Technology for Games in Argentina

An Interactive Qualifying Project Report
Submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE

by

____
Olivia Bogs

Approved: ____
Professor Ivon Arroyo, Project Advisor

Table of Contents

1. Abstract

The following studies aim to explore whether games children in the U.S. and in Argentina create vary within countries and between countries, and what those variations might be. Data was gathered using a specific coding guide. It was found that games do vary both within and between countries; U.S. games had a greater emphasis on technology while Argentina games had a greater emphasis on math concepts.

2. Introduction

As far back as humanity has records of, children have been creating playing games. Common childhood games include tag, hide-and-seek, and many others. Children play social games such as these to improve their social interactions with other children. Play is natural; it is how children learn, develop, and grow.

In our modern world of technology, another type of game has become commonplace: video games. Now that this technology has become a common household item, it is expanding its boundaries over into the educational world. Educational computer games have been increasingly used in the classroom as a learning tool to provide enrichment, reinforce the curriculum, and keep students engaged. And, with this technology becoming more popular in schools, not only is game playing being used as a learning tool, but so is game creation.

Although the types of games children create may vary depending on a variety of factors, especially the instructions and resources they are provided for game creation, generally the games children create demonstrate and improve their understanding of programming knowledge, and understanding of whatever subject the game may be about. When given the opportunity to create an educational game, children often create games based off of what is familiar or what they are currently learning in school.

It is important to take a closer look at the type of educational games children create to better understand if games can be an effective learning tool. As popular as games - and the computer science knowledge needed to create them - are becoming in schools, only 45% of U.S. schools teach computer science, according to code.org, a national organization that helps students learn computer science. By analyzing the types of games children create, we can understand whether game creation is a useful and valuable enough tool to consider implementing on a larger scale, and provide all schools with game creation as a potential teaching tool or curriculum supplement to help students not only learn computer science, but also math or other subjects.

The Wearable Learning Cloud Platform is a website where children can create mobile math games. Using this platform, American children in grades seven and eight and Argentine children in grades six and seven created games for math learning. Through analysis and comparison of their games, the resulting data can be used to answer the following research questions: What kinds of games do middle school students create when provided specific instructions and requirements? Do games vary between countries? Do games vary within the country? If so, how?

3. Background Research

Video and computer games have only been around for about sixty years. The first video game was created in 1958 (Tretkoff, 2008) and this technology has grown exponentially since then. As the popularity and quality of video games has increased over the decades, so have its uses in society. Video games originally started out as a tool for simulation for the military. Then they rooted hold in public as arcade games, and eventually with the invention of personal computers and home video game consoles, video games became a standard household form of entertainment, especially for children.

Now, video games have a place in the classroom as well. In schools, games are used as learning tools. Take, for example, websites such as Kahoot.com, which is used as a study tool, or prodigygame.com, a website with math games for first through eighth grade children, with customizable curriculum-based content and a theme much like that of the popular video game Pokemon. There are even typing programs that function as games to help children learn how to use a keyboard. Games have become such an excellent education tool due to their engaging and motivating nature. While playing games has become an excellent learning tool for children of all ages, actually creating the games is an emerging method that may reap even more benefits.

Research on game creation is relatively new, given that video games are a relatively new technology. Most research on game creation as a tool for learning began in the nineties and is still a growing topic, with game playing still the standard over game creation. While game playing can reinforce topics by repeatedly exposing children to its educational content, game creation helps children learn in a different way. Game creation helps children learn and grow in several different areas. The first area is in coding. Creating games exposes children to basic programming concepts, such as loops, and other program logic (Kafai, 2015, pg. 318). Game creation also improves children's understanding of the content present in the game. Yasmin Kafai conducted a study where fourth grade children created math games designed to teach younger children fractions. At the end of the study, not only had children's understanding of programming improved, but so had their understanding of fractions (Kafai, 2015, 320).

The Wearable Learning Cloud Platform team is curious of the value of children creating games in the classroom (Harrison et al., 2018b, Hulse et al., 2018). Is this a valuable tool worth implementing on a larger scale? Do kids get value out of game creation? The Wearable Learning Cloud Platform (WLCP), developed by WPI students and faculty (Arroyo et al, 2017), is software that allows children to program their own games, and upon completion of the programming, then play their own games. The WLCP is student-friendly as it does not require users to have any prior programming experience. It is a visual-based programming language - meaning it uses drag-and-drop style boxes called "states" to represent each stage of the game, and arrows known as "transitions" to connect the states - see Figure 1 for an example. This style of game programming, known as a finite state machine (FSM), makes it easy for children to use and understand, while building their logic skills and understanding of coding - this is known as Computational Thinking (CT).

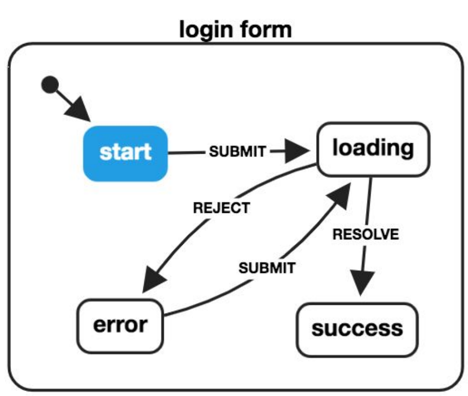

Figure 1: *An example of an FSM representing logging into a website.*

The WLCP provides a platform for children to practice using FSMs to create mobile math-related games, that use cell phones to support individual players (Micciolo et al., 2018). The WLCP is a platform to help children learn mathematics by playing physically active, highly social games that involve mobile devices such as cell phones (Arroyo et al., 2017; Micciolo, 2018). The WLCP provides an outlet for students to use game creation as a means of learning.

The WLCP features three different “modes”. The first is a game editor mode which allows users to create games, as previously mentioned. The second is a game player mode, which is usually accessed via mobile device, and allows users to play the games created in the game editor mode. Lastly, there is a game manager mode, which is used for setting up a game for playing. The name of the desired game is selected from a drop-down menu, and an instance - essentially a new game session - is created and assigned a unique number which players use to join the game in the game player mode.

Two key games created using the WLCP are *EstimateIt!* and *Tangrams Race*. In *EstimateIt!*, players are split into three teams consisting of three players each. Various objects representing geometric three-dimensional shapes, such as pyramids, spheres, cubes, and triangular prisms, are scattered around the room. On each object is a paper with a unique color code. Each player uses a cell phone to login into the Player mode of the WLCP and receives various questions. Each question provides a measurement, and then asks the player to find the object in the room that best matches the provided measurements. Once a player finds an object they believe is the same dimension as the measurements provided in the question, he or she enters the color code found on the paper attached to the object into a text input box in the game.

If the color code corresponds to the object that correctly answers the given question, the player is given a new question. If the color code corresponds to an incorrect answer, the player is informed of the error and asked to reattempt the question. The game continues until a set time limit is up. Figure 2 shows a screenshot of what *EstimateIt!*'s code looks like in the WLCP, represented as an FSM.

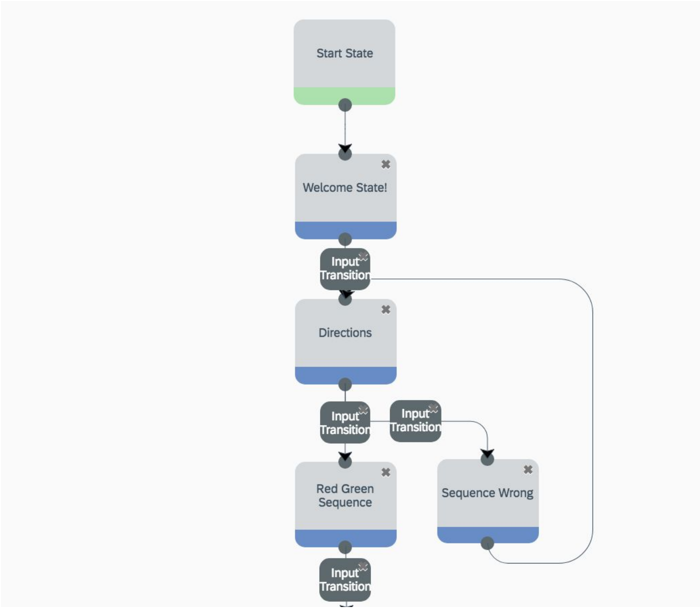

Figure 2: EstimateIt! - *a game created using the WLCP.*

In *Tangrams Race*, players are also split into three teams of three. The teams are placed on one side of the room, and on the opposite side of the room are three piles of foam tangram pieces, one pile for each team. Like the three-dimensional objects in *EstimateIt!*, attached to each tangram is a piece of paper with a unique color code for each tangram. When the game starts, each player receives a question describing a tangram in the pile using geometric terms, referencing number of angle or sides, or type of angles or sides, such as right angles or parallel sides. One person at a time leaves the team and searches for the tangram that matches the given description, and enters its corresponding color code.

4. Research Plan

The research for this project is broken up into two parts. The same study and procedure was repeated in the United States and in Argentina. In the U.S. study (Study 1), participants were seventh and eighth graders attending a summer camp. In the Argentina study (Study 2), participants were sixth and seventh grade students from three different schools in Córdoba, Argentina. In each study, children were given a set of criteria to create games that use math, physical activity, and technology. Using a special coding guide, the games created by each study's participants were analyzed and turned into quantitative measures that represent game elements. The data set from each study were then compared. The main research question these studies are trying to answer is: *Are there differences in the games students from two different countries create when asked to create games for math learning? What are those differences, if they exist?*

5. Study 1: The USA Study

5.1 Methodology

Participants. Seven groups totaling twenty-one students participated in this study. Students were part of a summer camp on game development at a university in the northeastern U.S.; they were seventh and eighth grade students. The summer camp was a paid summer camp, and as a result the students may have been of various socio-economic status but were likely middle to middle-high, but not low, socioeconomic status.

Procedure. The procedure for this study was conducted over the course of five days, with each daily session lasting for about sixty minutes.

During day one, students were presented with explanations of the activities that followed. During the first day, they played the *EstimateIt!* game and were also given a questionnaire to assess their CT before starting. (This questionnaire is not relevant to the specific research question this paper aims to explore; this questionnaire was administered due to a separate, unrelated study being conducted at the same time as this procedure. This questionnaire is referenced throughout this paper because it contains examples of FSMs and may be an influencing factor on the results from day three of this study). The purpose of playing *EstimateIT!* was to give the participants an understanding of educational games, specifically ones that involved physical activity, math, and cell phones for each player.

During day two, students worked in groups of three to design a math game on large paper pads. They were given a worksheet with the following instructions: Create a game that is designed for third and fourth grade students; teaches or reinforces a specific math concept; requires the players to perform a physical activity or movement that is related to the math concept, and requires players to use mobile technology. Based on these criteria, the groups of students each used their pad of paper and markers to write out the rules for their games, as well as draw a picture representing or further explaining the game.

During day three, students received a slideshow presentation introducing FSMs. A simple FSM representing a door being opened and closed was included in the presentation. The presentation then explained that *EstimateIt!* was an example of an FSM. Students were shown what the finite state machine diagram (FSMD) for *EstimateIt!* looked like via the game editor mode in the WLCP. Then, students were shown examples of educational games represented as FSMDs on pads of paper, and were asked to turn their written games from day two into FSMDs.

Students were allowed to adjust their games if needed to better fit the structure of an FSMD, or even create an entirely new game if the game could not be easily adjusted or adapted. At the end of the third day students logged into the WLCP and setup their games for development the following day.

During day four, students implemented their games in the WLCP game editor based off of the FSMDs they had drawn on paper during day three. During day five, students finished any last minute details or bugs in their games before groups took turns showcasing their games to the rest of the students. Additionally, each student repeated the same questionnaire from day one as a posttest (the implementation of this postest is irrelevant to this paper's research question, much like the pretest).

Measures. The games created by the children were all analyzed by using a custom coding guide that was created by the WLCP team to code student productions (see Appendix A). This coding guide breaks the games down into basic categories, such as the math concepts present in the game, physical actions present in the game, use of technology in the game, and how closely related these concepts are to each other. The coding guide also analyzes the children's level of understanding of basic programming concepts by analyzing the FSM materials present in the game.

In order to use this coding guide, one must first be trained using a two-stage training procedure to ensure accuracy. In the first stage, the trainee must code at least three games with results that are in at least eighty percent agreement with the master coding guide, or pre-existing data for games that have already been coded using the guide. In the second stage, the trainee and a master coder - someone who has successfully completed training and is certified to code games using the coding guide - must be in at least eighty percent agreement with each other after coding at least three of the same games.

There are two parts to the coding guide - the guide itself as well as an answer sheet to record the coded values for a game. Both are attached in Appendix A. This coding guide is very large and contains many sections. The data from this study has been broken into tables that correspond with each major section of the coding guide to keep data grouped in a more easily readable format. In addition, some sections may feature two or more tables per heading due to the nature of the coding guide. Some variables in the coding guide are based on a zero or one scale: is this element not present (zero) or present (one) in the game? In the results, this data is represented as a percentage of occurrence, demonstrating what percentage of games out of the total games analyzed have this element present. Other variables in the coding guide are based on an increasing number scale, where each number signifies a various level of depth, presence, or specification of the game element in question. Additionally, there are several variables that use a zero/one scale not to represent whether a game element is present or not, but to represent a style of gameplay. This data is represented as averages (along with standard deviations), demonstrating how well-developed these concepts were (if present at all) in the seven games, with the averages corresponding to the number scale for that specific variable in the coding guide.

In the following results section, some variables do not have data from all fourteen groups, or do not have data at all. This is due to some variables being dependent on the responses to previous variables - for example, if a game does not have team-based gameplay, then any following variables in the guide referring to teams will not have data for the given game. Other times, some games were so underdeveloped that no information for a given variable could be reasonably assumed and was not coded at all.

Additionally, each table features columns for data from both days two and three of the procedure, as the games created on each day are treated as separate entities when coded with the guide, rather than two parts of a single game. During day two of the procedure, participants created written instructions and occasionally drawings to describe their game. These elements are coded as one entity and recorded as day two data. During day three of the procedure, participants created FSMDs representing their games created during day two. However, because participants have the option to change or add aspects of the game, the FSMDs are treated as an entirely new game when coded and are recorded as separate, day three data. Below, the coding guide is summarized by section. A coding guide for a single game from Study 1 is attached at the end for further clarification, in Figures 3 through 8.

General Game Characteristics

This section of the coding guide aims to analyze the main features of the game in terms of content. *Game Descriptor* reflects whether the game is a unique idea or based off of an existing game. An existing game could be a video game or computer game, a board game, or a game already created with the WLCP (for example, *EstimateIt!* or *Tangrams Race*) as it is not uncommon for participants to base their games off of the game provided as an example during the day one procedure. *Content* uses a list of variables to note the presence or absence of types of mathematics in the game. *Targeted Grade Level* is an increasing scale variable that measures whether the game mentions a target audience, with zero being unspecified and one through four representing various levels of school. *Progressive Levels* denotes whether the game gets more difficult as the player progresses through the game. Content Adaptability denotes whether the game has an option to change its content depending on the player's math ability, age, or any other characteristic. *Game Facilitator* represents to what degree the game specifies the presence of a helper or manager to run the game. *End-Goal* marks the presence or absence of a win condition which marks the official end of gameplay.

Technological Descriptors

This brief section analyzes the use of technology in the game. *Technological Incorporation* notes whether the game uses technology, or in other words makes an *explicit* mention of technology - participants are aware that the games they are creating are meant to be played on cell phones or some other technological device and often fail to explicitly mention the use of technology in the game; for example, specifically using the words "cell phone" or "computer" at any point.

Technological Dependency measures how heavily integrated technology is in the context of gameplay. Depending on the game rules and mechanics, some games implement technology in such a way that the game could easily be adapted to a paper and pencil version and played entirely without technology. Other games may use the technology in such a way that there is no possible way for the game to be played without the use of technology.

Team Descriptors

All games participants create can be classified as having team-based gameplay, or having no teams. At this point in the coding guide, whether some variables are coded or not are dependent on responses to previous variables. For example, *Presence of Teams* is an increasing scale variable denoting whether the game is meant to be played individually, with teams, or can be played both individually or with teams. If a game does not have teams and is coded as such then many of the following variables in this guide will not have data for the given game as they refer only to games with teams.

Team Dynamics No Teams refers to the style of gameplay when teams are not present in the game. Zero denotes parallel gameplay, or gameplay where all players can participate at the same time. One denotes turn-based gameplay, or gameplay where only one player is participating at a time while other players wait.

Team Size refers to whether the game specifies the number of players on a team, and if so, whether it was implicitly or explicitly stated. Number of Teams is coded in the same manner but refers to the number of teams present in the game.

Team Dynamics Between Teams and *Team Dynamics Within Teams* are coded in the same manner as Team Dynamics No Teams; however, these variables measure the presence of parallel or turn-based gameplay both between all teams participating as well as between all players within a team.

Collaboration and Competition

This section, much like the previous section, aims to further analyze the gameplay. This section focuses on the dynamics between various participating entities in the game and whether they are competitive or collaborative in nature, with zero denoting the absence of the element in question and one denoting its presence. *Player Competition (No Teams)* measures the presence or absence of competition between players when no teams are present in the game. *Player Collaboration* is coded in the same manner but with reference to collaboration. *Team Competition* and *Team Collaboration* refer to these dynamics when teams are present in the game, and *Facilitator Competition* and *Facilitator Collaboration* refers to these dynamics when a Game Facilitator (as mentioned in the first section of the coding guide) is present in the game.

Kinesthetics and Physicality

This section of the coding guide analyzes various aspects of the physical activity or movements present in the game. *Physicality* represents the amount of movement required of the players, on a scale of zero through two representing low, medium, and high levels of physicality. *Physicality Option* refers to whether players have the option of performing physical movement or if it is mandatory. *Sweat Factor* aims to classify what types of actions players must perform - for example, a zero representing “No Sweat” could be a physical movement such as moving one’s hand, whereas a two representing “High Sweat Factor” could be a physical movement such as running or another cardio-intensive exercise.

Physical Contact refers to the presence or absence of physical contact in the game (examples of physical contact include holding hands, tapping shoulders, or any other movement where players intentionally make contact with one another as part of gameplay). *Style of Physical Contact*, which is only coded if Physical Contact is present in the game, refers to whether the physical contact is collaborative, competitive, or both.

