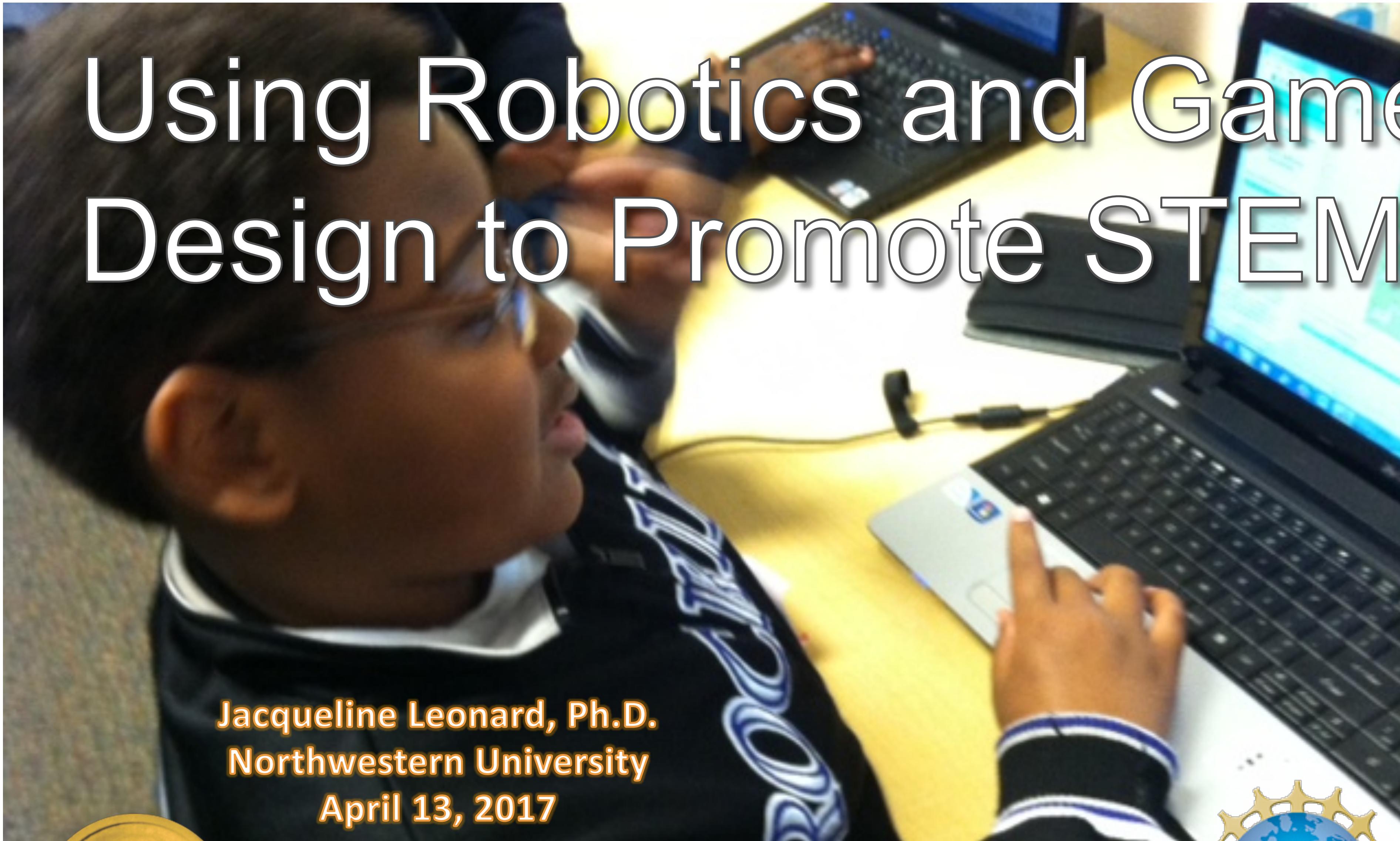
# Using Robotics and Game Design to Promote STEM



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# Visualization Basics: uGame-iCompute

- Funded by the National Science Foundation's Innovative Technology Experiences for Students and Teachers (ITEST) from 2013-2017
- Combines robotics and game design with cultural contexts to improve elementary and middle students' computational thinking (CT)
- Project was implemented in Wyoming and Pennsylvania

# Project Goals

- The project goals were:
  - Enhancing Students' Attitudes toward science, technology, engineering, and mathematics (STEM)
  - Enhancing Students' Computational Thinking
  - Providing Professional Development for Teachers
  - Enhancing STEM Content with Culturally Relevant Pedagogy (Ladson-Billings, 1995 & 2009)

