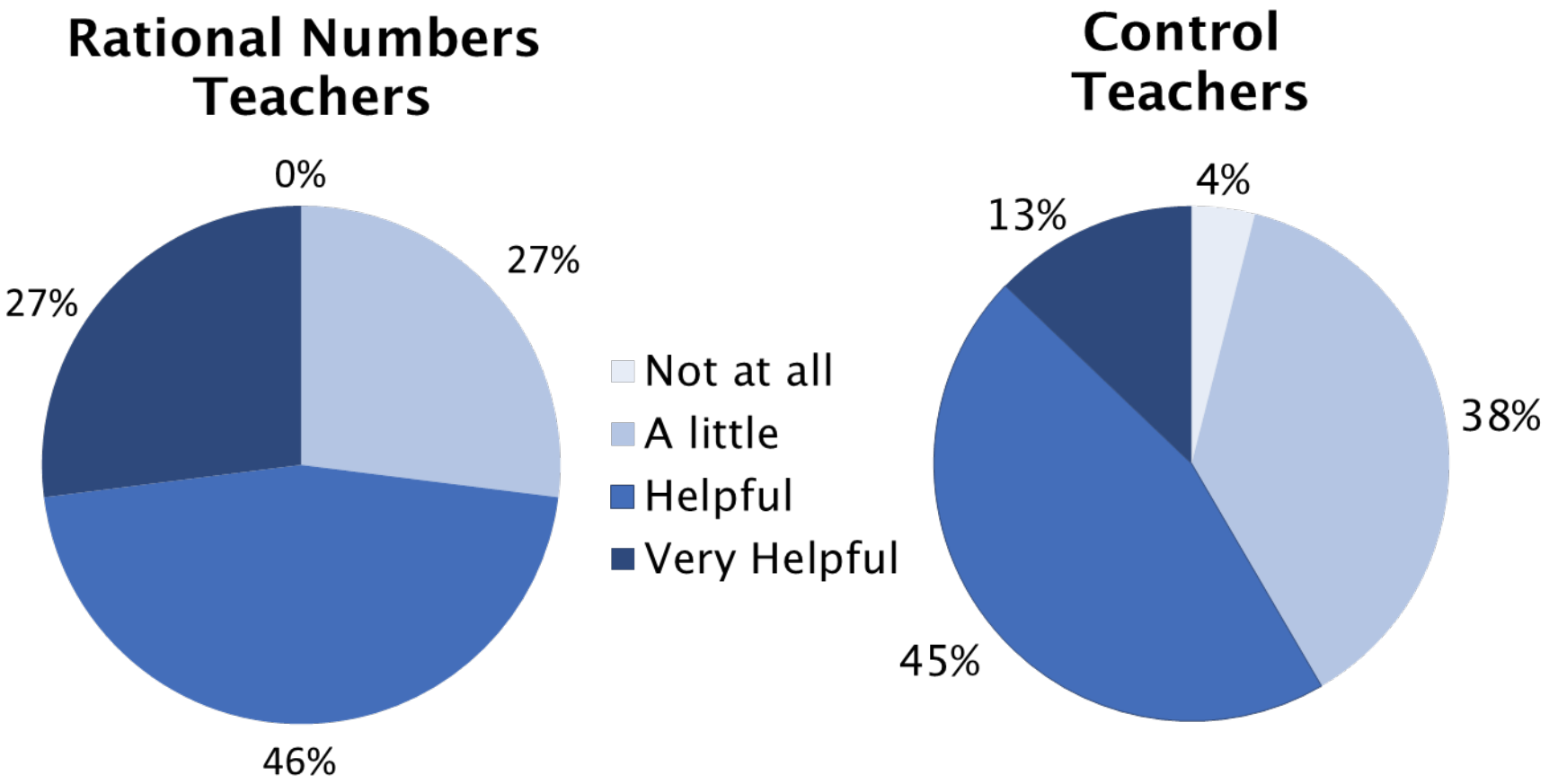
- Over 90% of teachers claimed to be prepared or very prepared to:
  - ✓ *give students instruction on the games*
  - ✓ *help students who have trouble with the games*
  - ✓ *explain math in the games*
  - ✓ *connect the games to classroom instruction*
  - ✓ *manage the classroom during game play*
  - ✓ *fill out teacher logs*

Post-Efficacy Study
Teacher Survey: Self-report

- Playing games was essential part of PD: 96-100% agree or strongly agree

The PD helped me understand…	Rational Numbers Teachers	Control (SE) Teachers
the key math ideas	89%	80%
student misconceptions that might show up in games	78%	72%
link of games to math instruction	66%	52%

How helpful were the games in helping students learn math concepts?



Design Process Overview

- Review log data during game design process to identify common successes and errors
- Modify game based on log data findings
- Involve teachers in studies through professional development

National Center for Research
on Evaluation, Standards, & Student Testing

UCLA | Graduate School of Education & Information Studies

VISIT US ON THE WEB

cresst.org