Physical Space Diagram denotes the presence or absence of a drawing included in the game instructions which demonstrates the physical space or play area for the game. *Physical*

Environment is an increasing scale variable which analyzes the type of space where the game should be played. If the game makes no explicit mention to any physical space, zero is recorded for this variable and a second variable is recorded where one denotes an inferred small play area and two denotes an inferred large play area.

Mathematical Relevance/Importance to Gameplay

This section analyzes the relationship between math concepts and physical movements present in the game. *Motor Action and Math Relationship* analyzes how closely related the math and movement are to each other. For example, in a hypothetical game where the player must walk around a room in search of a multiplication problem, the act of walking and the multiplication have no relevance to each other. However, in a hypothetical game where the player must stand on a number line, the act of walking up or down the number line is relevant to the math as the action represents the placement of numbers on the number line.

Mathematical Importance refers to the level of importance math holds in the game - how heavily integrated is the use of math in the game? *Mathematical Utilization* refers to how often players must perform some type of math while playing the game.

Game Representation Components

In this section, the presence or absence of specific elements students included to describe their game is analyzed. There are three “categories” of components: *Written Narrative Components*, *Drawing Components*, and *Finite State Machine Diagram (FSMD) Components*. During the coding of games created during day two of the procedure, the FSMD Components section is skipped as students have not yet created a FSMD. Each category of components contains the same five variables representing the absence (zero) or presence (one) of the given components, which are as follows: *Rules, Physical Objects, Physical Space, Timing,* and *Physicality*. *Rules* refers to specific instructions, or at least enough knowledge provided that someone without any context could read and understand how the game should be played. *Physical Objects* refers to an explicit reference to *any* physical object - the presence of a physical object in the game cannot be inferred, and the name or type of the object must be explicitly stated or drawn. *Physical Space* refers to an explicit mention or depiction of a room, area, or general space, such as a classroom. The use of general words such as "inside" or "outside" also count. *Timing* refers to the presence of language related to time. There are many ways this variable can be coded as present in the game; for example, the end-goal being whichever team finishes the game first, the mention of a certain amount of time players are allotted to complete the game, a drawing of a timer or clock, and even general language such as "first", "next", "while", etc. implying an order. Lastly, *Physicality* refers to any mention or depiction of physical action in the game.

Finite State Machine Diagram (FSMD)

This final section of the coding guide analyzes the elements present in a given FSMD. This section is only used for games from day three of the procedure as there is no FSMD to code in day two games. The first variable in this section, *Presence of Finite State Machine Diagram*, denotes the absence or presence of a FSMD.

Input Types is a variable which analyzes the absence or presence of the mention of various types of inputs the player can perform. *Output State Representation* refers to how often states in the FSMD are represented in a box or circle, on a scale of zero to three. *Transition State Representation* uses the same scale to measure how often transitions between states are represented with arrows (a line does not count as an arrow, it must have a distinct point at its end to qualify as an arrow). *Finite State Machine Diagram Consistency* also uses a zero to three scale to represent how closely the FSMD matches any additional written narrative components that are present. *State Consistency* uses the same scale to determine how often states represent exactly what the player should be seeing when playing the game (as opposed to the logic of the game or any other information), and *Transition Consistency* uses this scale to determine how often arrows are labeled in the FSMD.

Specification of Mistakes refers to the absence or presence of some mechanism to accommodate for possible mistakes player may make - for example, a state after a question in case a player answers the question incorrectly informing them of their error. *Domain Level: Management-Level* refers to absence or presence of a FSMD depicting what a gamer manager would see while running the game. *Domain Level: Team-Level* refers to the absence or presence of a FSMD representing what a team would see while running the game, and whether there are multiple FSMDs present representing multiple teams. *Domain Level: Team-Level* refers to the absence or presence of a FSMD depicting what a single player would see while running the game, and whether there are multiple FSMDs representing multiple players in the game.

Finite State Machine Diagram Completion uses a scale from zero to three to determine how complete the FSMD is overall based off of the responses to previous variables in this section of the guide. In the *Quantitative Analysis of FSMD*, the total number of *States* (Boxes), *Transitions* (Arrows), *Labeled Arrows*, and *Numbered States* are counted and recorded.

The final variables of the coding guide aim to analyze the participants' understanding of programming by analyzing the structure of the FSMD and the absence or presence of specific elements within the FSMD. In computer science, an if-then statement is a section of code that only executes if a certain true/false condition is evaluated to be true. A "while" loop is a section of code that repeats while a given condition is true.

In the coding guide, a reference to if-then statements could include branching states, for example, the presence of a "correct" state and an "incorrect" state after a question depending on what answer a player inputs. A reference to while loops loops can be represented by a state looping upon itself (an arrow pointing back to the same state from which it originated). Arrow(s) that loop back to a previous state, while self-explanatory, demonstrates a more general knowledge of loops.

Group 5

Answer Sheet

3 Digit Code______________ Day 2

Category						Page
General Game Characteristics						21-23
Game Descriptor	0	1	2			21
State the **name of the game** specified by the students or that you believe it to be.	Pokemon GO					
Content						21
Counting and Cardinality	0	1				
Operations and Algebraic Thinking	0	1				
Number and Operations in Base Ten	0	1				
Number and Operations with Fractions	0	1				
Measurement and Data	0	1				
Geometry	0	1				
Ratios and Proportions	0	1				
The Number System	0	1				
Expressions and Equations	0	1				
Functions	0	1				
Statistics and Probability	0	1				
Targeted Grade Level	0	1	2	3	4	23
If specified, state the grade level.						
Progressive Levels	0	1				23
Content Adaptability	0	1				23
Game Facilitator	0	1	2	3		23
End-Goal	0	1				
Technological Descriptors						24
Technological Incorporation	0	1				24
If you selected **1**, list all technology here.						
Technological Dependency	0	1				24
Team Descriptors						25-26
Presence of Teams	0	1	2			25
Team ~~Dynamics No Teams~~	0	1				25
Team Size	0	1	2			25
If you selected **1** or **2**, write the team size here.						
Number of Teams	0	1	2			
If you selected **1** or **2**, write the number of teams here.						

38 | Page

Figure 3: *Page 1 of Day 2 - example of a coded guide for a game.*

Team ~~Dynamics Between~~ Teams	0			1				26
Team ~~Dynamics Within~~ Teams	0			1				26
Collaboration and Competition								27-28
Player Competition	0			1				27
Player Collaboration	0			1				27
Team Competition	0			1				27
Team Collaboration	0			1				27
Facilitator Competition	0			1				28
Facilitator Collaboration	0			1				28
Kinesthetics and Physicality								29-30
Physicality	0	1	2					29
Physicality Option	0			1				29
Sweat Factor	0	1	2					29
Physical Contact	0			1				29
~~Style of Physical Contact~~	0	1	2					30
Physical Space Diagram	0			1				30
Physical Environment	0	1	2	3	4	5	6	30
(ii) If you selected **0**, select one of the codes.	1			2				
(iii) If you selected **6**, write the specified environment here.								
List any secondary locations here.								
Mathematical Relevance/Importance to Gameplay								31
Motor Action/Math Relationship	0	1	2					31
Mathematical Importance	0	1	2					31
Mathematical Utilization	0	1	2					31
Game Representation Components								32
Written Narrative Components								32
Rules	0			1				
Physical Objects	0			1				
Physical Space	0			1				
Timing	0			1				
Physicality	0			1				
Drawing Components								32
Rules	0			1				
Physical Objects	0			1				
Physical Space	0			1				
Timing	0			1				
Physicality	0			1				

39 | Page

Figure 4: *Page 2 of Day 2 - example of a coded guide for a game.*

FSMD Components					32
Rules	0	1			
Physical Objects	0	1			
Physical Space	0	1			
Timing	0	1			
Physicality	0	1			
Finite State Machine Diagram					33
Presence of State Diagram	0	1			34
If you selected **1**, write the number of Finite State Machine Diagrams here.					
Input Types					34
RFID	0	1			
Buttons	0	1			
GPS	0	1			
Keyboard	0	1			
Touch Interface	0	1			
Timer	0	1			
Another Player	0	1			
Other (Please write)					
Output State Representation	0	1	2	3	34
Transition State Representation	0	1	2	3	35
FSMD Consistency with Rules	0	1	2	3	35
FSMD State Consistency	0	1	2	3	35
FSMD Transition Consistency	0	1	2	3	35
Specification of Mistakes	0	1			36
Domain Level: Management-Level	0	1			36
Domain Level: Team-Level	0	1	2		36
Domain Level: Player-Level	0	1	2		37
FSMD Completion	0	1	2	3	37
Quantitative Analysis					37
States/Boxes (Total)					
Transitions/Arrows (Total)					
Labeled Arrows (Total)					
Numbered States (Total)					
Evidence of Programming Language Knowledge					37
If-then statements	0	1			
Loops	0	1			
Arrow(s) that loop to a previous state	0	1			

40 | Page

Figure 5: *Page 3 of Day 2 - example of a coded guide for a game.*

Group 5

Answer Sheet

3 Digit Code______________ Day 3

Category						Page
General Game Characteristics						21-23
Game Descriptor	0	1	2			21
State the **name of the game** specified by the students or that you believe it to be.	Pokemon Go					
Content						21
Counting and Cardinality	0	1				
Operations and Algebraic Thinking	0	1				
Number and Operations in Base Ten	0	1				
Number and Operations with Fractions	0	1				
Measurement and Data	0	1				
Geometry	0	1				
Ratios and Proportions	0	1				
The Number System	0	1				
Expressions and Equations	0	1				
Functions	0	1				
Statistics and Probability	0	1				
Targeted Grade Level	0	1	2	3	4	23
If specified, state the grade level.						
Progressive Levels	0	1				23
Content Adaptability	0	1				23
Game Facilitator	0	1	2	3		23
End-Goal	0	1				
Technological Descriptors						24
Technological Incorporation	0	1				24
If you selected **1**, list all technology here.						
Technological Dependency	0	1				24
Team Descriptors						25-26
Presence of Teams	0	1	2			25
Team Dynamics No Teams	0	1				25
Team Size	0	1	2			25
If you selected ~~**1** or **2**~~, write the team size here.						
Number of Teams	0	1	2			
If you selected ~~**1** or **2**~~, write the number of teams here.						

38 | Page

Figure 6: *Page 1 of Day 3 - example of a coded guide for a game.*

~~Team Dynamics Between Teams~~	0			1				26
Team Dynamics Within Teams	0			1				26
Collaboration and Competition								27-28
Player Competition	0			1				27
Player Collaboration	0			1				27
Team Competition	0			1				27
Team Collaboration	0			1				27
Facilitator Competition	0			1				28
Facilitator Collaboration	0			1				28
Kinesthetics and Physicality								29-30
Physicality	0		1		2			29
Physicality Option	0			1				29
Sweat Factor	0		1		2			29
Physical Contact	0			1				29
~~Style of Physical Contact~~	0		1		2			30
Physical Space Diagram	0			1				30
Physical Environment	0	1	2	3	4	5	6	30
(ii) If you selected **0**, select one of the codes.	1			2				
(iii) If you selected **6**, write the specified environment here.								
List any secondary locations here.								
Mathematical Relevance/Importance to Gameplay								31
Motor Action/Math Relationship	0		1		2			31
Mathematical Importance	0		1		2			31
Mathematical Utilization	0		1		2			31
Game Representation Components								32
Written Narrative Components								32
Rules	0			1				
Physical Objects	0			1				
Physical Space	0			1				
Timing	0			1				
Physicality	0			1				
Drawing Components								32
Rules	0			1				
Physical Objects	0			1				
Physical Space	0			1				
Timing	0			1				
Physicality	0			1				

39 | Page

Figure 7: *Page 2 of Day 3 - example of a coded guide for a game.*

FSMD Components					32
Rules	0		1		
Physical Objects	0		1		
Physical Space	0		1		
Timing	0		1		
Physicality	0		1		
Finite State Machine Diagram					33
Presence of State Diagram	0		1		34
If you selected **1**, write the number of Finite State Machine Diagrams here.	5				
Input Types					34
RFID	0		1		
Buttons	0		1		
GPS	0		1		
Keyboard	0		1		
Touch Interface	0		1		
Timer	0		1		
Another Player	0		1		
Other (Please write)					
Output State Representation	0	1	2	3	34
Transition State Representation	0	1	2	3	35
FSMD Consistency with Rules	0	1	2	3	35
FSMD State Consistency	0	1	2	3	35
FSMD Transition Consistency	0	1	2	3	35
Specification of Mistakes	0		1		36
Domain Level: Management-Level	0		1		36
Domain Level: Team-Level	0	1	2		36
Domain Level: Player-Level	0	1	2		37
FSMD Completion	0	1	2	3	37
Quantitative Analysis					37
States/Boxes (Total)	39				
Transitions/Arrows (Total)			59		
Labeled Arrows (Total)	11				
Numbered States (Total)	0				
Evidence of Programming Language Knowledge					37
If-then statements	0		1		
Loops	0		1		
Arrow(s) that loop to a previous state	0		1		

40 | Page

Figure 8: *Page 3 of Day 3 - example of a coded guide for a game.*

5.2 Results

5.2.1 General Game Characteristics

Table 1

Percent occurrence of math concepts present in Day 2 and Day 3 U.S. games.

	Day 2	**Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Counting and Cardinality	0.00	0.00
Operations and Algebraic Thinking	71.43	28.57
Number and Operations in Base Ten	14.29	0.00
Number and Operations with Fractions	28.57	0.00
Measurement and Data	0.00	0.00
Geometry	0.00	0.00
Ratios and Proportions	0.00	0.00
The Number System	0.00	0.00
Expressions and Equations	0.00	0.00
Functions	0.00	0.00
Statistics and Probability	0.00	0.00

Table 1 shows that, in all games created during day two, 71.43% of games used Operations and Algebraic Thinking, 14.29% of games used Number and Operations in Base Ten, and 28.57% of games used Number and Operations with Fractions. No other math concepts were present in any of the games.

In all games created during day three, 28.57% of games used Operations and Algebraic Thinking. No other math concepts were present in any of the games.

Table 2

Percent occurrence of gameplay elements in Day 2 and Day 3 U.S. games.

	Day 2	**Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Progressive Levels	0.00	0.00
Content Adaptability	14.29	14.29
End-Goal	71.43	28.57

Table 2 shows that 0.00% of both day two and day three games implemented Progressive Levels. Also, there was no change in Content Adaptability, as 14.29% of both day two and day three games implemented Content Adaptability. On day two, 71.43% of games explicitly stated an End-Goal; 28.57% of day three games stated an End-Goal.

Table 3

Average scores of Day 2 and Day 3 U.S. games for gameplay element variables.

	Day 2	**Day 3**
Variable Name	**Mean (SD)**	**Mean (SD)**
Game Descriptor	0.43 (0.79)	0.28 (0.76)
Targeted Grade Level	0.00 (0.00)	0.00 (0.00)
Game Facilitator	0.57 (1.13)	0.43 (1.13)

Table 3 reveals that, on average, day two games scored 0.43 for Game Descriptor (SD = 0.79), 0.00 for Targeted Grade Level (SD = 0.00), and 0.57 for Game Facilitator (SD = 1.13). Day three games on average scored 0.28 for Game Descriptor (SD = 0.76), 0.00 for Targeted Grade Level (SD = 0.00), and 0.43 for Game Facilitator (SD = 1.13).

5.2.2 Technological Descriptors

Table 4

Percent occurrence of technological aspects in Day 2 and Day 3 U.S. games.

	Day 2	**Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Technological Incorporation	100.00	71.43
Technological Dependency	57.14	57.14

Regarding technological descriptors, Table 4 shows that 100.00% of day two games incorporated technology; 71.43% of day three games incorporated technology. On both day two and day three, the same 57.14% of games were found to be dependent on technology.

5.2.3 Team Descriptors

Table 5

Average scores of Day 2 and Day 3 U.S. games for team-specific variables.

	Day 2	Day 3	
Variable Name	**Mean (SD)**	**Mean (SD)**	
Presence of Teams	0.57 (0.53)	0.14 (0.38)	
Team Dynamics No Teams*	0.00 (0.00)	0.00 (0.00)	*Day 2: 2/7 groups *Day 3: 4/7 groups
Team Size*	0.25 (0.50)	0.00 (N/A)	*Day 2: 4/7 groups *Day 3: 1/7 groups
Number of Teams*	0.50 (1.00)	2.00 (N/A)	*Day 2: 4/7 groups *Day 3: 1/7 groups
Team Dynamics Between Teams*	0.00 (0.00)	0.00 (N/A)	*Day 2: 3/7 groups *Day 3: 1/7 groups
Team Dynamics Within Teams*	0.00 (0.00)	0.00 (N/A)	*Day 2: 3/7 groups *Day 3: 1/7 groups

Table 5 shows that on day two, games scored an average of 0.57 for Presence of Teams (SD =0.53). On day three, games scored an average of 0.14 for Presence of Teams (SD = 0.38).

On day two, two out of seven games scored an average of 0.00 for Team Dynamics No Teams (SD = 0.00), with no data for the remaining five groups. On day three, four out of seven games scored an average of 0.00 for Team Dynamics No Teams (SD = 0.00), with no data for the remaining three groups.

Four out of seven games scored an average of 0.25 for Team Size (SD = 0.50) on day two, with no data for the remaining three groups. One out of seven games scored an average of 0.00 for Team Size (SD Not Applicable) on day three, with no data for the remaining six groups.

Four out of seven games scored an average of 0.50 for Number of Teams (SD = 1.00) on day two, with no data for the remaining three groups. One out of seven games scored an average of 2.00 for Number of Teams (SD Not Applicable) on day three, with no data for the remaining six groups.

On day two, three out of seven games scored an average of 0.00 for Team Dynamics Between Teams (SD = 0.00) and 0.00 for Team Dynamics Within Teams (SD = 0.00), with no data for the remaining four groups. On day three, one out of seven games scored an average of 0.00 for Team Dynamics Between Teams (SD Not Applicable) and 0.00 for Team Dynamics Within Teams (SD Not Applicable), with no data for the remaining six groups.

5.2.4 Collaboration and Competition

Table 6

Percent occurrence of competition and collaboration in Day 2 and Day 3 U.S. games.