# Rationale

- Need for mathematicians and computer scientists will grow by 22% and 24%, respectively over the next decade
- Computer science field growing rapidly (more than 50% of jobs will entail computing)
- Limited information about engineering careers
  – Robotics and game design are pathways to STEM careers (e.g., robots in car, medical, and shoe industry)

# Theoretical Framework

- Edelson (2001) Learning for Use (LfU)
  - **Connects previous knowledge** to new knowledge
  - Acquisition of knowledge is **goal directed**;
  - Acquisition of knowledge is **situated**;
  - Procedural strategies for supporting and reinforcing **incremental** learning
- Culturally responsive pedagogy (Gay, 2010)
- Zone of proximal development (Vygotsky, 1978)

# Literature Review: Equitable STEM Education

- ***Equitable teaching practices*** ~ term used in Kate Scantlebury's dissertation (1990)
- Goffney (2010) defined equitable mathematics teaching practices as a ***fair distribution*** of opportunities for underperforming groups to learn mathematics.
- Shah et al. (2015) described equitable computer science teaching as ***disrupting inequities*** that occur during classroom interactions.
- Leonard et al. (2016) defined equitable science teaching as ***increasing opportunities*** students have for science engagement.

# Literature Review: Robotics

- Provides students with rich, **hands-on experiences** that support teamwork and engagement in multidisciplinary tasks (Caron, 2010; Gura, 2012; Karp & Maloney, 2013)
- Advances knowledge of **engineering, scientific processes**, (Blanchard, Judy, Mueller, Crawford, & Petrosino, 2015; Nugent, Barker, Grandgenett, & Adamchuk, 2010) and **mathematical reasoning** (Gura, 2012; Karp & Maloney, 2013; Martinez Ortiz, 2015)
- Improves **spatial visualization skills, attitudes toward STEM** (Coxon, 2012; Julià & Antolí, 2016), and **computational thinking** (Sullivan & Heffernan, 2016)

# Literature Review: Digital Gaming

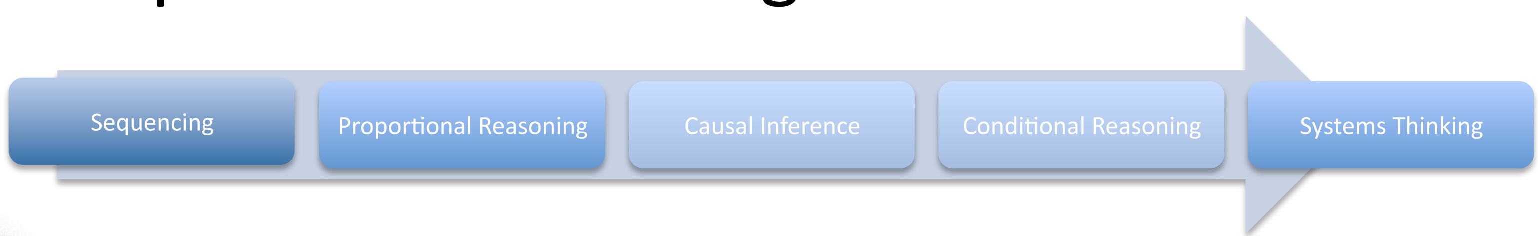
- K-12 students are part of a digital and gaming culture (Barr, Harrison, & Conery, 2011).
- Gaming and simulation design address middle school students' motivation and interest in computer science courses and careers (Webb et al., 2012).
- Software tools have been used successfully with elementary and middle school students.
  - Scratch (Israel et al., 2015; Mouza et al., 2016)
  - Scalable Game Design (Repenning et al., 2015)

# Literature Review: Computational Thinking

- CT emerged from Papert's LOGO work (1993).
- ISTE defines computational thinking as formulating problems; logical thinking; representation of data through abstractions; algorithmic thinking; analyzing and implementing possible solutions; and generalizing and transferring the problem-solving process (ISTE & CSTA, 2011).
- We used the ISTE framework to assess CT in game design and the modified learning progression model to assess CT in robotics.

# Literature Review: Learning Progressions

- Learning progressions mark those intermediate learning points between the two ends or anchors (NRC, 2007).
- We adapted Sullivan and Heffernan's (2016) learning progression model to promote computational thinking in robotics.



# Research Questions

1. How did students' self-efficacy in technology (SETS) and Student Attitudes toward STEM (SATS) change after participating in a blended robotics and game design summer camp?
   – How did students' pre-post scores on the SETS differ by learning environment (i.e., rural vs. urban)?
   – How did students' posttest scores on the SETS and SATS surveys differ controlling for race and gender?
2. How did rural and urban children's computational thinking (CT) compare and contrast during robotics and game design?
3. What aspects of the learning environment and activities contributed to focal students' interest and participation in robotics and game design?

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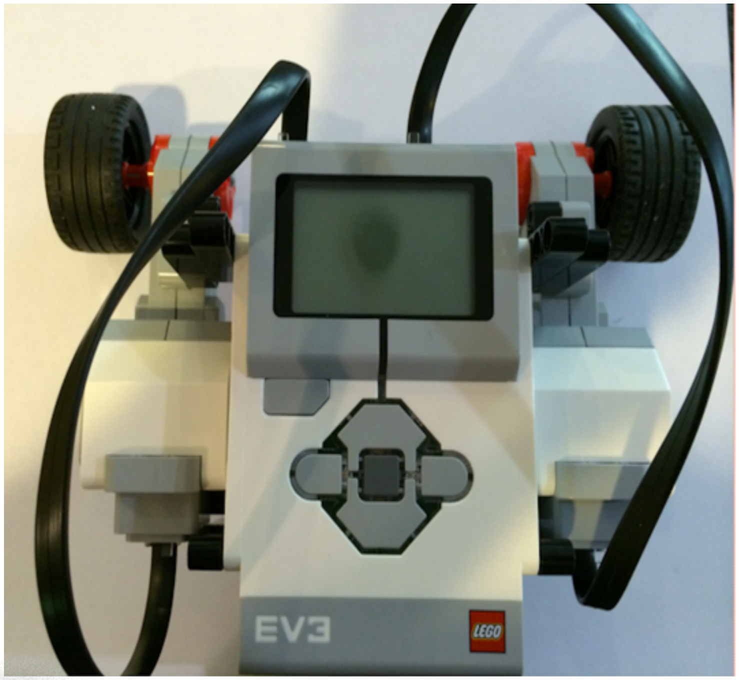
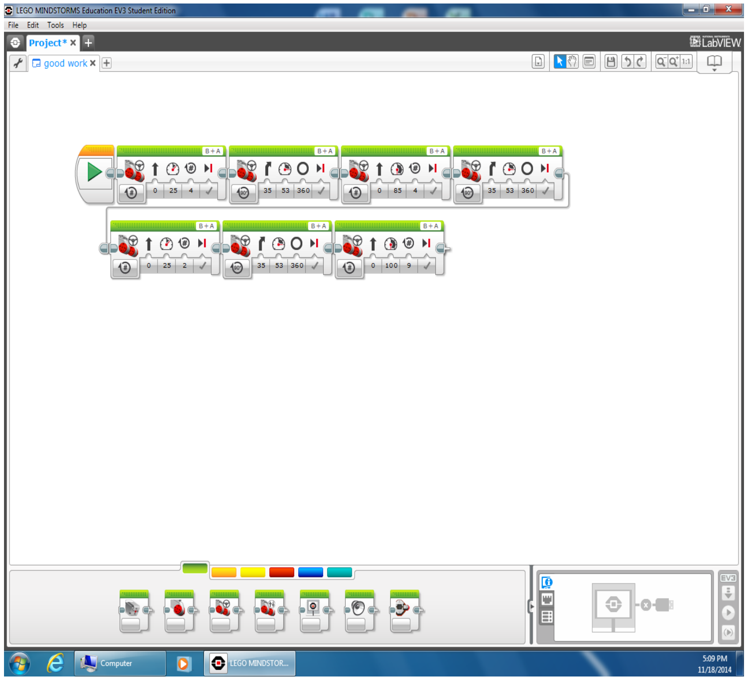
# Learning Contexts: LEGO® EV3 Robotics ~ Part 1