	Day 2	**Day 3**	
Variable Name	**% Occurrence**	**% Occurrence**	
Player Competition (No Teams)*	66.67	57.14	*Day 2: 3/7 groups *Day 3: 5/7 groups
Player Collaboration*	25.00	0.00	*Day 2: 4/7 groups *Day 3: 5/7 groups
Team Competition*	75.00	100.00	*Day 2: 4/7 groups *Day 3: 1/7 groups
Team Collaboration*	0.00	0.00	*Day 2: 3/7 groups *Day 3: 1/7 groups
Facilitator Competition*	0.00	0.00	*Day 2: 1/7 groups *Day 3: 1/7 groups
Facilitator Collaboration*	0.00	0.00	*Day 2: 1/7 groups *Day 3: 1/7 groups

On day two, 66.67% of three total games had Player Competition when no teams were present, with no data for the four remaining groups, as can be seen in Table 6. On day three, 57.14% of five total games had Player Competition, with no data for the remaining two groups.

Out of four groups, 25.00% of day two games had Player Collaboration when no teams were present, with no data for the remaining three groups. Out of five groups, 0.00% of day three games had Player Collaboration, with no data for the remaining two groups.

On day two, 75.00% of four total games had Team Competition, with no data for the remaining three groups. On day three, 100.00% of games had Team Competition based on one game, with no data for the remaining six groups.

Out of three groups, 0.00% of day two games had Team Collaboration, with no data for the remaining four groups. Out of one group, 0.00% of day three games had Team Collaboration, with no data for the remaining six groups.

Out of one group, 0.00% of day two and day three games had Facilitator Competition, with no data for the remaining six groups. Out of one group, 0.00% of day two and day three games had Facilitator Collaboration, with no data for the remaining six groups.

5.2.5 Kinesthetics and Physicality

Table 7

Percent occurrence of physicality elements in Day 2 and Day 3 U.S. games.

	Day 2	Day 3	
Variable Name	**% Occurrence**	**% Occurrence**	
Physicality Option*	14.29	0.00	*Day 3: 6/7 groups
Physical Contact	0.00	0.00	
Physical Space Diagram	0.00	0.00	

On day two, 14.29% of all games had a Physicality Option. On day three, 0.00% of six total games had a Physicality Option, with no data for the one remaining group. 0.00% of all day two and day three games had Physical Contact; 0.00% of day two and day three games had a Physical Space Diagram present.

Table 8

Average scores of Day 2 and Day 3 U.S. games for physicality variables.

	Day 2	Day 3	
Variable Name	**Mean (SD)**	**Mean (SD)**	
Physicality	0.86 (0.38)	0.00 (0.00)	
Sweat Factor*	0.86 (0.38)	0.00 (0.00)	*Day 3: 6/7 groups
Style of Physical Contact	N/A	N/A	
Physical Environment	0.43 (0.53)	0.00 (0.00)	
Physical Environment (Unspecified)*	1.25 (0.50)	1.14 (0.38)	*Day 2: 4/7 groups

Table 8 shows that the average score for Physicality for day two games was 0.86 (SD = 0.38) and for day three games was 0.00 (SD = 0.00). The average score for Sweat Factor was 0.86 (SD =0.38) for all day two games, and 0.00 (SD = 0.00) for six total day three games, with no data for the one remaining day three game. No games on day two or day three had data for Style of Physical Contact.

On day two, the average score for Physical Environment was 0.43 (SD = 0.53). Four out of seven day two games scored an average of 1.25 (SD = 0.50) when the Physical Environment was Unspecified. On day three, the average score for Physical Environment was 0.00 (SD = 0.00), with all seven games scoring an average of 1.14 (SD = 0.38) for an Unspecified Physical Environment.

5.2.6 Mathematical Relevance/Importance to Gameplay

Table 9

Average scores of Day 2 and Day 3 U.S. games for mathematical-physicality relation variables.

	Day 2	**Day 3**
Variable Name	**Mean (SD)**	**Mean (SD)**
Motor Action and Math Relationship	0.00 (0.00)	0.00 (0.00)
Mathematical Importance	1.86 (0.38)	1.43 (0.79)
Mathematical Utilization	1.86 (0.38)	1.43 (0.79)

In Table 9, all day two and day three games scored an average of 0.00 (SD = 0.00) for Motor Action and Math Relationship. On day two, all games scored an average of 1.86 (SD = 0.38) for both Mathematical Importance and Mathematical Utilization. On day three, all games scored an average of 1.43 (SD = 0.79) for both Mathematical Importance and Mathematical Utilization.

5.2.7 Game Representation Components

Table 10

Percent occurrence of written narrative components present in Day 2 and Day 3 U.S. games.

	Day 2	**Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Rules	100.00	0.00
Physical Objects	85.71	0.00
Physical Space	57.14	0.00
Timing	57.14	0.00
Physicality	71.43	0.00

On day two, 100.00% of games had Rules present, 85.71% made a reference to a Physical Object, 57.14% made a reference to a Physical Space, 57.14% made a reference to Timing, and 71.43% had Physicality present (see Table 10).

On day three, 0.00% of games had Rules, a reference to Physical Objects, a reference to a Physical Space, a reference to Timing, or Physicality present in the written narrative components.

Table 11

Percent occurrence of drawing components present in Day 2 and Day 3 U.S. games.

	Day 2	**Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Rules	42.86	0.00
Physical Objects	100.00	14.29
Physical Space	28.58	0.00
Timing	14.29	0.00
Physicality	42.86	0.00

On day two, 42.86% of games had Rules present, 100.00% made a reference to a Physical Object, 28.58% made a reference to a Physical Space, 14.29% made a reference to Timing, and 42.86% had Physicality present.

On day three, 14.29% of games made a reference to a Physical Object. 0.00% of games had Rules, a reference to a Physical Space, a reference to Timing, or Physicality present in the drawing components.

Table 12

Percent occurrence of FSMD components present in Day 2 and Day 3 U.S. games.

	Day 2	Day 3
Variable Name	**% Occurrence**	**% Occurrence**
Rules	N/A	42.86
Physical Objects	N/A	28.57
Physical Space	N/A	0.00
Timing	N/A	100.00
Physicality	N/A	0.00

Table 12 shows that, on day two, there is no data for these variables as no games had FSMDs present. On day three, 42.86% of games had Rules present, 28.57% made a reference to a Physical Object, 0.00% made a reference to Physical Space, 100.00% made a reference to Timing, and 0.00% had Physicality present.

5.2.8 Finite State Machine Diagram (FSMD)

Table 13

Percent occurrence of FSMD specific variables in Day 2 and Day 3 U.S. games.

	Day 2	Day 3
Variable Name	**% Occurrence**	**% Occurrence**
Presence of Finite State Machine Diagram	0.00	100.00
Specification of Mistakes	N/A	71.43
Domain Level: Management-Level	N/A	0.00

Note: all following tables are for Day 3 games only as Day 2 games do not include FSMDs.

On day two, 0.00% of games had a Finite State Machine Diagram present.

On day three, 100.00% of games had a Finite State Machine Diagram present. 71.43% of games included Specification of Mistakes, and 0.00% of games included a FSMD at the Management-Level.

Table 14

Average scores for FSMD specific variables in Day 3 U.S. games.

Variable Name	**Mean (SD)**
Output State Representation	2.71 (0.76)
Transition State Representation	2.00 (1.29)
FSMD Consistency with Specified Rules	1.14 (1.21)
State Consistency (Boxes)	1.14 (1.07)
Transition Consistency (Arrows)	1.00 (1.15)
Domain Level: Team-Level	0.29 (0.76)
Domain Level: Player-Level	1.00 (0.00)
FSMD Completion	1.43 (0.79)

Table 14 shows that, on day three, the average score for Output State Representation was 2.71 (SD = 0.76), the average score for Transition State Representation was 2.00 (SD = 1.29), the average score for FSMD Consistency with Specified Rules was 1.14 (SD = 1.21), the average score for State Consistency (Boxes) was 1.14 (SD = 1.07), the average score for Transition Consistency (Arrows) was 1.00 (SD = 1.15), the average score for Domain Level: Team-Level was 0.29 (SD = 0.76), the average score for Domain Level: Player-Level was 1.00 (SD = 0.00), and the average score for FSMD Completion was 1.43 (SD = 0.79).

Table 15

Percent occurrence of input types present in Day 3 U.S. games.

Variable Name	% Occurrence
RFID	0.00
Buttons	0.00
GPS	0.00
Keyboard	85.71
Touch Interface	0.00
Timer	0.00
Other User	0.00

On day three, 85.71% of games used Keyboard as an input type, while 0.00% of games used RFID, Buttons, GPS, Touch Interface, Timer, or Other User.

Table 16

Average total number of states and transitions present in FSMDs in Day 3 U.S. games.

Variable Name	Mean (SD)
States/Boxes	10.57 (8.50)
Transitions/Arrows	10.71 (15.12)
Labeled Arrows	5.57 (7.81)
Numbered States	3.29 (8.69)

In day three FSMDs, the average number of States was 10.57 (SD = 8.50), the average number of Transitions was 10.71 (SD = 15.12), the average number of Labeled Arrows was 5.57 (SD = 7.81), and the average number of Numbered States was 3.29 (SD = 8.69).

Table 17

Percent occurrence of FSMD elements that imply comprehension of programming knowledge in Day 3 U.S. games.

Variable Name	% Occurrence
A reference to "If-then" Statements	14.29
A reference to "While" Loops	85.71
Arrow(s) that loop to a previous state	57.14

On day three, 14.29% of games contained FSMD elements which referenced “If-then” Statements, 85.71% of games contained FSMD elements which referenced “While” Loops, and 57.14% of games contained arrows that looped back to a previous state.

5.3 Discussion

With the results of the Study 1 games using the coding guide, a comparison between day two and day three results can begin to answer whether games vary within a country with regard to the U.S. On day two, three different math concepts were found to be present in games. These concepts were Operations and Algebraic Thinking, Number and Operations in Base Ten, and Number and Operations with Fractions. In other words, games used general calculations and algebra problems, or problems involving decimals or fractions. However, on day three, only one math concept was found to be present in games, with 28.57% of games using Operations and Algebraic Thinking (see Table 1). This is a sharp decrease from the 71.43% of the games that used this concept on day two. 0.00% of games on day three used any other math concept. This suggests that when participants were asked to take their existing game idea from day two and represent it as an FSM, math problems or concepts that may have seemed more “difficult” than just straightforward calculation problems got cut from the game. Whether this was because problems involving decimals and fractions seemed more challenging to implement in a programming context, or because these types of math were more difficult to create in-game questions and content for, is uncertain.

Table 2 shows that no games on day two or day three implemented Progressive Levels, meaning the game difficulty increases as the player makes progress. The same 14.29% of the games on both day two and day three implemented Content Adaptability, making the game customizable in content depending on the player. For both of these variables, the percentages stayed consistent on both days. These percentages are also very low, implying most or all groups did not think to implement these concepts in their games, or did not know how to implement them.

End-Goal, however, had a very noticeable change (see Table 2), with 71.43% of games explicitly stating an end goal or win condition on day two, but only 28.57% of games doing so on day three.

As seen in Table 3, the mean score of day two games for *Game Descriptor* was 0.43. This is closest to a score of 0 in the coding guide, which represents a game that is “not based on any previously existing game” (Ottmar et al., 2017). The mean score of day three games for this variable was 0.28, which also is closest to a score of 0. This shows that overall most games created by Study 1 participants were original concepts not copied from any existing game. While there was a change from day two to day three for the average score for *Game Descriptor*, was not a dramatic change.

The average score for both day two and day three games was 0.00 for *Targeted Grade Level*, which is equivalent to a score of 0 in the coding guide, representing that none of the groups specified a target audience or grade level for their games.

In Table 3, the average score for *Game Facilitator* on day two was 0.57. This is closest to a score of 1 in the coding guide, meaning on average games implicitly expressed the need for a facilitator to help run the game. On day 3, however, the average was slightly lower at 0.43, which is closest to a score of 0 in the coding guide, meaning on average games implicitly did not require a game facilitator. Overall, there was a reduction in explicit gameplay element variables from day two to day three.

On day two, 100.00% of games incorporated some type of technology (phones, tablets, computers, etc.), as shown in Table 4. However, only 71.43% of games on day three explicitly incorporated technology. While this is a decrease from day two, it is still a majority of games.

For both day two and day three, 57.14% of games were found to be dependent on technology, showing that there was no change for this variable.

Overall, Table 5 reveals a reduction in explicit gameplay element variables from day two to day three. The average score for *Presence of Teams* on day two was 0.57, which is closest to a score of 1 in the coding guide. This shows that on average day two games were specified to be played only in teams. However, on day three, the average score was 0.14, closest to a value of 0 in the coding guide. This represents that on average day three games did not have teams, and were designed to be played individually.

Across both day two and day three, the average score for *Team Dynamics No Teams* was 0.00. This means on average, when no teams were present in a game, gameplay was parallel - *not* turn-based - in nature. This is true for both day two and day three, with no change in the averages.

On day two, the average for *Team Size* was 0.25 (see table 5), which is closest to a score of 0 in the coding guide, representing that on average team sizes were not specified by participants. On day three the average was 0.00. This was a decrease from day two's average, but overall indicates the same result in the coding guide with team sizes not specified.

The average for *Number of Teams* on day two was 0.50, which is closest to a score of 1 in the coding guide, showing that on average groups implicitly stated the number of teams in their games on day two. On day three, however, there was an increase for this variable, with an average score of 2.00, equivalent to a score of 2 in the coding guide. This reflects that on day three, groups *explicitly* stated the number of teams in their games.

On both day two and day three, the average score for *Team Dynamics Between Teams* was 0.00, which is equivalent to a score of 0 in the coding guide. This reflects that on average, when teams were present, the style of gameplay was parallel. This also reflects that there was no change in the style of gameplay between day two and day three.

Additionally, Table 5 shows that the average score for *Team Dynamics Within Teams* on both day two and day three was also 0.00. This is equivalent to a 0 in the coding guide, which reflects that gameplay style within teams was parallel as well, and that this did not change between day two and day three.

Table 6 shows that overall, there was a decrease in the presence of collaboration and competition in games. On day two, 66.67% of games had player competition present when there were no teams in the game. However, on day three only 57.14% of games had player competition present. On day two, 25.00% of games had player collaboration present, but on day three 0.00% of games had player collaboration present. This shows that these variables decreased between day two and day three.

On day two, 75.00% of games had competition when teams were present in the game. This increased to 100.00% of games on day three. This was the only variable to show an increase in Table 6.

On day two and day three, 0.00% of games had collaboration when teams were present, showing no overall change. Likewise, 0.00% of games had competition or collaboration from a facilitator on both day two and day three, also showing no change.

Table 7 suggests a very low presence of physicality elements in the USA children's games representations. On day two, 14.29% of games had a physicality option. This decreased to 0.00% of games having such an option on day three. 0.00% of games had physical contact present on day two and day three; 0.00% of games had a physical space diagram present either. Most elements in this table were not found to be present in Study 1 games.

Table 8 suggests a drop of focus on physicality from day two to day three. On day two, the average score for *Physicality* was 0.86, which is closest to a score of 1 in the coding guide, representing a medium physicality present in day two games. However, on day three, the average score was 0.00, equivalent to a score of 0 in the coding guide. This represents a low level of physicality present in the day three games.

Table 6 also shows a reduction in *Sweat Factor*, with an average score of 0.86 on day two. This is closest to a score of 1 in the coding guide, representing a low sweat factor, or activities that are middle level in cardio intensity. On day three this average dropped to 0.00, equivalent to a score of 0 in the coding guide, meaning there were no cardio-intense activities present.

There was also a drop in the specification of physical environment between day two and day three. On day two the average score for this variable was 0.43, while on day three the average score was 0.00. These averages are both closest to a score of 0, or unspecified environment, in the coding guide.

One variable that showed little change between day two and day three was the type of physical environment implied when the physical environment was not explicitly stated. On day two, the average score was 1.25, and on day three the average was 1.14. Both of these averages are closest to a value of 1 in the coding guide, representing an implied small play area when a physical play area was unspecified.

Table 9 shows only slight changes in scores between days two and three, and overall suggests a medium relationship between math and other game elements. Games from day two and day three scored an average of 0.00 for *Motor Action and Math Relationship*. This score of 0 in the coding guide reflects that no math in any of the games was related to the physical activity present in the games. This did not change between days.

On day two, games scored an average of 1.86 for *Mathematical Importance*, which is closest to a score of 2 in the coding guide, reflecting that the math in day two games was necessary to succeed in the games. On day three, this average dropped to a score of 1.43, closest to a score of 1 in the coding guide. This reflects math that is only partially necessary to succeed in the games.

On day two games also scored an average of 1.86 for *Mathematical Utilization*, which is closest to an overall score of 2 in the coding guide. This implies most day two games required players to do some type of math in order to progress through the games. On day three, this average score dropped to 1.43 as well, bringing the overall average score closest to a 1 in the coding guide. This implies that on day three players only had to do math in certain situations to make progress.

Table 10 reflects an extreme drop in the presence of written narrative components between day two and day three. On day two, 100.00% of games listed some type of rules, 85.71% mentioned physical objects, 57.14% mentioned both physical space and timing, and 71.43% of games expressed some type of physical activity. On day three 0.00% of games had *any* of these written narrative components present.

Table 11 shows a drop in drawing components between day two and day three. On day two, 42.86% of games had drawings the implied rules, 100.00% had a drawing of a physical object, 28.58% of games drew a physical space, 14.29% of games included a drawing the implied timing, 42.86% of games drew a reference to physical activity. On day three, drawings of physical objects dropped from 100.00% to a mere 14.29%, while the presence of all other drawing components dropped to 0.00% The decrease in written and drawing components as seen in Tables 10 and 11 suggests that participants focused solely on the creation of a FSMD on day three, losing some detailed expression of their games as a result.

Tables 12 through 17 do not contain data for day two games as these games do not contain FSMDs. Therefore, no comparison can be made between day two and day three for these variables. However, the day three data in these Tables will be used in the cross-cultural comparison (see section 7).

6. Study 2: The Argentina Study

6.1 Methodology

Participants. Forty-one groups totaling one-hundred fifty-one students participated in this study. However, data is only analyzed from a sample size of fourteen groups totaling forty-two students. The participants were sixth and seventh grade math and technology students from three different schools in Córdoba, Argentina: School N, School M, and School C. The three schools are paid private schools of middle/middle-high class socioeconomic status. The sample of student teams was chosen using a random number generator, which randomly selected about 30% of the team identifiers to be considered.

Procedure. The procedure for the Argentina study was nearly identical to that of the U.S. study but with several minor changes. The study ran for a total of six days rather than five; this was to give children more time developing and testing their games in the WLCP (This change did not affect the data collected as the data for this particular study was gathered during days two and three of the procedure). Days four and five were used as development days, and day six was used for testing and presentation of games. All other days followed the same procedure as the U.S. study.