**Five-Minute Bot**

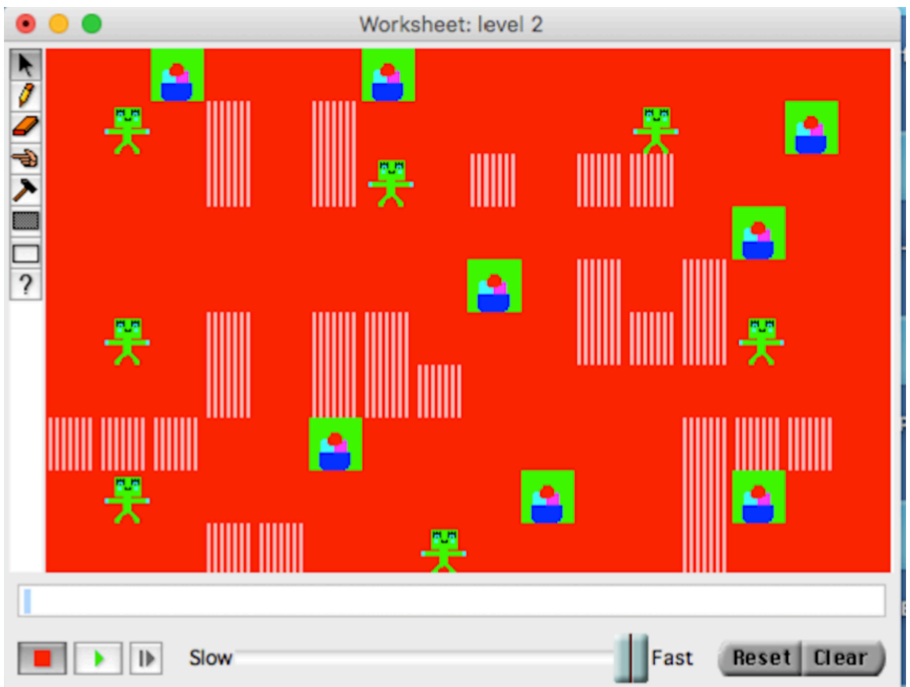



**Sample Mindstorms Code**

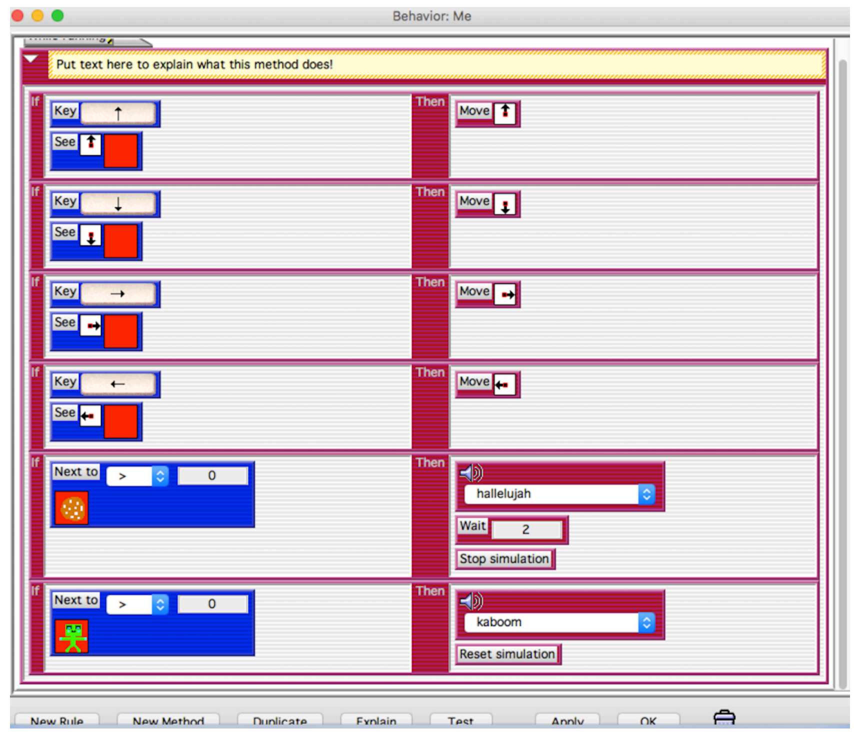


# Learning Contexts:
# Scalable Game Design ~ Part 2

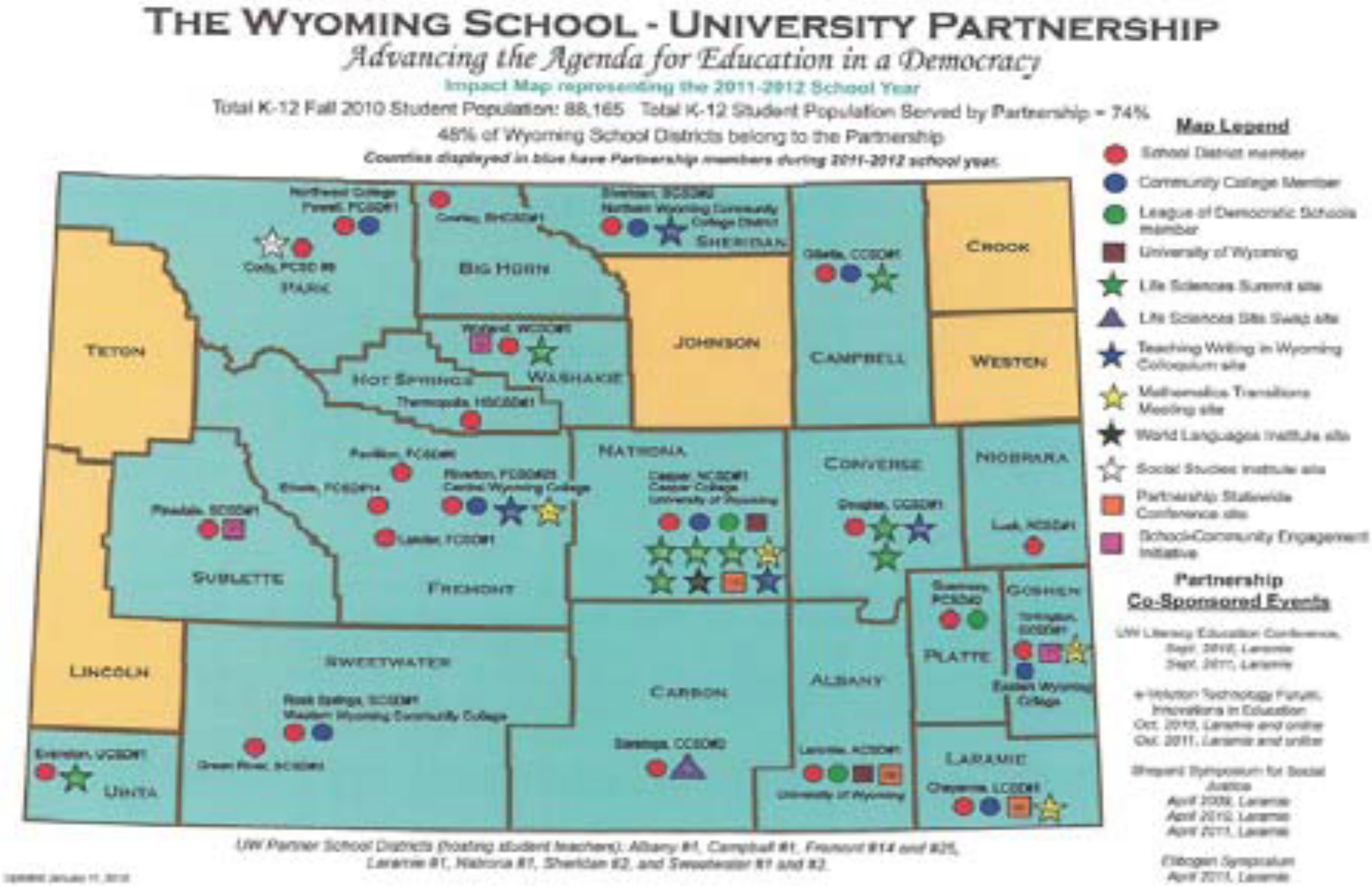
**Sample Maze Game**




**Code for Maze**



# Sample: Wyoming



# Wyoming Participants

- Twelve School Districts
- Statewide Demographics
  - 77.8% White
  - 15.3% Latin@
  - 3.6% Asian
  - 2.2% American Indian
  - 2.1% African American
  - 2.5% Two or more races
- Year 1: 8 Schools
  - 11 Teachers
  - 124 Students
- Year 2: 15 Schools
  - 27 Teachers (21 new)
  - 314 Students
- Year 3: 16 Schools
  - 25 Teachers (12 new)
  - 365 Students
- Summer Program
  - 3 Teachers
  - 28 Students

# Sample: Pennsylvania

- First Tier Suburban School District (four elementary schools)
  - 91% African American
  - 3.8% White
  - 2.1% Latin@
  - 3% Other
- Teachers and Students
  - Academic Year
    - 8 teachers
    - 90 students
  - Summer Program
    - 4 teachers
    - 2 interns
    - 35 students

# Starbase Summer Program

- When: August 3 – 14, 2015 (9 am – 3 pm)
- Where: Starbase, Cheyenne, Wyoming
- What: Robotics and Game Design
- How: Funding by National Science Foundation
  - Parents dropped students off
  - Lunch and snacks provided each day
  - Field trips to NCAR/Wings over the Rockies

# Temple Summer Program

- When: June 22 – July 1 (8 am – 3 pm)
- Where: Temple University, Philadelphia, PA
- What: Robotics and Game Design
- How: Funding by National Science Foundation
  - Yellowbird Bus Company transported students from to Temple each day (Teacher/facilitator chaperones)
  - Lunch and snacks provided each day
  - Field trip to Franklin Institute/Campus tours

# Data Sources: Quantitative

- Self-Efficacy in Technology and Science (SETS) survey (Ketelhut, 2010)
  - Three Constructs
    - Videogaming (8 items)
    - Computer gaming (5 items)
    - Using the computer to solve problems (5 items)
- Student Attitudes toward STEM (SATS) survey (Friday Institute, 2012)
- Two Subscales
  - Engineering/Technology (9 items)
  - 21st Century Skills (11 items).

# Data Sources: Qualitative

- Questionnaire to gather data during focus group interviews with several students after attending the summer camps.
- Constant comparative method (Strauss & Corbin, 1990) used to determine participants' learning and interest in STEM.
- Open-coding procedures (Glaser, 1978) and QDA Miner (Lewis & Maas, 2007) for patterns and themes.

# Wyoming Survey Results

| Survey | Pre-Survey Mean | Standard Deviation | Post-Survey | Standard Deviation |
|---|---|---|---|---|
| SETS (n=21) | | | | |
| Videogaming | **4.32** | **0.59** | **4.22** | **0.65** |
| Computer gaming | **4.08** | **0.76** | **4.04** | **0.68** |
| Using the Computer | **4.05** | **0.99** | **4.04** | **0.80** |
| SATS (n=21) | | | | |
| ENG/TECH | **3.87** | **0.80** | **3.93** | **0.72** |
| 21st Century Skills | **4.12** | **0.72** | **4.24** | **0.65** |

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# Pennsylvania Survey Results

| Survey | Pre-Survey Mean | Standard Deviation | Post-Survey | Standard Deviation |
|---|---|---|---|---|
| SETS | | | | |
| Videogaming (n=33) | **4.11** | **0.74** | **4.04** | **0.74** |
| Computer gaming (n=31) | **3.90** | **0.80** | **4.16*** | **0.64** |
| Using the Computer (n=32) | **4.19** | **0.68** | **4.19** | **0.65** |
| SATS | | | | |
| ENG/TECH (n=32) | **4.05** | **0.79** | **4.23** | **0.61** |
| 21st Century Skills (n=24) | **4.28** | **0.69** | **4.39** | **0.58** |

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# Results: ANCOVA

- The Analysis of Covariance (ANCOVA) was used to determine if there were significant differences on the posttests.
- Covariates were race (Black/White) and gender (male/female).
- Significant main effects on the ENG/TECH posttest by race: $F(1,47) = 17.961$, $p = .000$, partial Eta square = 0.28. However, the effect size is small.

# Comparison of Wyoming & Pennsylvania Students

| Participants | Construct | n | M Post-test | SD | Participants | Construct | n | M Post-test | SD |
|---|---|---|---|---|---|---|---|---|---|
| Black | Videogaming | **28** | **4.08** | **0.79** | White | Videogaming | **22** | **4.22** | **0.62** |
| | Computer Gaming | **26** | **4.22** | **0.67** | | Computer Gaming | **22** | **4.05** | **0.64** |
| | Computer Use | **27** | **4.24** | **0.70** | | Computer Use | **22** | **4.12** | **0.71** |
| | ENG/TECH | **28** | **4.30*** | **0.59** | | ENG/TECH | **22** | **3.88*** | **0.71** |
| | 21st century Skills | **21** | **4.48** | **0.57** | | 21st Century Skills | **21** | **4.18** | **0.65** |
| Females | Videogaming | **18** | **3.86** | **0.81** | Males | Videogaming | **36** | **4.24** | **0.62** |
| | Computer Gaming | **18** | **4.02** | **0.68** | | Computer Gaming | **34** | **4.15** | **0.64** |
| | Computer Use | **17** | **4.06** | **0.78** | | Computer Use | **36** | **4.16** | **0.69** |
| | ENG/TECH | **17** | **4.09** | **0.74** | | ENG/TECH | **36** | **4.12** | **0.64** |
| | 21st Century Skills | **16** | **4.56** | **0.47** | | 21st Century Skills | **29** | **4.19** | **0.65** |