Additionally, instead of each day being run in a consecutive order, students worked on their games for one day out of the week. This allowed students and teachers to focus on their regular coursework as the Argentina study was performed during the academic year, as opposed to the U.S. study which was run during a summer camp. One other change of note is the length of time students spent working each session; due to this study being conducted in schools during a normal class period, students received eighty minutes per day instead of sixty, as class periods are eighty minutes long in the participating schools. The students did not necessarily receive eighty minutes to complete each day's procedure; rather, multiple days of the procedure were conducted during a single eighty minute class period. For example, the first day spent working with a given school encompassed both the day one and day two procedure rather than an entire eighty minute period following the day one procedure.

All necessary materials, including the CT questionnaire, game creation instructions, and FSM slideshow presentation, were translated into Spanish, but contained identical content as the English materials. Although the CT questionnaire pretest and posttest are not relevant to this particular study, the questionnaire does contain references to and images of various FSMDs, which may have affected students' understanding and creation of FSMDs during the day three procedure in the US study. For consistency this questionnaire was administered in the Argentina study as well.

During day one, the game used as an example was *Tangrams Race*, rather than *EstimateIt!*. This change was made due to the mathematical concepts and language present in *EstimateIt!*. For example, the in-game measurements used in *EstimateIt!* are provided in inches, while the metric system is used in Argentina. It was anticipated that these concepts would not translate well and would make for a confusing example for the participants in Study 2, and as a result *Tangrams Race* was used in place of *EstimateIt!*.

During day three, the screenshot of *EstimateIt!* represented as an FSMD in the WLCP was replaced both in content and appearance. It was replaced with an FSMD representing *Tangrams Race* due to the change in the day one procedure. Additionally, drawings were used in place of screenshots of the WLCP due to an ongoing separate study, which the students' viewing of said screenshots would affect. However, these drawings were exact replicas of the WLCP screenshots in terms of content. See Figure 9 and Figure 10 below.

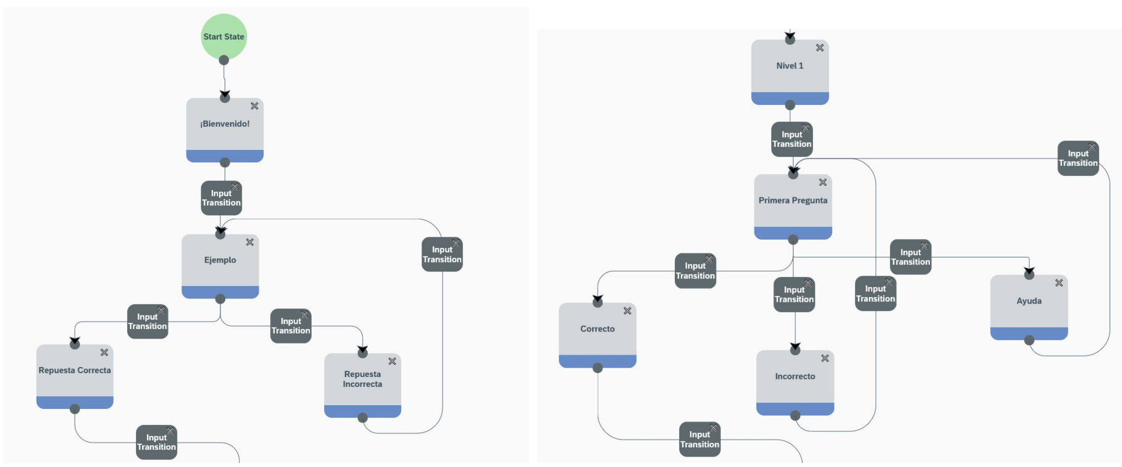

Figure 9: *Screenshots of* Tangrams Race *represented as a FSMD in the WLCP originally used in the presentation given during day three of the procedure.*

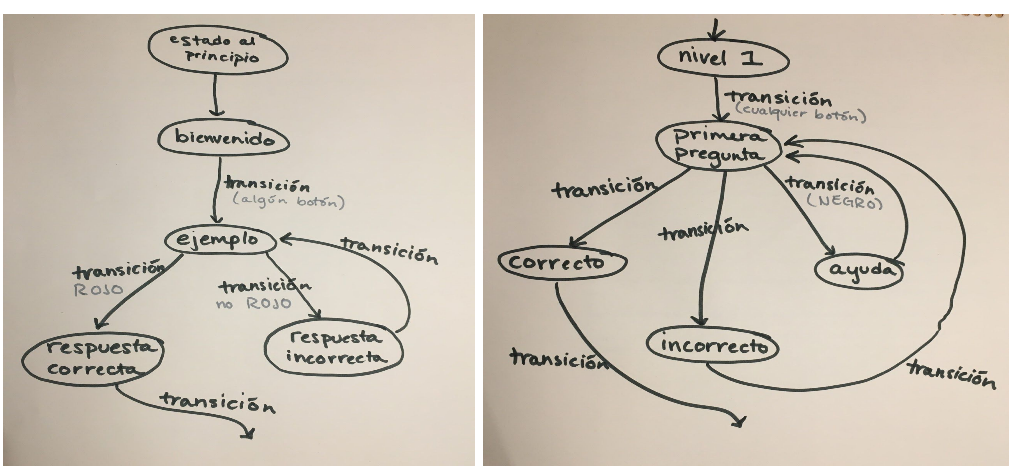

Figure 10: *The screenshots in Figure 9 were replaced with these drawings. While visually different, they contain the same content depicted in the original screenshots.*

For development of games on day two and day three, custom large notebook-style paper pads were provided to the students, whereas in Study 1, students were provided with large plank sheets of paper. The booklets were used in Study 2 to ease transportation of materials to and from the schools where the study was being conducted.

All participants received a letter to parents/guardians informing them of the study and obtaining permission for students to be photographed (see Appendix B).

Measures. The same coding guide in Appendix A will be used to analyze the games created in Study 2. The data is represented in the same manner as the results from Study 1.

6.2 Results

6.2.1 General Game Characteristics

Table 18

Percent occurrence of math concepts present in Day 2 and Day 3 Argentina games.

	Day 2	Day 3
Variable Name	**% Occurrence**	**% Occurrence**
Counting and Cardinality	0.00	0.00
Operations and Algebraic Thinking	64.29	35.71
Number and Operations in Base Ten	7.14	0.00
Number and Operations with Fractions	14.29	7.14
Measurement and Data	0.00	0.00
Geometry	42.86	21.43
Ratios and Proportions	0.00	0.00
The Number System	0.00	0.00
Expressions and Equations	0.00	0.00
Functions	0.00	0.00
Statistics and Probability	0.00	0.00

Table 18 shows that in all games created during day two, 64.29% of games used Operations and Algebraic Thinking, 7.14% of games used Number and Operations in Base Ten, 14.29% of games used Number and Operations with Fractions, and 42.86% of games used Geometry. No other math concepts were present in any of the games (see Table 18).

In all games created during day three, 35.71% of games used Operations and Algebraic Thinking, 7.14% of games used Number and Operations with Fractions, and 21.43% used Geometry. No other math concepts were present in any of the games.

Table 19

Percent occurrence of gameplay elements in Day 2 and Day 3 Argentina games.

	Day 2	**Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Progressive Levels	14.29	0.00
Content Adaptability	7.14	7.14
End-Goal	35.71	35.71

Table 19 shows that 14.29% of day two games implemented Progressive Levels; 0.00% of day three games implemented Progressive Levels. 7.14% of both day two and day three games implemented Content Adaptability. 35.71% of both day two and day three games explicitly stated an End-Goal.

Table 20

Average scores of Day 2 and Day 3 Argentina games for gameplay element variables.

	Day 2	**Day 3**
Variable Name	**Mean (SD)**	**Mean (SD)**
Game Descriptor	0.29 (0.47)	0.07 (0.27)
Targeted Grade Level	0.00 (0.00)	0.00 (0.00)
Game Facilitator	0.00 (0.00)	0.21 (0.80)

On average, day two games scored 0.29 for Game Descriptor (SD = 0.47), 0.00 for Targeted Grade Level (SD = 0.00), and 0.00 for Game Facilitator (SD = 0.00). Day three games on average scored 0.07 for Game Descriptor (SD = 0.27), 0.00 for Targeted Grade Level (SD = 0.00), and 0.21 for Game Facilitator (SD = 0.80).

6.2.2 Technological Descriptors

Table 21

Percent occurrence of technological aspects in Day 2 and Day 3 Argentina games.

	Day 2	**Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Technological Incorporation	78.57	14.29
Technological Dependency	14.29	0.00

Table 21 indicates that 78.57% of day two games incorporated technology; 14.29% of day three games incorporated technology. 14.29% of day two games were found to be dependent on technology and 0.00% of day three games were found to be dependent on technology.

6.2.3 Team Descriptors

Table 22

Average scores of Day 2 and Day 3 Argentina games for team-specific variables.

	Day 2	Day 3	
Variable Name	**Mean (SD)**	**Mean (SD)**	
Presence of Teams	0.50 (0.52)	0.07 (0.27)	
Team Dynamics No Teams*	0.50 (0.71)	1.00 (0.00)	*Day 2: 2/14 groups *Day 3: 3/14 groups
Team Size*	2.00 (0.00)	0.00 (N/A)	*Day 2: 7/14 groups *Day 3: 1/14 groups
Number of Teams*	1.57 (0.79)	2.00 (N/A)	*Day 2: 7/14 groups *Day 3: 1/14 groups
Team Dynamics Between Teams*	0.00 (0.00)	N/A	*Day 2: 4/14 groups
Team Dynamics Within Teams*	1.00 (0.00)	N/A	*Day 2: 4/14 groups

Table 22 shows that on day two, games scored an average of 0.50 for Presence of Teams (SD =0.52). On day three, games scored an average of 0.07 for Presence of Teams (SD = 0.27).

On day two, two out of fourteen games scored an average of 0.50 for Team Dynamics No Teams (SD = 0.71), with no data for the remaining twelve groups. On day three, three out of fourteen games scored an average of 1.00 for Team Dynamics No Teams (SD = 0.00), with no data for the remaining eleven groups.

Seven out of fourteen games scored an average of 2.00 for Team Size (SD = 0.00) on day two, with no data for the remaining seven groups. One out of fourteen games scored an average of 0.00 for Team Size (SD Not Applicable) on day three, with no data for the remaining thirteen groups.

Seven out of fourteen games scored an average of 1.57 for Number of Teams (SD = 0.79) on day two, with no data for the remaining seven groups. One out of fourteen games scored an average of 2.00 for Number of Teams (SD Not Applicable) on day three, with no data for the remaining thirteen groups.

On day two, four out of fourteen games scored an average of 0.00 for Team Dynamics Between Teams (SD = 0.00), with no data for the remaining ten groups. There is no data for this variable on day three.

On day two, four out of fourteen games scored an average of 1.00 for Team Dynamics Between Teams (SD = 0.00), with no data for the remaining ten groups. There is no data for this variable on day three.

6.2.4 Collaboration and Competition

Table 23

Percent occurrence of competition and collaboration in Day 2 and Day 3 Argentina games.

	Day 2	**Day 3**	
Variable Name	**% Occurrence**	**% Occurrence**	
Player Competition (No Teams)*	33.33	25.00	*Day 2: 3/14 groups *Day 3: 4/14 groups
Player Collaboration*	66.67	25.00	*Day 2: 3/14 groups *Day 3: 4/14 groups
Team Competition*	100.00	N/A	*Day 2: 5/14 groups
Team Collaboration*	0.00	N/A	*Day 2: 5/14 groups
Facilitator Competition*	N/A	0.00	*Day 3: 1/14 groups
Facilitator Collaboration*	N/A	0.00	*Day 3: 1/14 groups

Table 23 shows that on day two, 33.33% of three total games had Player Competition when no teams were present, with no data for the eleven remaining groups. On day three, 25.00% of four total games had Player Competition, with no data for the remaining ten groups.

Out of three groups, 66.67% of day two games had Player Collaboration when no teams were present, with no data for the remaining eleven groups. Out of four groups, 25.00% of day three games had Player Collaboration, with no data for the remaining ten groups.

On day two, 100.00% of five total games had Team Competition, with no data for the remaining nine groups. There is no data for this variable on day three.

Out of five groups, 0.00% of day two games had Team Collaboration, with no data for the remaining nine groups. There is no data for this variable on day three.

There is no data for Facilitator Competition and Facilitator Collaboration in day two games. Out of one group, 0.00% of day three games had Facilitator Competition and Facilitator Collaboration, with no data for the remaining thirteen groups.

6.2.5 Kinesthetics and Physicality

Table 24

Percent occurrence of physicality elements in Day 2 and Day 3 Argentina games.

	Day 2	**Day 3**	
Variable Name	**% Occurrence**	**% Occurrence**	
Physicality Option*	10.00	0.00	*Day 2: 10/14 groups *Day 3: 5/14 groups
Physical Contact	0.00	0.00	
Physical Space Diagram	28.57	0.00	

On day two, 10.00% of ten total games had a Physicality Option, with no evidence of physicality being present for the remaining four groups. On day three, 0.00% of five total groups had a Physicality Option, with no data for the remaining nine groups. 0.00% of all day two and day three games had Physical Contact. 28.57% of day two and 0.00% of day three games had a Physical Space Diagram present.

Table 25

Average scores of Day 2 and Day 3 Argentina games for physicality variables.

	Day 2	**Day 3**	
Variable Name	**Mean (SD)**	**Mean (SD)**	
Physicality*	1.18 (0.40)	0.43 (0.53)	*Day 2: 11/14 groups *Day 3: 7/14 groups
Sweat Factor*	1.50 (0.53)	0.75 (0.96)	*Day 2: 10/14 groups *Day 3: 4/14 groups
Style of Physical Contact	N/A	N/A	
Physical Environment	0.43 (1.60)	0.00 (0.00)	
Physical Environment (Unspecified)*	1.50 (0.52)	1.21 (0.43)	*Day 2: 12/14 groups

The average score for Physicality for eleven total day two games was 1.18 (SD = 0.40) with no data for the remaining three groups; the average score for Physicality for seven total day three games was 0.43 (SD = 0.53) with no data for the remaining seven groups. Out of ten games, the average score for Sweat Factor was 1.50 (SD =0.53) on day two, with no data for the remaining four groups. Out of four games, the average score for Sweat Factor was 0.75 (SD = 0.96) on day three, with no data for the ten remaining groups. No games on day two or day three had data for Style of Physical Contact.

On day two, the average score for Physical Environment was 0.43 (SD = 1.60). Twelve out of fourteen day two games scored an average of 1.50 (SD = 0.52) when the Physical Environment was Unspecified. On day three, the average score for Physical Environment was 0.00 (SD = 0.00), with all fourteen games scoring an average of 1.21 (SD = 0.43) for an Unspecified Physical Environment.

6.2.6 Mathematical Relevance/Importance to Gameplay

Table 26

Average scores of Day 2 and Day 3 Argentina games for mathematical-physicality relation variables.

	Day 2	**Day 3**	
Variable Name	**Mean (SD)**	**Mean (SD)**	
Motor Action and Math Relationship*	0.08 (0.29)	0.25 (0.50)	*Day 2: 12/14 groups *Day 3: 4/14 groups
Mathematical Importance*	1.18 (0.98)	0.14 (0.38)	*Day 2: 11/14 groups *Day 3: 7/14 groups
Mathematical Utilization*	1.64 (0.50)	1.00 (0.58)	*Day 2: 11/14 groups *Day 3: 7/14 groups

Out of twelve total games, the average score for Motor Action and Math Relationship in day two games was 0.08 (SD = 0.29), with no data for the remaining two groups. Out of four total day three games, the average score for Motor Action and Math Relationship was 0.25 (SD = 0.50), with no evidence of this present for the remaining ten groups.

Out of eleven total day two games, the average score for Mathematical Importance was 1.18 (SD = 0.98), with no data for the remaining three groups. Out of seven total day three games, the average score for Mathematical Importance was 0.14 (SD = 0.38), with no data for the remaining seven groups.

On day two, the average score for Mathematical Utilization was 1.64 (SD = 0.50) out of eleven total groups, with no data for the remaining three groups. On day three, the average score for Mathematical Utilization was 1.00 (SD = 0.58) out of seven total groups, with no data for the remaining seven groups.

6.2.7 Game Representation Components

Table 27

Percent occurrence of written narrative components present in Day 2 and Day 3 Argentina games.

	Day 2	**Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Rules	85.71	7.14
Physical Objects	71.43	0.00
Physical Space	35.71	0.00
Timing	64.29	0.00
Physicality	71.43	0.00

On day two, 85.71% of games had Rules present, 71.43% made a reference to a Physical Object, 35.71% made a reference to a Physical Space, 64.29% made a reference to Timing, and 71.43% had Physicality present.

On day three, 7.14% of games had Rules; 0.00% of game had a reference to Physical Objects, a reference to a Physical Space, a reference to Timing, or Physicality present in the written narrative components.

Table 28

Percent occurrence of drawing components present in Day 2 and Day 3 Argentina games.

	Day 2	**Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Rules	7.14	0.00
Physical Objects	85.71	14.29
Physical Space	28.57	0.00
Timing	7.14	0.00
Physicality	57.14	0.00

On day two, 7.14% of games had Rules present, 85.71% made a reference to a Physical Object, 28.57% made a reference to a Physical Space, 7.14% made a reference to Timing, and 57.14% had Physicality present.

On day three, 14.29% of games made a reference to a Physical Object. 0.00% of games had Rules, a reference to a Physical Space, a reference to Timing, or Physicality present in the drawing components.

Table 29

Percent occurrence of FSMD components present in Day 2 and Day 3 Argentina games.

	Day 2	**Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Rules	N/A	42.86
Physical Objects	N/A	42.86
Physical Space	N/A	7.14
Timing	N/A	64.29
Physicality	N/A	28.57

On day two, there is no data for these variables as no games had FSMDs present. On day three, 42.86% of games had Rules present, 42.86% made a reference to a Physical Object, 7.14% made a reference to Physical Space, 64.29% made a reference to Timing, and 28.57% had Physicality present.

6.2.8 Finite State Machine Diagram (FSMD)

Table 30

Percent occurrence of FSMD specific variables in Day 2 and Day 3 Argentina games.