# Item Analyses: SETS Computer Gaming Construct (Pennsylvania,*n*=31)

| Item number | Mean Pretest | Mean Posttest | Gain Score |
|---|---|---|---|
| 1. No matter how hard I try, I do not do well when playing computer games. | 3.88 | 4.03 | 0.15 |
| 2. I can keep winning at computer games for a long time. | 3.42 | 3.66 | 0.24 |
| 3. I can learn how to play any computer game if I don't give up. | 4.27 | 4.22 | (0.05) |
| 4. I am very good at building things in simulation games | 3.65 | 3.85 | 0.20 |
| 5. I can figure out most computer games. | 3.70 | 3.94 | 0.24 |

# Students Working on Robotics

**Temple Program ~ Summer 2016**

**Starbase ~ Summer 2015**

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# Learning Progressions: Wyoming

| Robotics Tasks | Sequencing | Proportional Reasoning | Causal Inference | Conditional Reasoning | Systems Thinking |
|---|---|---|---|---|---|
| Basic Programming | X | X | X | X | |
| Sensors | X | | X | X | X |
| Loops & Switches | X | X | | X | |
| Obstacle Courses | X | X | X | X | X |

# Learning Progressions: Pennsylvania

| Robotics Tasks | Sequencing | Proportional Reasoning | Causal Inference | Conditional Reasoning | Systems Thinking |
|---|---|---|---|---|---|
| Basic Programming | X | X | X | X | |
| Sensors | X | | X | X | X |
| Obstacles Courses | X | X | X | X | X |
| Music & Sound | X | | X | X | |

# Engagement in Game Design

**Temple Program ~ Summer 2016**

**Starbase Program ~ Summer 2015**

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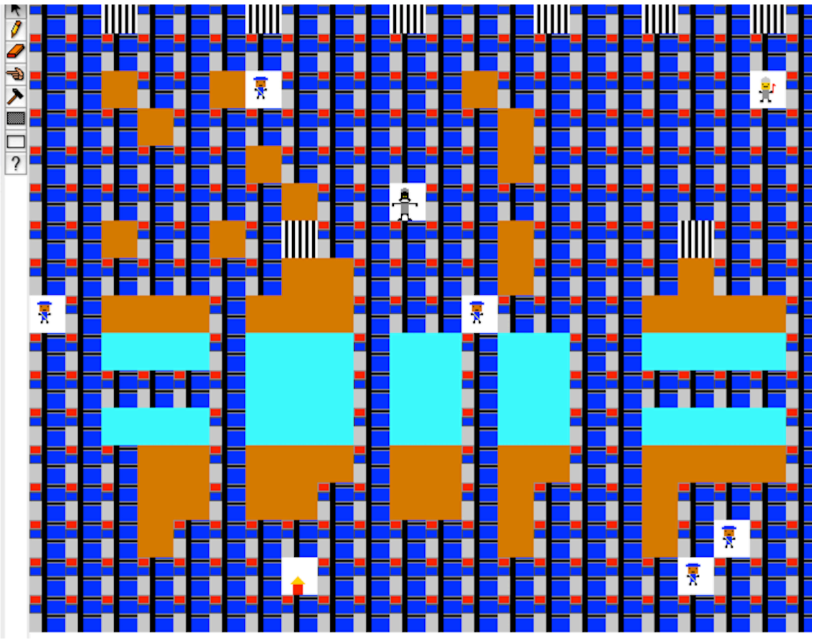
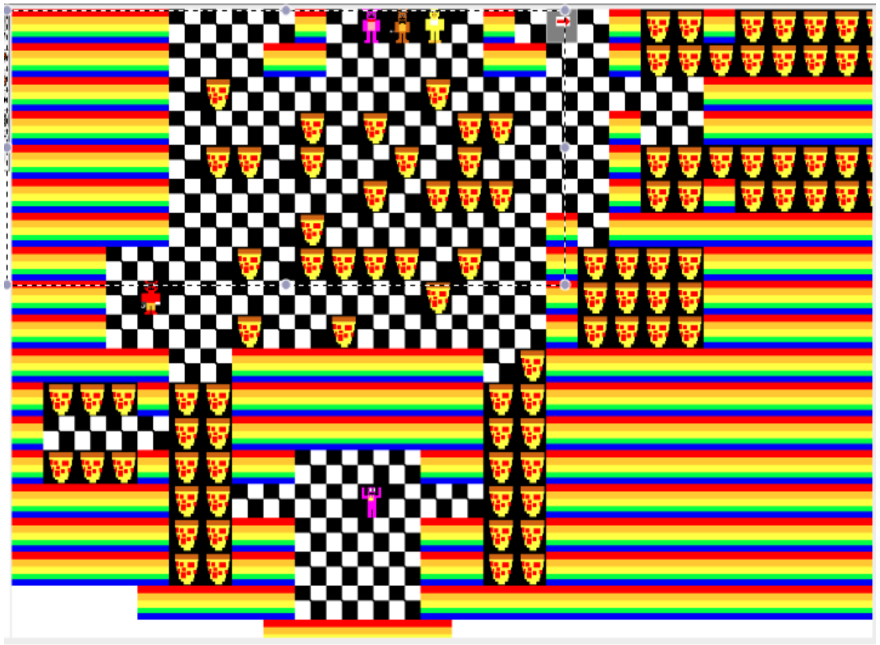
# Examples of Students' Games