	Day 2	**Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Presence of Finite State Machine Diagram	0.00	100.00
Specification of Mistakes	N/A	85.71
Domain Level: Management-Level	N/A	0.00

Note: all following tables are for Day 3 games only as Day 2 games do not include FSMDs.

On day two, 0.00% of games had a Finite State Machine Diagram present.

On day three, 100.00% of games had a Finite State Machine Diagram present. 85.71% of games included Specification of Mistakes, and 0.00% of games included a FSMD at the Management-Level.

Table 31

Average scores for FSMD specific variables in Day 3 Argentina games.

Variable Name	**Mean (SD)**
Output State Representation	2.21 (1.12)
Transition State Representation	2.50 (1.09)
FSMD Consistency with Specified Rules	0.14 (0.53)
State Consistency (Boxes)	0.64 (0.74)
Transition Consistency (Arrows)	0.43 (0.65)
Domain Level: Team-Level	0.07 (0.27)
Domain Level: Player-Level	1.00 (0.00)
FSMD Completion	0.93 (0.62)

On day three, the average score for Output State Representation was 2.21 (SD = 1.12), the average score for Transition State Representation was 2.50 (SD = 1.09), the average score for FSMD Consistency with Specified Rules was 0.14 (SD = 0.53), the average score for State Consistency (Boxes) was 0.64 (SD = 0.74), the average score for Transition Consistency (Arrows) was 0.43 (SD = 0.65), the average score for Domain Level: Team-Level was 0.07 (SD = 0.27), the average score for Domain Level: Player-Level was 1.00 (SD = 0.00), and the average score for FSMD Completion was 0.93 (SD = 0.62).

Table 32

Percent occurrence of input types present in Day 3 Argentina games.

Variable Name	% Occurrence
RFID	0.00
Buttons	71.43
GPS	0.00
Keyboard	7.14
Touch Interface	28.57
Timer	0.00
Other User	0.00

On day three, 71.43% of games used Buttons as an input type, 7.14% of games used Keyboard, 28.57% of games used Touch Interface, and 0.00% of games used RFID, GPS, Timer, or Other User.

Table 33

Average total number of states and transitions present in FSMDs in Day 3 Argentina games.

Variable Name	Mean (SD)
States/Boxes	8.14 (6.20)
Transitions/Arrows	7.50 (5.00)
Labeled Arrows	2.50 (3.16)
Numbered States	1.07 (2.30)

In day three FSMDs, the average number of States was 8.14 (SD = 6.20), the average number of Transitions was 7.50 (SD = 5.00), the average number of Labeled Arrows was 2.50 (SD = 3.16), and the average number of Numbered States was 1.07 (SD = 2.30).

Table 34

Percent occurrence of FSMD elements that imply comprehension of programming knowledge in Day 3 Argentina games.

Variable Name	% Occurrence
A reference to "If-then" Statements	64.29
A reference to "While" Loops	0.00
Arrow(s) that loop to a previous state	64.29

On day three, 64.29% of games contained FSMD elements which referenced “If-then” Statements, 0.00% of games contained FSMD elements which referenced “While” Loops, and 64.29% of games contained arrows that looped back to a previous state.

6.3 Discussion

With the results of the Study 2 games using the coding guide, a comparison between day two and day three results can continue to answer whether games vary within a country with regard to Argentina. Table 18 shows an overall decrease in math concepts in games between day two and day three. On day two, four main math concepts were present in games, with 64.29% of games implementing Operations and Algebraic Thinking, 7.14% of games using Number and in Base Ten, 14.29% using Number and Operations with Fractions, 42.86% of games implementing

Geometry. 0.00% of games used any other math concept on day two. These values decreased in day three games, with only 35.71% of games using Operations and Algebraic Thinking. The presence of Number and Operations in Base Ten dropped completely to 0.00%. The presence of Number and Operations with Fractions dropped to 7.14%, and Geometry dropped to 21.43%. 0.00% of games implemented the remaining math concepts. These drops suggest again that math elements were either cut from the content entirely in day three, or not explicitly expressed, implying challenges adapting game ideas to a FSMD.

Table 19 shows almost no changes in the presence of basic gameplay elements between day two and day three. *Progressive Levels* was the only variable to show a change, decreasing from 14.29% on day two to 0.00% on day three. On both day two and day three, the amount of games that had an option to adapt content based on the player was 7.14%. On both day two and day three, the amount of games that explicitly stated an end goal or win condition was 35.71%. This shows no change for both of these variables.

For the remaining variables in the first section of the coding guide, Table 20 shows that while games were original, there was a relatively low presence of gameplay elements, with only slight changes between day two and day three overall. On day two the average score for *Game Descriptor* was 0.29, which is closest to a score of 0, reflecting that the Argentina games were almost all based upon original ideas not copied from an existing game. On day three, the average score for *Game Descriptor* dropped to 0.07, which again is closest to a score of 0 in the coding guide, with the same implications as day two. The average score for *Targeted Grade Level* on both day two and day three was 0.00, equivalent to a score of 0 in the coding guide, meaning no games specified a target audience of players.

On day two, the average score for *Game Facilitator* was 0.00, equivalent to a 0 in the coding guide, reflecting that no games on day two included a game facilitator. On day three this increased to an average score of 0.21; however, this is still representative of an overall 0 in the coding guide.

Regarding technological descriptors, Table 21 shows that 78.57% of games explicitly incorporated technology on day two, while only 14.29% of games did so on day three. On day two, 14.29% of games were found to be dependent on technology, while 0.00% of day three games were dependent on technology. Overall, there was a reduction in explicit gameplay element variables from day two to day three.

Table 22 reflects overall mixed changes in team-specific variables, with some increasing between day two and day three, and other variables decreasing instead. On day two, the average score for *Presence of Teams* was 0.50, which is closest to a score of 1 in the coding guide, This reflects that on average, day two games were to be played in teams only. On day three, however, this average dropped to 0.07, closest to a value of 0 in the coding guide. This implies that on day three, games were specified to be played individually rather than in teams.

The average score for *Team Dynamics No Teams* was 0.50 on day two, closest to a score of 1 in the coding guide. This score reflects that when teams were not present in day two games, gameplay was turn-based in nature. On day three, the average increased to 1.00, which also represents turn-based gameplay in the coding guide.

On day two, the average score for *Team Size* was 2.00, equivalent to a value of 2 in the coding guide. In other words, on day two, all games explicitly stated the number of players on each team. On day three, this average dropped to 0.00, equivalent to a zero in the coding guide. This score represents that on day three none of the games specified team sizes.

The average score for *Number of Teams* on day two was 1.57, which is closest to a score of 2 in the coding guide, reflective of all games explicitly stating the number of teams present. On day three, the average score increased slightly to 2.00, also representing a 2 in the coding guide.

On day two, the average score for *Team Dynamics Between Teams* was 0.00, equivalent to a score of 0 in the coding guide which indicates that when teams were present in day two games, the gameplay was parallel in nature. There is no data for this variable for day three, so ultimately no comparison can be made. The lack of data suggests that FSMDs on day three were not as thorough in their descriptions of games as opposed to the day two game creations.

On day two the average score for *Team Dynamics Within Teams* was 1.00, equivalent to a value of 1 in the coding guide, which indicates when teams were present in day two games, the gameplay between players within a team was turn-based in nature. There is also no data for this variable on day three, with similar implications as the lack of data for the previous variable.

Table 23 demonstrates that 33.33% of day two games had competition present between players when no teams were present. This value dropped to 25.00% on day three.On day two 66.67% of games had player collaboration present, but only 25.00% of games had this element present on day three. 100.00% of games had team competition on day two, but there is no data for this variable on day three. Likewise, 0.00% of games had team collaboration on day two, but there is no data for this variable on day three.

There was no data for facilitator competition or collaboration on day two, implying no day two games had a facilitator present. On day three a facilitator was present in at least one of the games, but 0.00% of these games incorporated both facilitator competition and facilitator collaboration, implying the facilitator served a neutral role. Overall, there was a decrease in the number of games with competition and/or collaboration elements, with a large number of games making no mention of competition or collaboration at all. This suggests gameplay and interaction between teams and/or players was not as well-thought out or heavily present as other game elements.

In Table 24 there is a low presence and overall decrease of physicality elements. 10.00% of games had a physicality option on day two, while 0.00% of games had such an option on day three. On both day two and day three, 0.00% of games had physical contact present. On day two, 28.57% of games included a physical space diagram, but this decreased to 0.00% of games on day three.

Table 25 shows similar trends as Table 24, with a low presence and overall decrease of physicality elements. On day two, the average score for *Physicality* was 1.18, which is closest to a score of 1 in the coding guide, representative of a medium physicality level. On day three, this average dropped to 0.43, closest to a score of 0 in the coding guide, which indicates a low physicality level. The average score for *Sweat Factor* was 1.50 on day two, closest to a score of 2 in the coding guide. This represents a high sweater factor, or the presence of physicality that is cardio-intensive in nature. On day three, the average was 0.75, closest to a score of 1 in the coding guide. This indicates a drop to a low sweat factor.

On day two, the average score for *Physical Environment* was 0.43, closest to a score of 0 in the coding guide, reflecting that on average day two games did not specify a physical environment. This is true for day three games as well, although the average score dropped to 0.00. On day two, when the physical environment was unspecified, games had an average score of 1.50 for a physical play area. This is closest to a 2 in the coding guide, which represents that on average day two games implicitly required a large play area. On day three, the average score for an unspecified physical environment dropped slightly to 1.21, closer to a 1 in the coding guide, which is indicative of a small play area.

Table 26 shows an overall decrease in the strength of the relationships between math elements and other game elements. On day two, the average score for *Motor Action and Math Relationship* was 0.08, which is closest to a score of 0 in the coding guide. This indicates that on average day two games had no relationship between the physicality and math content present. This is true for day three games as well, although with a slight increase to 0.25 for the average.

On average the score for *Mathematical Importance* for day two games was 1.18, closest to a score of 1 in the coding guide. This reflects that on average the math in day two games was of low importance to succeeding in the games. On day three, this average decreased to 0.14, closest to a score of 0 in the coding guide, indicating that the math in day three games on average was not important at all for any goal.

On day three, the average for *Mathematical Utilization* was 1.64, closest to a score of 2 in the coding guide. This represents that on average day two games require players to do math in order to make progress in the game. On day three this average dropped to 1.00, equivalent to a score of 1 in the coding guide, which is indicative of games requiring players to do math only in certain situations.

Table 27 shows a decrease in the written narrative components present in games between day two and day three. On day two, 85.71% of games specified some set of rules, 71.43% of games made a reference to physical objects, 35.71% mentioned a physical space, 64.29% of games used language indicative of timing, and 71.43% of games included physicality. By contrast, on day three, only 7.14% of games had written narrative components that mentioned rules, and 0.00% of games on day three included any other written narrative components.

Table 28 similarly shows a decrease in drawing components between day two and day three. On day two, 7.14% of games had drawings that implied rules, 85.71% of games included a drawing of a physical object, 28.57% of games included a drawing of a physical space, 7.14% of games implied timing through drawing components, and 57.14% of games included drawings depicting physical activity. On day three, there was a dramatic decrease as well, with 14.29% of games including a drawing of a physical object, and 0.00% of games including any other drawing components.

Tables 29 through 34 do not contain any data for day two games as the tables are specific to FSMD elements which participant did not create on day two. Therefore, no comparison can be made between day two and day three for these variables. This data, however, will be compared in the cross-cultural comparison section (see section 7).

6.4 Limitations

There were several noteworthy limitations in Study 2. At school N, after the first day of procedure, the teacher held onto the booklets until the following week. It is unknown whether participants received extra time outside of the procedure to continue developing their day two games. If this is the case, it is possible that overall data may be higher due to these games being more well-developed.

At school C, without approval from those conducting the study, a teacher instructed students to make more “simple” games because they would be “easier to program”, before the study conductors stepped in to correct this statement to the participants. However, it is possible that participants were swayed to make more simple games in the first place, which may have brought overall data scores down, or contributed to it being non-existent for some variables by as a result of the games being less-developed. Additionally, a teacher at school C graded participants on their final games created in the WLCP as the study was conducted as part of the curriculum. This pressure may have affected participant’s game creation process as well.

7. Cross-Cultural Comparison

7.1 Comparison of Data

7.1.1 General Game Characteristics

Table 35

Percent occurrence of math concepts present in Day 2 games from both US Study 1 and Argentina Study 2.

	Study 1 Day 2	**Study 2 Day 2**
Variable Name	**% Occurrence**	**% Occurrence**
Counting and Cardinality	0.00	0.00
Operations and Algebraic Thinking	71.43	64.29
Number and Operations in Base Ten	14.29	7.14
Number and Operations with Fractions	28.57	14.29
Measurement and Data	0.00	0.00
Geometry	0.00	42.86
Ratios and Proportions	0.00	0.00
The Number System	0.00	0.00
Expressions and Equations	0.00	0.00
Functions	0.00	0.00
Statistics and Probability	0.00	0.00

Table 35 shows that on day two, a similar amount of games from Study 1 and Study 2 had the same types of math concepts present, excluding Geometry. 71.43% of Study 1 games and 64.29% of Study 2 games had Operations and Algebraic thinking present; 14.29% of Study 1 games and 7.14% of Study 2 games had Number and Operations in Base Ten present; 28.57% of

Study 1 games and 14.29% of Study 2 games had Number and Operations with Fractions present. These percentages are likely similar because the participants in each study are in the same or similar grade levels and are likely learning similar math topics at such an age. One key difference, however, is that 0.00% of Study 1 games utilized Geometry, while 42.86% of Study 2 games had Geometry present. One possible reason for this stark difference is that *Tangrams Race*, a game based heavily on geometry was used as an example in Study 2, but not in Study 1, and may have influenced many students in their game creation.

Table 36

Percent occurrence of math concepts present in Day 3 games from both US Study 1 and Argentina Study 2.

	Study 1 Day 3	**Study 2 Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Counting and Cardinality	0.00	0.00
Operations and Algebraic Thinking	28.57	35.71
Number and Operations in Base Ten	0.00	0.00
Number and Operations with Fractions	0.00	7.14
Measurement and Data	0.00	0.00
Geometry	0.00	21.43
Ratios and Proportions	0.00	0.00
The Number System	0.00	0.00
Expressions and Equations	0.00	0.00
Functions	0.00	0.00
Statistics and Probability	0.00	0.00

Table 36 shows a much bigger difference in math concepts between Study 1 and Study 2 on day three. Only one math concept was present in Study 1 games, while three concepts were present in Study 2 games. Regarding the math concept that was present in Study 1, Operations and Algebraic Thinking, a similar percentage of games used the same concept in Study 2 (28.57% of Study 1 games and 35.71% of Study 2 games).

Table 37

Percent occurrence of gameplay elements in Day 2 games from both US Study 1 and Argentina Study 2.

	Study 1 Day 2	**Study 2 Day 2**
Variable Name	**% Occurrence**	**% Occurrence**
Progressive Levels	0.00	14.29
Content Adaptability	14.29	7.14
End-Goal	71.43	35.71

There were many differences in the occurrence of gameplay elements between Study 1 and Study 2 games on day two, as seen in Table 37. 0.00% of Study 1 games implemented progressive levels, while 14.29% of Study 2 games implemented progressive levels. Overall, most games across both studies did not implement this concept.

A similar amount of games implemented content adaptability, with 14.29% of Study 1 games and 7.14% of Study 2 games incorporating this feature. However, there was a noticeable difference between studies regarding the presence of an end goal, with 71.43% of Study 1 games expressing an explicit end goal, while only 35.71% of Study 2 games included an end goal.

Table 38

Percent occurrence of gameplay elements in Day 3 games from both US Study 1 and Argentina Study 2.

	Study 1 Day 3	**Study 2 Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Progressive Levels	0.00	0.00
Content Adaptability	14.29	7.14
End-Goal	28.57	35.71

Table 38 shows that there are few differences between day three Study 1 and Study 2 games. 0.00% of the games in either study implemented progressive levels. A similar percentage of games implemented content adaptability, with 14.29% of Study 1 games and 7.14% of Study 2 games including the feature. Additionally, a similar amount of games stated an end goal, with 28.57% of Study 1 games and 35.71% of Study 2 games explicitly mentioning an end goal.

Table 39

Average scores of US Study 1 and Argentina Study 2, Day 2 games for gameplay element variables.

	Study 1 Day 2	**Study 2 Day 2**
Variable Name	**Mean (SD)**	**Mean (SD)**
Game Descriptor	0.43 (0.79)	0.29 (0.47)
Targeted Grade Level	0.00 (0.00)	0.00 (0.00)
Game Facilitator	0.57 (1.13)	0.00 (0.00)

As seen in Table 39, there were slight differences between day three Study 1 and Study 2 games regarding gameplay elements. The average score for *Game Descriptor* in Study 1 games was 0.43 (SD = 0.79) and in Study 2 was 0.29 (SD = 0.47). Both of these averages equate to a score of 0 in the coding guide, meaning on average, in both studies games were original and not copied or based off of an existing game. Both studies had an average of 0.00 (SD = 0.00) - or 0, in the coding guide - for *Targeted Grade Level*, meaning games in both studies did not specify their target audience. *Game Facilitator* is the only variable in this table to have a difference between studies, with an average score of 0.57 (SD = 1.13) - closest to a 1 in the coding guide - for Study 1, and an average of 0.00 (SD = 0.00) - equivalent to a 0 in the coding guide - for Study 2. In other words, Study 1 games on average implicitly required a game facilitator, while Study 2 games did not require a game facilitator.

Table 40

Average scores of US Study 1 and Argentina Study 2, Day 3 games for gameplay element variables.

	Study 1 Day 3	**Study 2 Day 3**
Variable Name	**Mean (SD)**	**Mean (SD)**
Game Descriptor	0.28 (0.76)	0.07 (0.27)
Targeted Grade Level	0.00 (0.00)	0.00 (0.00)
Game Facilitator	0.43 (1.13)	0.21 (0.80)

Table 40 reflects no major differences between Study 1 and Study 2 games on day three. For *Game Descriptor*, Study 1 had an average of 0.28 (SD = 0.76) while Study 2 had an average of 0.07 (SD = 0.27). Both of these averages equate to a score of 0 in the coding guide, reflecting the games in both studies were original ideas and not copied from existing games. Games in both studies had an average of 0.00 (SD = 0.00) for *Targeted Grade Level*. In the coding guide this is equivalent to a score of 0, representing that games in both studies did not specify a target audience or grade level. For *Game Facilitator*, games in Study scored an average of 0.43 (SD = 1.13) while games in Study 2 scored an average of 0.21 (SD = 0.80). Both of these averages are closest to a score of 0 in the coding guide, meaning both Study 1 and Study games did not have a game facilitator present on day three.

7.1.2 Technological Descriptors

Table 41

Percent occurrence of technological aspects in Day 2 games from both US Study 1 and Argentina Study 2.

	Study 1 Day 2	**Study 2 Day 2**
Variable Name	**% Occurrence**	**% Occurrence**
Technological Incorporation	100.00	78.57
Technological Dependency	57.14	14.29

Table 41 reflects that Study 2 day two games had a lower occurrence of technological aspects than Study 1 day two games. 100.00% of Study 1 games incorporated technology, while only 78.57% of Study 2 games did so. 57.14% of Study 1 games were dependent on technology, while only 14.29% of Study 2 games were dependent on technology.

Table 42

Percent occurrence of technological aspects in Day 3 games from both US Study 1 and Argentina Study 2.

	Study 1 Day 3	**Study 2 Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Technological Incorporation	71.43	14.29
Technological Dependency	57.14	0.00

Table 42 shows a similar pattern to that of Table 41; on day three Study 2 games also had a lower occurrence of technological aspects than Study 1 games. 71.43% of Study 1 games incorporated technology, while only 14.29% of Study 2 games did so. 57.14% of Study 1 games were dependent on technology, while 0.00% of Study 2 games were dependent on technology.

7.1.3 Team Descriptors

Table 43

Average scores of Day 2 from US Study 1 and Argentina Study 2 games for team-specific variables.

	Study 1 Day 2	**Study 2 Day 2**
Variable Name	**Mean (SD)**	**Mean (SD)**
Presence of Teams	0.57 (0.53)	0.50 (0.52)
Team Dynamics No Teams	0.00 (0.00)	0.50 (0.71)
Team Size	0.25 (0.50)	2.00 (0.00)
Number of Teams	0.50 (1.00)	1.57 (0.79)
Team Dynamics Between Teams	0.00 (0.00)	0.00 (0.00)
Team Dynamics Within Teams	0.00 (0.00)	1.00 (0.00)

Table 43 shows that for day two, on average Study 2 games scored higher than Study 1 games for team-specific variables. The average score for *Presence of Teams* for Study 1 games was 0.57 (SD = 0.53) and for Study 2 games was 0.50 (SD = 0.52). Both of these averages translate to a score of 1 in the coding guide, meaning on average games in both studies were specified to be played in teams only. For *Team Dynamics No Teams*, Study 1 games scored an average of 0.00 (SD = 0.00) - equivalent to a 0 in the coding guide - and Study 2 games scored an average of 0.50 (SD = 0.71) - closest to a score of 1 in the coding guide. This shows that in the absence of teams, Study 1 games tended to utilize parallel gameplay between players while Study 2 games tended to utilize turn-based gameplay.

The average Study 1 score for *Team Size* was 0.25 (SD = 0.50), which is closest to a score of 0 in the coding guide. The average Study 2 score for *Team Size* was 2.00 (SD = 0.00), equivalent to a 2 in the coding guide. This reflects that on average Study 1 games did specify team sizes when teams were present, but Study 2 games explicitly stated team sizes.

Study 1 games had an average score of 0.50 (SD = 1.00) for *Number of Teams*, closest to a score of 1 in the coding guide. Study 2 games had an average score of 1.57 (SD = 0.79) for this variable, closest to a score of 2 in the coding guide. This means that on overall Study 1 games implicitly stated the number of teams present while Study 2 games explicitly stated the number of teams in the game.

Both Study 1 and Study 2 games scored an average of 0.00 (SD = 0.00) for *Team Dynamics Between Teams*. This is equivalent to a 0 in the coding guide and reflects parallel gameplay between teams in the games of both studies. For *Team Dynamics Within Teams*, Study 1 games had an average score of 0.00 (SD = 0.00), while Study 2 games had an average of 1.00 (SD = 0.00). These are equivalent to coding guide scores of 0 and 1 respectively, showing that Study 1 games tended to have parallel gameplay within a team's players, while Study 2 tended to use turn-based gameplay within teams.

Table 44

Average scores of Day 3 games from US Study 1 and Argentina Study 2 for team-specific variables.

	Study 1 Day 3	**Study 2 Day 3**
Variable Name	**Mean (SD)**	**Mean (SD)**
Presence of Teams	0.14 (0.38)	0.07 (0.27)
Team Dynamics No Teams	0.00 (0.00)	1.00 (0.00)
Team Size	0.00 (N/A)	0.00 (N/A)
Number of Teams	2.00 (N/A)	2.00 (N/A)
Team Dynamics Between Teams	0.00 (N/A)	N/A
Team Dynamics Within Teams	0.00 (N/A)	N/A

Table 44 shows many variables missing for Study 2 games. For those variables that are present for games of both studies, there appeared to be minimal to no differences between studies. The average score for *Presence of Teams* in Study 1 games was 0.14 (SD = 0.38) and in Study 2 was 0.07 (SD = 0.27). Both of these averages are closest to a score of 0 in the coding guide, representing that most games in both studies did not have teams present. The average score for *Team Dynamics No Teams* in Study 1 was 0.00 (SD = 0.00) and in Study 2 was 1.00 (SD = 0.00). These are equivalent to a 0 and 1 respectively in the coding guide; this represents parallel gameplay in Study 1 games and turn-based gameplay in Study 2 games.

The average score for *Team Size* in both studies was 0.00 (SD Not Applicable), equivalent to a score of 0 in the coding guide. This represents that games in both studies did not specify team sizes. The average score for *Number of Teams* in both studies was 2.00 (SD Not Applicable), equivalent to a score of 2 in the coding guide. This represents that games in both studies explicitly stated the number of teams present.

Study 1 had an average score of 0.00 for *Team Dynamics Between Teams* (SD Not Applicable), equivalent to a 0 in the coding guide. This shows parallel gameplay between teams in Study 1 games. Additionally, Study 1 games had an average score of 0.00 (SD Not Applicable) for *Team Dynamics Within Teams*, also equivalent to a 0 in the coding guide, which indicates parallel gameplay between players on a team. Study 2 did not have data for either of these variables, which suggests that games in Study 2 did not properly express, or express at all, interactions between teams and within teams, making Study 2 games less developed than Study 1 games with regard to these variables.

7.1.4 Collaboration and Competition

Table 45

Percent occurrence of competition and collaboration in Day 2 games from both US Study 1 and Argentina Study 2.

	Study 1 Day 2	**Study 2 Day 2**
Variable Name	**% Occurrence**	**% Occurrence**
Player Competition (No Teams)	66.67	33.33
Player Collaboration	25.00	66.67
Team Competition	75.00	100.00
Team Collaboration	0.00	0.00
Facilitator Competition	0.00	N/A
Facilitator Collaboration	0.00	N/A

Table 45 shows that overall, Study 2 games had a higher occurrence of competition and collaboration elements on day two. 66.67% of Study 1 games had competition between players when no teams were present, while 33.33% of Study 2 games had player competition present. 25.00% of Study 1 games had collaboration between players, but a larger amount of Study 2 games (66.67%) had collaboration between players. 75.00% of Study 1 games had competition between teams, while 100.00% of Study 2 games had team competition. 0.00% of both Study 1 and Study 2 games implemented team collaboration. 0.00% of Study 1 games had facilitator competition or collaboration, while Study 2 games did not have a facilitator present at all.

Table 46

Percent occurrence of competition and collaboration in Day 3 games from both US Study 1 and Argentina Study 2.

	Study 1 Day 3	**Study 2 Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Player Competition (No Teams)	57.14	25.00
Player Collaboration	0.00	25.00
Team Competition	100.00	N/A
Team Collaboration	0.00	N/A
Facilitator Competition	0.00	0.00
Facilitator Collaboration	0.00	0.00

Table 46 reflects that Study 1 games had an overall higher occurrence of competition and collaboration elements on day three. 57.14% of Study 1 games had competition between players present, while only 25.00% of Study 2 games had this element present. 0.00% of Study 1 games utilized player collaboration while 25.00% of Study 2 games had this element present. 100.00% of Study 1 games had team competition present, while Study 2 games did not mention team competition at all. 0.00% of Study 1 games utilized team collaboration, while Study 2 games also made no mention of team collaboration. 0.00% of both Study 1 and Study 2 games had facilitator competition or collaboration elements present.

7.1.5 Kinesthetics and Physicality

Table 47

Percent occurrence of physicality elements in Day 2 games from both US Study 1 and Argentina Study 2.

	Study 1 Day 2	**Study 2 Day 2**
Variable Name	**% Occurrence**	**% Occurrence**
Physicality Option	14.29	10.00
Physical Contact	0.00	0.00
Physical Space Diagram	0.00	28.57

Table 47 shows mixed results for the number of day two games in both studies that had physicality elements present. 14.29% of Study 1 games provided physical activity that was optional, but 0.00% of Study 2 games provided such an option. 0.00% of games in both studies contained physical contact. 0.00% of Study 1 games included a physical space diagram, while 28.57% of Study games included a physical space diagram.

Table 48

Percent occurrence of physicality elements in Day 3 games from both US Study 1 and Argentina Study 2.

	Study 1 Day 3	**Study 2 Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Physicality Option	0.00	0.00
Physical Contact	0.00	0.00
Physical Space Diagram	0.00	0.00

On day three, games in both studies had none of the physical elements present in the table above. 0.00% of both Study 1 and Study 2 games had a physicality option, physical contact, or a physical space diagram. This suggests that in both studies, when participants were asked to take their written game and put it into a FSMD, physicality elements were lost in the process.

Table 49

Average scores of US Study 1 and Argentina Study 2, Day 2 games for physicality variables.

	Study 1 Day 2	Study 2 Day 2
Variable Name	**Mean (SD)**	**Mean (SD)**
Physicality	0.86 (0.38)	1.18 (0.40)
Sweat Factor	0.86 (0.38)	1.50 (0.53)
Style of Physical Contact	N/A	N/A
Physical Environment	0.43 (0.53)	0.43 (1.60)
Physical Environment (Unspecified)	1.25 (0.50)	1.50 (0.52)

Table 49 shows that Study 2 games scored slightly higher overall for physicality variables on day two. Study 1 games scored an average of 0.86 (SD = 0.38) for *Physicality*, and Study 2 games scored an average of 1.18 (SD = 0.40). Both of these averages are closest to a score of 1 in the coding guide; both Study 1 and Study 2 games had a medium level of physicality on average.

Study 1 games scored an average of 0.86 (SD = 0.38) for *Sweat Factor*, while Study 2 games scored an average of 1.50 (SD = 0.53). These are closest to scores of 1 and 2 respectively. In other words, Study 1 games had a low sweat factor on average, while Study 2 games had a high sweat factor - Study 2 games were more cardio intensive that Study 1 games.

Both Study 1 and Study 2 games scored an average of 0.43 (Study 1 SD = 0.50, Study 2 SD = 1.60) for *Physical Environment*. This average is closest to a value of 0, or unspecified, in the coding guide. In cases where the physical environment was unspecified, Study 1 games scored an average of 1.25 (SD = 0.50), closest to a value of 1, while Study 2 games scored an average of 1.50 (SD = 0.52), closest to a value of 2. In other words, when the physical environment was unspecified, Study 1 games tended to imply needing a small play area while Study games implied the need for a large play area.

Table 50

Average scores of US Study 1 and Argentina Study 2, Day 3 games for physicality variables.

	Study 1 Day 3	**Study 2 Day 3**
Variable Name	**Mean (SD)**	**Mean (SD)**
Physicality	0.00 (0.00)	0.43 (0.53)
Sweat Factor	0.00 (0.00)	0.75 (0.96)
Style of Physical Contact	N/A	N/A
Physical Environment	0.00 (0.00)	0.00 (0.00)
Physical Environment (Unspecified)	1.14 (0.38)	1.21 (0.43)

Table 50 shows relatively similar averages for physicality variables on day three between both studies. For *Physicality*, Study 1 games scored an average of 0.00 (SD = 0.00), while Study 2 games scored an average of 0.43 (SD = 0.53). These both equate to a value of 0 in the coding guide, meaning on average day three Study 1 and 2 games had low levels of physicality.

Study 1 games scored an average of 0.00 (SD = 0.00) for *Sweat Factor*, equivalent to a 0 in the coding guide. Study 2 games scored an average of 0.75 (SD = 0.96) for *Sweat Factor*, closest to a score of 1. This shows that generally Study 1 games had no cardio-intensive activities while Study 2 had a low level of cardio intensity.

Study 1 and Study 2 games had an average of 0.00 (SD = 0.00) for *Physical Environment*, equivalent to a score of 0 in the coding guide. This means that on day three games in both studies did not specify a physical play environment. When the environment was unspecified, Study 1 games scored an average of 1.14 (SD = 0.38) and Study 2 games scored an average of 1.21 (SD = 0.43), both closest to a value of 1 in the coding guide. When physical environment was unspecified, both Study 1 and Study 2 games required a small play area.

7.1.6 Mathematical Relevance/Importance to Gameplay

Table 51

Average scores of US Study 1 and Argentina Study 2, Day 2 games for mathematical-physicality relation variables.

	Study 1 Day 2	**Study 2 Day 2**
Variable Name	**Mean (SD)**	**Mean (SD)**
Motor Action and Math Relationship	0.00 (0.00)	0.08 (0.29)
Mathematical Importance	1.86 (0.38)	1.18 (0.98)
Mathematical Utilization	1.86 (0.38)	1.64 (0.50)

Table 51 shows that on day two, Study 1 and Study 2 games had similar averages for math relationship variables and therefore have nearly identical scores in the coding guide. For *Motor Action and Math Relationship*, Study 1 games scored an average of 0.00 (SD = 0.00); Study 2 games scored an average of 0.08 (SD = 0.29). Both of these averages are closest to a score of 0 in the coding guide, reflecting that both Study 1 and Study 2 games had no relationship between math concepts and physicality elements.

Study 1 games scored an average of 1.86 (SD = 0.38) for *Mathematical Importance*, while Study 2 games scored an average of 1.18 (SD = 0.98). This equates to coding guide scores of 2 for Study 1 and 1 for Study 2. In other words, math in Study 1 games was highly necessary to succeed in the game, while math in Study 2 games was only somewhat necessary.

For *Mathematical Utilization*, Study 1 games scored an average of 1.86 (SD = 0.38), while Study 2 games scored an average of 1.64 (SD = 0.50). these are both representative of a score of 2 in the coding guide, showing that both Study 1 and Study 2 games required players to perform math to make progress in the games.

Table 52

Average scores of US Study 1 and Argentina Study 2, Day 3 games for mathematical-physicality relation variables.

	Study 1 Day 3	**Study 2 Day 3**
Variable Name	**Mean (SD)**	**Mean (SD)**
Motor Action and Math Relationship	0.00 (0.00)	0.25 (0.50)
Mathematical Importance	1.43 (0.79)	0.14 (0.38)
Mathematical Utilization	1.43 (0.79)	1.00 (0.58)

Table 52 shows that on day three, however, Study 2 games scored slightly lower than Study 1 games on math relationship variables. Study 1 had an average of 0.00 (SD = 0.00) for *Motor Action and Math Relationship*, while Study 2 had an average of 0.25 (SD = 0.50). These both represent a value of 0 in the coding guide, showing no relationship between math and physicality in both studies.

The average score for *Mathematical Importance* in Study 1 was 1.43 (SD = 0.79), closest to a score of 1 in the coding guide. The average in Study 2 was 0.14 (SD = 0.38), closest to a score of 0 in the coding guide. This means that Study 1 games on average had math that was partially necessary to succeed, while math in Study 2 games was not necessary to succeed at all.

Study 1 games scored an average of 1.43 (SD = 0.79) for *Mathematical Utilization*, while Study 2 games scored an average of 1.00 (SD = 0.58). These both are closest to a score of 1 in the coding guide, showing that in both studies, games required players to perform math only sometimes.

7.1.7 Game Representation Components

Table 53

Percent occurrence of written narrative components present in Day 2 games from both US Study 1 and Argentina Study 2.

	Study 1 Day 2	**Study 2 Day 2**
Variable Name	**% Occurrence**	**% Occurrence**
Rules	100.00	85.71
Physical Objects	85.71	71.43
Physical Space	57.14	35.71
Timing	57.14	64.29
Physicality	71.43	71.43

Table 53 shows that overall, Study 1 games had more written narrative components than Study 2 games on day two. 100.00% of Study 1 games had rules present, while only 85.71% of Study 2 games had rules present. 85.71% of Study 1 games referenced physical object, while only 71.43% of Study 2 games did so. 57.14% of Study 1 games mentioned a physical space, while only 35.71% of Study 2 games mentioned a physical space. 57.14% of Study 1 referenced timing; a slightly higher amount of Study 2 games referenced timing at 64.29%. 71.43% of both Study 1 and Study 2 games contained physicality.

Table 54

Percent occurrence of written narrative components present in Day 3 games from both US Study 1 and Argentina Study 2.

	Study 1 Day 3	**Study 2 Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Rules	0.00	7.14
Physical Objects	0.00	0.00
Physical Space	0.00	0.00
Timing	0.00	0.00
Physicality	0.00	0.00

Table 54 shows an overall lack of written narrative components in both studies on day three. 0.00% of Study 1 games contained rules, while 7.14% of Study 2 games contained rules on day three. 0.00% of games in both studies contained any other written narrative components on day three.

Table 55

Percent occurrence of drawing components present in Day 2 games from both US Study 1 and Argentina Study 2.

	Study 1 Day 2	**Study 2 Day 2**
Variable Name	**% Occurrence**	**% Occurrence**
Rules	42.86	7.14
Physical Objects	100.00	85.71
Physical Space	28.58	28.57
Timing	14.29	7.14
Physicality	42.86	57.14

Table 55 shows that on day two, more games in Study 1 had drawing components present than games in Study 2. 42.86% of Study 1 games had drawing components that implied rules, while only 7.14% of Study 2 games had such drawings. 100.00% of Study 1 games contained drawings of physical objects; 85.71% of Study 2 games contained drawings of physical objects. A similar amount of games in both studies had drawings of a physical space, with 28.58% of Study 1 games and 28.57% of Study 2 games containing these drawings. 14.29% of Study 1 games had drawings that implied timing; only 7.14% of Study 2 games had drawings that implied timing. 42.86% of Study 1 games contained drawings of physicality, while a slightly higher amount of Study 2 games contained drawings of physicality at 57.14%.