**Pennsylvania ~ Maze**



**Wyoming ~ PacMan**



# Comparison of CT Strategies: Wyoming (*n*=18) & Pennsylvania (n=14)

| Sample | Problem Formation | Abstraction | Logical Thinking | Algorithms | Analyzing & Implementin g | Generalizing & Transfer | AVG |
|---|---|---|---|---|---|---|---|
| WY | 2.33 | 2.67 | 2.17 | 1.94 | 1.89 | 2.00 | 2.17 |
| PA | 2.28 | 2.21 | 2.21 | 1.71 | 1.71 | 1.86 | 2.00 |

# Focus Group Interviews: Robotics

| Wyoming Focus Group Responses | Pennsylvania Focus Group Responses |
|---|---|
| Interviewer: What one or two things did you think were cool about participating in robotics? | |
| Student 1: What I thought was cool about participating in robotics was that we got to build our own robots and try out different things with our sensors, and we got to activate our robots….<br><br>Student 2: I liked building the robots, and I also liked programming the robots and finding out how far you could make the thing go.<br><br>Student 3: I liked it so much I have been to [this facility] three times…two camps and once at school.<br><br>Student 4: I like building robots and putting on the sensors. | Student 1: What I thought was cool was how we was able to make actual live robots, and I also liked that we were able to program different types of video games.<br><br>Student 2: Um, what I liked about it was how we got to make LEGO robots that actually move and we got to program them ourselves instead of just getting them from the store and just playing with them.<br><br>Student 3: I liked how we got to make the robots out of LEGOs because usually LEGOs take a very long time to put together and to start moving 'cause you have to push it, but it was neat how we got to use the iPads to control them…<br><br>Student 4: I liked that we could do it with groups so we could get everyone's idea about how the robot would be built… |

# Focus Group Interviews: Game Design

<table>
<tr><th>Wyoming Focus Group Responses</th><th>Pennsylvania Focus Group Responses</th></tr>
<tr><td colspan="2">Interviewer: What one or two things did you think was cool about gaming?</td></tr>
<tr><td>Student 3: What I liked about the gaming was that we learned how to make our own avatar thing out the little pixels, and programming was fun, too.<br><br>Student 4: I get to create my own game. Just creativity, and you can actually play the game.<br><br>Student 6: I like what we are doing right now with PacMan. My favorite game was my first game. I made snakes, and it was really fun. I think snakes are cool.<br><br>Student 7: I like how you can make it impossible for people to beat your game and that the teacher told me she never tried [a game like mine] before.</td><td>Student 3: I also like how we programmed the games and created our characters.<br><br>Student 4: I like how we got to customize our characters and program them and I also liked how we could program our games and people could actually play them.</td></tr>
</table>

# Emergent Themes

- Themes that positively impacted students' interest and participation robotics and game design:
  - Opportunities for tinkering or self-exploration within the learning environment
  - STEM activities that allowed for self-expression and creativity.
- Themes that negatively impacted students' participation in robotics and game design:
  - Engaging in activities that were deemed as overly difficult;
  - Engaging in practices and activities that were interpreted as prescriptive in nature;
  - Limited roles during robotics

# Discussion

- The results of this sub-study reveal four important findings:
  1. Urban students scored significantly higher on computer gaming from pre- to posttest compared to rural students.
  2. Black/African American students had stronger interests in engineering/technology than White students.
  3. Learning progressions provided compelling evidence that robotics lessons provided rural and urban students with multiple opportunities to use CT strategies (Sullivan & Heffernan, 2016).
  4. Rural and urban students had opportunities to learn CT during game design, which implies equitable teaching practices (Goffney, 2010; Shah et al, 2015).

**Wyoming ITEST RESEARCH TEAM**

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