Table 56

Percent occurrence of drawing components present in Day 3 games from both US Study 1 and Argentina Study 2.

	Study 1 Day 3	**Study 2 Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Rules	0.00	0.00
Physical Objects	14.29	14.29
Physical Space	0.00	0.00
Timing	0.00	0.00
Physicality	0.00	0.00

On day three, the same amount of games in both studies had identical drawing components present, as can be seen in Table 56. 14.29% of Study 1 and Study 2 games had drawings of physical objects. 0.00% of games in both studies had any other drawing components present on day three.

Table 57

Percent occurrence of FSMD components present in Day 3 games from both US Study 1 and Argentina Study 2.

	Study 1 Day 3	**Study 2 Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Rules	42.86	42.86
Physical Objects	28.57	42.86
Physical Space	0.00	7.14
Timing	100.00	64.29
Physicality	0.00	28.57

Table 57 shows that on day three, the presence of specific FSMD components varied greatly between studies, although generally a lower amount of Study 1 games had FSMD components present. 42.86% of both Study 1 games and Study 2 games had rules conveyed through their FSMDs. 28.57% of Study 1 games referenced physical objects in their FSMDs, while a higher amount of 42.86% of Study 2 games referenced physical objects. 0.00% of Study 1 games mentioned a physical space in their FSMDs, while 7.14% of Study 2 games did so. 100.00% of Study 1 games referenced timing, while only 64.29% of Study 2 games referenced timing. 0.00% of Study 1 games contained references to physicality in their FSMDs; 28.57% of Study 2 games referenced physicality.

7.1.8 Finite State Machine Diagram (FSMD)

Table 58

Percent occurrence of FSMD specific variables in US Study 1 and Argentina Study 2, Day 3 games.

	Study 1 Day 3	**Study 2 Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
Presence of Finite State Machine Diagram	100.00	100.00
Specification of Mistakes	71.43	85.71
Domain Level: Management-Level	0.00	0.00

On day three, 100.00% of games in both studies had a FSMD present, as shown in Table 58. A higher number of Study 2 games accounted for player errors, with 71.43% of Study 1 games including a specification of mistakes, and 85.71% of Study 2 games including a specification of mistakes. 0.00% of games in both studies included a FSMD at the management level.

Table 59

Average scores for FSMD specific variables in US Study 1 and Argentina Study 2, Day 3 games.

	Study 1 Day 3	**Study 2 Day 3**
Variable Name	**Mean (SD)**	**Mean (SD)**
Output State Representation	2.71 (0.76)	2.21 (1.12)
Transition State Representation	2.00 (1.29)	2.50 (1.09)
FSMD Consistency with Specified Rules	1.14 (1.21)	0.14 (0.53)
State Consistency (Boxes)	1.14 (1.07)	0.64 (0.74)
Transition Consistency (Arrows)	1.00 (1.15)	0.43 (0.65)
Domain Level: Team-Level	0.29 (0.76)	0.07 (0.27)
Domain Level: Player-Level	1.00 (0.00)	1.00 (0.00)
FSMD Completion	1.43 (0.79)	0.93 (0.62)

Table 59 shows that on average, while Study 1 games scored higher on FSMD-specific variables than Study 2 games, FSMDs in both studies were both relatively at the same level of completeness. The average score for *Output State Representation* by Study 1 games was 2.71 (SD = 0.76), closest to a score of 3 in the coding guide. The average for this variable by Study 2 games was 2.21 (SD = 1.12), closest to a score of 2 in the guide. In other words, Study 1 games almost always had states represented in boxes while Study 2 games had states represented in boxes only most of the time.

Study 2 did score higher for *Transition State Representation*, with an average of 2.00 (SD = 1.29) for Study 1 games and an average of 2.50 (SD = 1.09) for Study 2 games. These are closest to scores of 2 and 3 respectively in the coding guide. In other words, Study 1 games used arrows between states most of the time, while Study 2 games almost always used arrows between states.

The average score for *FSMD Consistency With Rules* was 1.14 (SD = 1.21) in Study 1 games, closest to a score of 1 in the coding guide. The average for Study 2 games was 0.14 (SD = 0.53), closest to a score of 0 in the coding guide. On average, Study 1 games were sometimes consistent with rules present in any day three written narrative components, while Study 2 games were never consistent with such rules.

Study 1 games scored an average of 1.14 (SD = 1.07) for *State Consistency*, while Study 2 games scored an average of 0.64 (SD = 0.74). These are closest to values of 1 and 0 respectively in the coding guide. This reflects that on average, Study 1 games sometimes used states to directly represent what the player should be seeing, while Study 2 games never did this. Study 1 games scored an average of 1.00 (SD = 1.15) for *Transition Consistency*, while Study games scored an average of 0.43 (SD = 0.65). These are representative of scores of 1 and 0 respectively in the coding guide. In other words, Study 1 games sometimes labeled the arrows of the FSMDs, while Study 2 games mostly never labeled arrows.

Study 1 games scored an average of 0.29 (SD = 0.76) for *Domain Level: Team-Level*, while Study 2 games scored an average of 0.07 (SD = 0.27). While this shows that there were more games in Study 1 that specified a FSMD at a team level, both of these averages are ultimately equivalent to a score of 0 in the coding guide; overall both Study 1 and Study 2 games did not specify FSMDs at the team level.

Study 1 and Study 2 games both scored an average of 1.00 (SD = 0.00) for *Domain Level: Player-Level*, equivalent to a score of 1 in the coding guide. This shows that all games in both studies specified their FSMDs for a single player.

Lastly, Study 1 games on average scored 1.43 (SD = 0.79) for *FSMD Completion*, while Study 2 games scored an average of 0.93 (SD = 0.62). These are both closest to a score of 1 in the coding guide, reflecting that FSMDs in both studies were of the same level of completeness.

Table 60

Percent occurrence of input types present in US Study 1 and Argentina Study 2, Day 3 games.

	Study 1 Day 3	**Study 2 Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
RFID	0.00	0.00
Buttons	0.00	71.43
GPS	0.00	0.00
Keyboard	85.71	7.14
Touch Interface	0.00	28.57
Timer	0.00	0.00
Other User	0.00	0.00

Table 60 shows that games in Study 2 used a wider variety of input types than games in Study 1. 85.71% of Study 1 games used a keyboard, and 0.00% of Study 1 games used any other type of input. By comparison, three input types were present in Study 2 games, with 71.43% of games using buttons, 7.14% using a keyboard, and 28.57% using a touch interface.

Table 61

Average total number of states and transitions present in FSMDs in US Study 1 and Argentina Study 2, Day 3 games.

	Study 1 Day 3	**Study 2 Day 3**
Variable Name	**Mean (SD)**	**Mean (SD)**
States/Boxes	10.57 (8.50)	8.14 (6.20)
Transitions/Arrows	10.71 (15.12)	7.50 (5.00)
Labeled Arrows	5.57 (7.81)	2.50 (3.16)
Numbered States	3.29 (8.69)	1.07 (2.30)

Table 61 reflects that on average, FSMDs in Study 1 games were longer and had more components present than those of Study 2 games. On average, Study 1 FSMDs had 10.57 states (SD = 8.50) while Study 2 FSMDs only had 8.14 states (SD = 6.20). Study 1 FSMDs had an average of 10.71 transitions (SD = 15.12) while Study 2 FSMDs had an average of 7.50 transitions (SD = 5.00). The average number of labeled arrows in Study 1 FSMDs was 5.57 (SD = 7.81) and 2.50 (SD = 3.16) in Study 2 FSMDs. Study 1 FSMDs had an average of 3.29 numbered states (SD = 8.69) while Study 2 FSMDs only had an average of 1.07 numbered states (SD = 2.30).

Table 62

Percent occurrence of FSMD elements that imply comprehension of programming knowledge in US Study 1 and Argentina Study 2, Day 3 games.

	Study 1 Day 3	**Study 2 Day 3**
Variable Name	**% Occurrence**	**% Occurrence**
A reference to "If-then" Statements	14.29	64.29
A reference to "While" Loops	85.71	0.00
Arrow(s) that loop to a previous state	57.14	64.29

Table 62 suggests that Study 2 games reflected a higher understanding of if-then statements, with 14.29% of Study 1 games making a reference to an if-then statement, and 64.29% of Study 2 games making such a reference. Study 1 games reflected a higher understanding of loops, however. 85.71% of Study 1 games made a reference to a “while” loop while 0.00% of Study 2 games made such a reference. A similar amount of games from both studies had arrows that looped back to a previous state, with 57.14% of Study 1 games and 64.29% of Study 2 games having this reference present.

7.2 Discussion

Overall, both U.S. games and Argentina games tended to score similarly on most variables in the coding guide. However, there were a few key differences in several variables which are highlighted below.

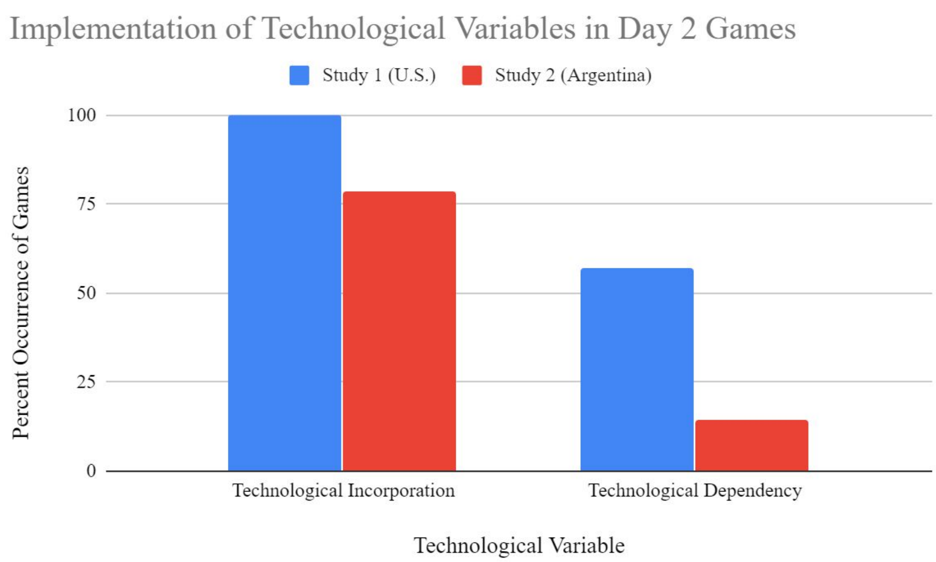

Figure 11: *Differences in utilization of technology between U.S. Study 1 and Argentina Study 2 games on Day 2.*

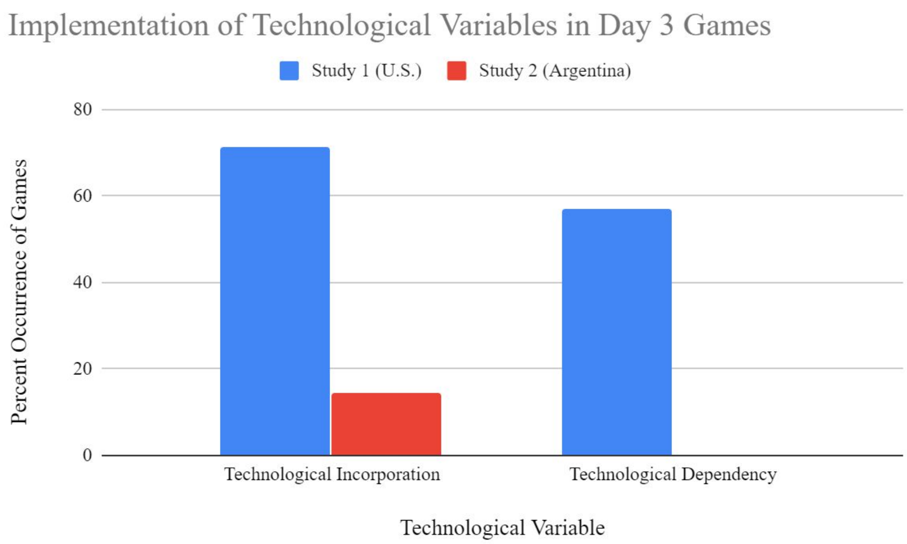

Figure 12: *Differences in utilization of technology between U.S. Study 1 and Argentina Study 2 games on Day 2.*

On both day two and day three, U.S. games scored higher than Argentina games for all technological variables, as can be seen in Figures 11 and 12. On day two, a similar, but still lower, amount of Argentina games utilized *Technological Incorporation* compared to U.S. games. For all other variables on all days, however, a significantly higher amount of U.S. games focused on technology than Argentina games. This may be because there is more access to technology in the U.S., as well as the fact that technology is more modern and updated in the U.S. and has a greater presence in daily life. Because children in the U.S. may tend to be exposed to technology more frequently than children in Argentina, this may be why utilization of technology was explicitly mentioned more often in U.S. games.

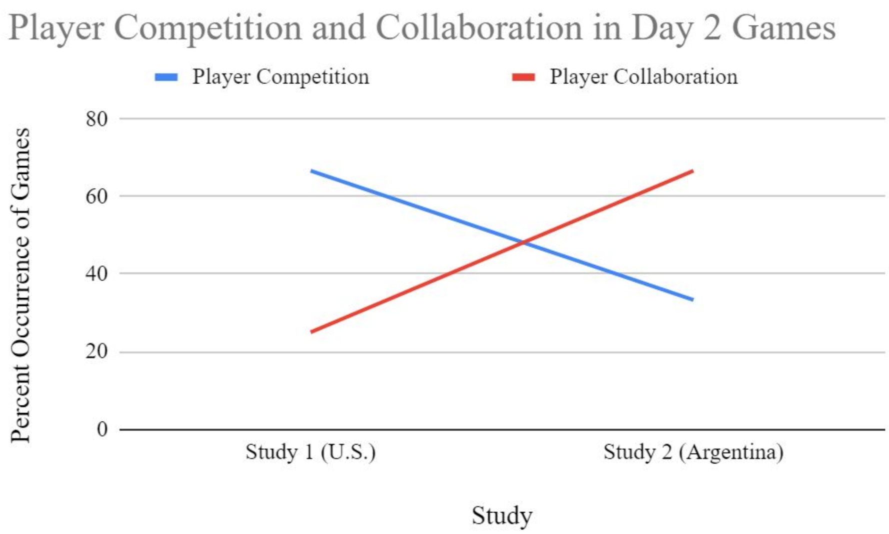

Figure 13: *Differences in percentage of Day 2 games that utilize competition and collaboration between US Study 1 and Argentina Study 2*

On day two, there was a noticeable difference between studies regarding the presence of competition and collaboration. Figure 13 shows an almost inverse relationship between these variables between U.S. games and Argentina games, with 66.67% of U.S. games utilizing player competition and only 33.33% of Argentina games utilizing player competition. By comparison, 66.67% of Argentina games utilized player collaboration, while only 25.00% of U.S. games had player collaboration present. This may be indicative of differences in school environments or social settings. This relationship between competition and collaboration may reflect that in the U.S. children are used to competing against each other in the classroom, while children in Argentina are accustomed to an environment where students help each other. These social dynamics clearly are reflected in the dynamics between players in their games.

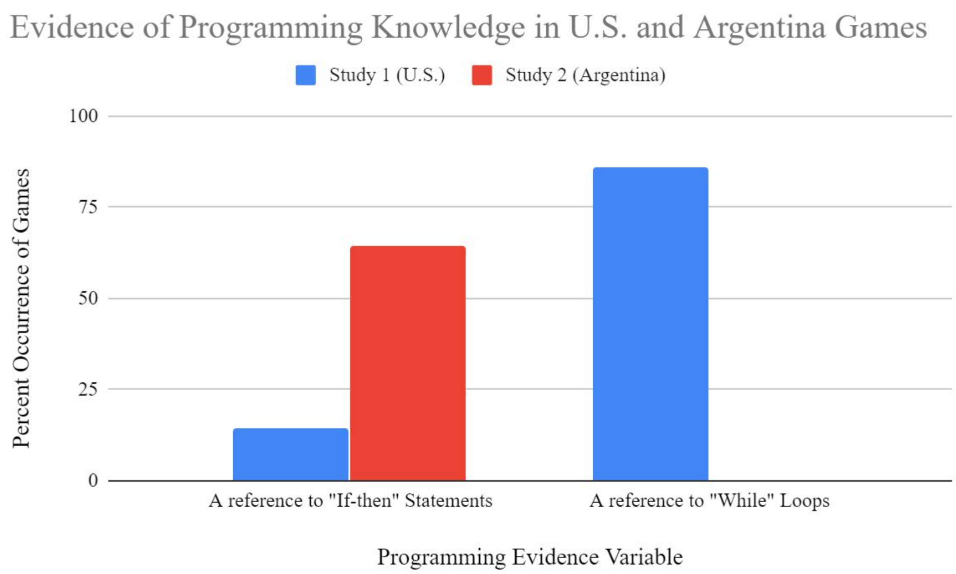

Figure 14: *Differences in the amount of games reflecting types of programming knowledge between U.S. Study 1 and Argentina Study 2.*

There was a difference between studies in the amount of games that reflected certain types of programming knowledge, as shown in Chart 4. A higher amount of games from Argentina showed evidence of if-then statements in their FSMDs. However, no games at all from Argentina reflected knowledge of loops while a high amount of U.S. games demonstrated this knowledge. Loops are a more complex topic in computer science than if-then statements. Because U.S. games focused more on loops, while Argentina games focused on if-then statements, this difference suggests that U.S. participants had a more advanced understanding of programming than Argentina participants.

While there are differences in U.S. and Argentina games as highlighted in the charts above, overall games tended to score similarly between studies. Overall, games in both studies scored similarly for or had a similar number of games that utilized gameplay elements, team dynamics, physicality elements, FSMD components and level of FSMD completion.

7.3 Limitations

Despite best efforts to maintain consistency between Study 1 and Study 2, there are several limitations to take into account. One such limitation is time of data collection. In Study 1, data was collected well after the procedure was fully complete - the study was run during a summer camp and data was not documented and analyzed until a later date. In Study 2, only seven weeks were available to both conduct the total procedure as well as collect and analyze the data. For this reason, a “cutoff point” was set upon starting day four of the procedure at any given school, and this cutoff point was the designated point at which data was collected and documented. All results from Study 2 are based off the data collected at this time - if students returned to the papers from the day two and/or day three procedures to add, edit, erase, or alter their work in any way, these changes were not taken into account. Because the data from Study 1 was documented at a later date, it is not possible to know whether students in Study 1 did in fact alter their work at any point past day four of the procedure, thus resulting in possible differences in time spent creating games and by extension possible differences in the games themselves.

Another limitation is the presence of teachers in Study 2. Because Study 2 was conducted in schools, teachers at times would jump in unprompted, or help students with their game creation, which may have impacted results as well.

8. Conclusion

8.1 Summary

The research questions this study had the goal of answering were as follows: *Are there differences in the games students from two different countries create when asked to create games for math learning? What are those differences, if they exist?* After examining the changes in games between day two and day three within countries, most games decreased in having elements present at all, or had a decrease in the level of importance or specification of some elements, implying that when children have a game idea and are asked to represent it in a format conducive to actually programming the game, many elements are lost, regardless of country.

Between countries, there were both similarities and differences between games. Overall, games in the U.S. and in Argentina scored similarly for gameplay elements, team dynamics, physicality elements, math-physicality relationships, and FSMD completion. Out of the noticeable differences, U.S. games tended to score higher for usage of technology, competition, presence of written and drawn game components, and U.S. games had longer FSMDs on average. Argentina games score higher for math concepts, collaboration, presence of FSMD components, and usage of input types. Both U.S. and Argentina games scored similarly overall for FSMD components that indicated programming knowledge, but U.S. games scored higher for an understanding of loops while Argentina games score higher for an understanding of if-then statements.

8.2 Future Work

There are several possibilities to continue with this research. First, only a sample of fourteen out of the total fort-one games created were analyzed in Study 2, due to time constraints. It would be interesting to code all remaining games to see if this additional data changes the results of Study 2 and/or of the cross-cultural comparison.

There could be two potential new studies based off of the findings of this paper. As seen in the cross-cultural comparison, games from the U.S. scored higher than games from Argentina for technological incorporation. This could be due to the fact that schools in the U.S. have more modern technology and likely more exposure to technology as well. This poses the question as to whether exposure to technology affects how heavily incorporated technology is in game creation. A study could be conducted in the U.S. with children in school districts with easy access to updated technology, and in school districts that have limited access to technology. The games created in these schools could analyzed and compared to see if exposure to technology in daily life affects the level of technological incorporation in games.

Games from Argentina score higher overall for math content than games from the U.S. This could be due to differences in the education systems. Another future study that could be conducted could explore whether curriculum or education styles in different U.S. schools has an effect on the math content present in games. A study could compare games created in math or technical middle/high schools and in public middle/high schools to see if schools that focus more heavily on math education influence the presence of math in game creation.

9. References

Arroyo, I.; Micciollo, M., Casano, N., Ottmar, E., Hulse, T., de Rodrigo, M. (2017). Wearable Learning: Multiplayer Embodied Games for Math.

Harrison A., Ottmar, E., Arroyo, I., Rosenbaum, L., Bakker, A., Abrahamson, D., Hulse, T., Manzo, D., & Landy, D. (2018a). Embodiment and action in mathematics games. Symposium presented at the American Psychological Association's conference on Technology, Mind & Society, April 5-7, 2018, Washington, DC.

Harrison, A., Hulse, T., Manzo, D., Micciolo, M., Ottmar, E., & Arroyo, I. (2018b). Computational thinking through game creation in STEM classrooms. Proceedings (Part II) of the 19th International Conference on Artificial Intelligence in Education. London, U.K. pp. 134-138

Hulse, T., Harrison, A., Arroyo, I., Ottmar, E. Developing Methods to Implement Embodied Game Design for Mobile Learning Technologies in STEM Classrooms (2018a). Presented at the 2018 conference of the North American Chapter of the Psychology of Mathematics Education.

Kafai, Yasmin & Burke, Quinn. (2015). Constructionist Gaming: Understanding the Benefits of Making Games for Learning. Educational Psychologist. 50. 313-334. 10.1080/00461520.2015.1124022.

Login form represented as a finite state machine. (n.d.). Retrieved from https://24ways.org/2018/state-machines-in-user-interfaces/

Micciolo, M., Arroyo, I., Ottmar, E., Hulse, T., & Harrison, A. (2018) The Wearable Learning Cloud Platform for the Creation of Embodied Multiplayer Math Games. 2018 conference on Artificial Intelligence in Education, London, UK.

Ottmar, E., Arroyo, I., Castro, F., Hulse, T., & Chatani, R. (2017). *Multiplayer Game Design and*

Computational Thinking Coding Guide. Worcester Polytechnic Institute, Worcester, MA.

Tretkoff, E. (2008, October). October 1958: Physicist Invents First Video Game. Retrieved from https://www.aps.org/publications/apsnews/200810/physicshistory.cfm.

What's wrong with this picture? (n.d.). Retrieved October 3, 2019, from https://code.org/promote.

APPENDIX A.

Coding Guide Descriptors

General Game Characteristics

The following codes relate to the following concepts: general gameplay mechanics, the style of play, the mathematical content and grade level of the games created by the students. In this section, select the most appropriate code based on the descriptions provided for each.

Game Descriptor

This refers to how the students describe the modeling aspects of the design process for their respective games. Did the creators base the game on a previously existing game?

0	1	2
This game is not based on any previously existing game and the team did not explicitly state the name of the game.	The name of the game was not explicitly stated by the team but the game is very synonymous to a preexisting game.	The team explicitly states that their game is based on previous game/games.

Content

This refers to which mathematical concepts are the main focus of the designed games. The categories for this section are taken from the *Common Core Standards 2016*. In this section, a 0 indicates that the concept is not tested within the game and a 1 indicates that it is tested within the game. A list of definitions and examples for the following categories can be found on the following page.

Counting and Cardinality	0	1
Operations and Algebraic Thinking	0	1
Number and Operations in Base Ten	0	1
Number and Operations with Fractions	0	1

Measurement and Data	0	1
Geometry	0	1
Ratios and Proportions	0	1
The Number System	0	1
Expressions and Equations	0	1
Functions	0	1
Statistics and Probability	0	1

Definition of Mathematical Content (Common Core 2016)

This section contains a brief description of the mathematical domains as stipulated by the Common Core Standards. Each subsection contains a definition and an example problem that shows how the mathematical domain can be tested.

Counting and Cardinality - Knowing the number names, counting and comparing numbers

Sample Problems: Which of the following is true: 7 > 4, 5 > 3, 1 > 2?

Operations and Algebraic Thinking – Using the four operations to solve problems, which may include variables

Sample Problems: 9 times 4, 8 divided by 3, seven plus five, 7 – x = 4

Number Operations in Base Ten - Understanding the place value system and performing operations with decimals, whole numbers, or integers (no variables)

Sample Problem: 3.175 + 4.7, understanding the 100 is 10 times 10

Number Operations in Fractions - Using the four operations with fractions (represented in fraction form)

Sample Problems: $\frac{1}{4} + \frac{1}{2}$, $\frac{5}{8} * \frac{2}{3}$, 9 / $\frac{1}{4}$ and $\frac{3}{4} - \frac{1}{2}$

Measurements and Data - Calculating expected values, using them to solve problems and using probability to evaluate

Sample Problem: The value of a car increases by 20% each year, if the value after 5 years is ______.

Geometry - Solving mathematical problems involving angle measure, area and volume for 2D and 3D shapes. Transferring 2D knowledge of geometry to Cartesian planes (using coordinates)

Sample Problem: Calculate the distance between the two points (1, 2) (4, 6)

Ratios and Proportions - Analyzing proportional relationships and using them to solve problems

Sample Problem: Profits are allocated in the ratio of 1:2:3. Express the largest share as a fraction.

The Number System - Analyzing and recognizing different types of number; rational, prime, irrational, etc.

Sample Problem: Which of the following are rational numbers: pi, √2, 7?

Expressions (with variables) and Equations - Analyzing and solving linear equations as well as simultaneous equations, using the properties of operations to generate equivalent expressions

Sample Problem: Solve the following pair of equations: $2x + 5y = 7$, $3x - 5y = 13$

Functions – Understanding, analyzing, and building functions in different contexts

Sample Problem: What is the return on 10,000 dollars invested at an annual rate of 5%? In this case, the return is a function of the length of time the money is invested.

Statistics and Probability - Investigating patterns of association in data sets and using sample sizes to draw inferences about populations

Sample Problem: If a die is rolled twice, what is the probability of rolling 2 even numbers?

Targeted Grade Level

This refers to the grade level that is specified as the target audience for the designed game.

0	1	2	3	4
Unspecified	Elementary School	Middle School	High School	College

Progressive Levels

This refers to the presence of a progressive level of difficulty within the game. Does the game get harder as the player makes progress?

0	1
The game does not get harder as the player makes progress.	The game gets harder as the player makes progress.

Content Adaptability

This refers to the flexibility of the game content to fit different grade levels and mathematical concepts. Do the students explicitly state that the game content can be changed to suit the needs of different groups while maintaining the same style of play? For example, the game could vary the levels of math or vary duration.

0	1
The students did NOT explicitly state that the game has Content Adaptability.	The students explicitly stated that the game has Content Adaptability.

Game Facilitator

This refers to the presence of a facilitator that helps the game run smoothly. Does the game require the help of a student or teacher who facilitates game-play?

0	1	2	3
It was IMPLICITLY implied that the game does NOT need a facilitator.	It was IMPLICITLY implied that the game needs a facilitator.	It was EXPLICITLY stated the game does NOT need a facilitator.	It was EXPLICITLY stated the game needs a facilitator.

End-Goal

This refers to the presence of an end-goal for players or teams to win or finish the game. Does the game have a clear end-goal?

0	1
The game does not contain an end-goal; the game resembles an activity.	The game does contain an end-goal that indicates the end of the game.

Technological Descriptors

The following codes relate to the technological aspects of the designed games. The aspects include: the incorporation of technology within the game as well as the technological dependency.

Technological Incorporation

This refers to whether or not the designed game makes use of any form of technology (smart watch, iPad, computer etc.) within the gameplay.

0	1
The designed game does not incorporate any technology.	The designed game does incorporate technology into the gameplay.

Technological Dependency

This refers to the level of dependency of the game on the incorporated technology. Is the game dependent on technology?

0	1
The game does not depend on technology.	The game does depend on technology.

Note: All technology could be replaced by index cards. However, for many games this would become a cumbersome/difficult experience and NOT feasible.

Team Descriptors

The following codes refer to the specifications of the team dynamics within the game. These include: the presence of teams as well as the average size of these teams.

Presence of Teams

This refers to whether or not the game was designed to be played individually or in teams. **If there are no teams, answer the next question then skip to the next section. If there are teams, select 1 then skip to Team Size. If teams are optional, select 2 and then complete every question in the next two sections (Team Descriptors and Collaboration and Competition) to account for individual and team play.**

0	1	2
No teams. Players participate in the game individually.	Teams are present. Players participate in the game within the confines of their teams.	Students EXPLICITLY state that the game can be played individually or within teams.

Team Dynamics No Teams

This refers to the style of interaction that the members of each team have with each other during gameplay. Parallel gameplay refers to all parties taking part in the game at the same time while turn-based gameplay is a style where some players take part in the game while others wait. Select the option that most accurately represent the game dynamics.

0	1
Parallel gameplay, no teams	Turn-based gameplay, no teams

Team Size

This refers to whether or not the size of the teams was explicitly or implicitly stated by the students. “Explicitly stated” means the students have a written documentation of the team size e.g. “There are 3 players on each team” while implicitly stated means the size of the team was inferred from a picture or text e.g. “Each member of the team can only answer one question, the first team to answer all four questions wins.” In this case we know that there are four questions and only 1 person can answer a question, therefore there needs to be four team members, hence, it was “implicitly stated”. Proportions, e.g. “half the class” do not apply.

0	1	2
The team sizes were not specified by the students.	The team sizes were IMPLICITLY specified by the students.	The team sizes were EXPLICITLY specified by the students.

Number of Teams

This refers to whether the number of teams necessary for the game was explicitly or implicitly stated by the students. Is a number of teams stated in the Day Summary?

0	1	2
The number of teams was not specified by the students.	The number of teams was IMPLICITLY specified by the students.	The number of teams was EXPLICITLY specified by the students.

Team Dynamics Between Teams

This refers to the interaction that one team as a whole has with other teams during gameplay. Parallel gameplay refers to a situation where all teams as a whole take part in the game at the same time. Turn-based gameplay refers to a situation where some teams take part in the game while other teams wait. Select the option that most accurately represents the game dynamics.

0	1
Parallel play between teams	Turn-based play between teams

Team Dynamics Within Teams

This refers to the interaction that members of a specific team have within their team during gameplay. Parallel gameplay refers to a situation where all members of a specific team are involved in the game at the same time. Turn-based gameplay refers to a situation where only select members of a team participate at a given time while the other team members wait. Select the option that most accurately represents the game dynamics.

0	1
Parallel play within teams	Turn-based play within teams

Collaboration and Competition

The following codes refer to the extent to which students engage in collaboration and competition while playing the game.

Player Competition (No Teams)

If no teams are involved, to what extent do players engage competitively with other players? **If there are teams, skip this question.**

0	1
There is NO competition between players.	There is competition between players.

Player Collaboration

This refers to the extent to which players engage collaboratively with other players.

0	1

0	1
There is NO collaboration between players.	There is collaboration between players.

Team Competition

This refers to the extent to which teams engage competitively with other teams. **If there are no teams, skip this question.**

0	1
There is NO competition between teams.	There is competition between teams.

Team Collaboration

This refers to the extent to which teams engage collaboratively with other teams. **If there are no teams, skip this question.**

0	1
There is NO collaboration between teams.	There is collaboration between teams.

Facilitator Competition

This refers to the extent to which players or teams engage competitively with the facilitator (e.g. teacher or fellow student). **If there is no facilitator, skip this question.**

0	1
There is NO competition between players/teams and the facilitator.	There is competition between players/teams and the facilitator.

Facilitator Collaboration

This refers to the extent to which players or teams engage collaboratively with the facilitator (e.g. teacher or fellow student). **If there is no facilitator, skip this question.**

0	1
There is NO collaboration between players/teams and the facilitator.	There is collaboration between players/teams and the facilitator.

Kinesthetics and Physicality

The following codes refers to the physical nature of the gameplay as well as the physical space necessary to play the game. The physical nature of the game includes: physical contact, physical movement and how intense the physical motion is.

Physicality

This refers to the intensity and amount of movement required by the players.

0	1	2
Low Physicality	*Medium Physicality*	*High Physicality*
Students rarely or do not move during the activity.	Students occasionally move.	Students are constantly moving.

Physicality Option

This refers to whether or not the student is required to engage in physical activity. Is it optional for students to engage in physical activity? **If you answered 0 for the previous question, skip this question.**

0	1

There is no option. Students are required to engage in physical activity.	There is an option for one or more players to not engage in physical activity.

Sweat Factor

This refers to the level of sweat measured as a function of cardiovascular activity that is involved during gameplay.

0	1	2
No Sweat	*Low Sweat Factor*	*High Sweat Factor*
No cardiac intensive activities (e.g. sitting and moving parts of the body)	Middle level cardio-intense activities (e.g. walking or brisk movement)	Cardio-intensive activities (e.g. running)

Physical Contact

This refers to the physical contact experienced by the players during gameplay. If you choose 1, answer the next question. **If you choose 0, skip the next question.**

0	1
There is no physical contact with other players.	There is physical contact with others.

Style of Physical Contact

This refers to the way in which physical contact between players is used during gameplay. It can be collaborative (hand-holding, arm-linking), competitive (tagging someone out) or both.

0	1	2
Physical contact is collaborative.	Physical contact is competitive.	Physical contact can be both collaborative and competitive.

Physical Space Diagram

This refers to whether or not the students included a diagram of the physical play area for their game.

0	1
Students did NOT include a diagram.	Students included a diagram.

Physical Environment

This refers to whether the students specified where the game will take place. Choose the primary environment if more than one is specified.

0	1	2	3	4	5	6
Unspecified	Indoor classroom	Open Outdoor Space	Gym	Playground	Computer Lab	Other

(ii) If you selected 0 (Unspecified), select one of the following codes related to the size of the environment for gameplay based on the students' descriptions.

1	2

A SMALL play area is *implicitly* required.	A LARGE play area is *implicitly* required.

Mathematical Relevance/Importance to Gameplay

The following codes describe the relationship between gestures and mathematical operations made during the game and the relevance as well as importance to gameplay.

Motor Action and Math Relationship

This describes how closely movement in the game represents math concepts. For example, students sitting or standing to represent 0 and 1, respectively, or using hand signals to describe math operators (addition, multiplication) would have strongly related motor action and math relationship. Conversely, tagging a random player would have no relationship to the mathematics involved.

0	1	2
No Relationship	*Weakly Related*	*Strongly Related*
Motor actions are not related/associated with any of the mathematics involved.	Motor actions are somewhat related/associated with the mathematics involved.	Actions are related/associated with the mathematics involved.

Mathematical Importance

This refers to how important doing math problems is to succeed within the game.

0	1	2
Not Important	*Low Importance*	*High Importance*
The math is not necessary for any goal.	The math is non-essential and marginally necessary to succeed in the game.	The math involved is necessary to succeed in the game.

Mathematical Utilization

This refers to how often the players are required to do any form of mathematical operations to make progress within the game.

0 *Never*	*1* *Sometimes*	*2* *Most of the Time*
Players can make progress without doing any math.	Players do math problems in certain situations to make progress.	Players must do some form of math to make progress in the game.

Game Representation Components

Game Representation Components

The following codes refers to how students described their designed games through multiple representations (e.g. Narrative, Drawings, Finite State Machine Diagrams). Within each representation students used a variety of components to express their game design (e.g. Rules, Materials, Space, Timing, Physicality). Rules refer to any expression of how to play the game and what players should do in general and specific situations. Physical Objects refers to any resources needed to play the game, including cards, technology, props, etc. Physical space refers to any expression of the physical environment needed to play the game. Timing refers to any expression of time within the game. For example, students may have periods of waiting time to take turns or react to an opponent's actions. Physicality refers to any expression of physical contact or physical engagement in the game. For example, students may need to physically tag opponents or run and jump to accomplish a goal of the game.

For each representation (Written Narrative, Drawings, and Finite State Machine Diagrams) code items as **not present (0)**, **present (1)**. Mark only one code per item. **If a component is not included, skip that section. For example, if there is no Drawing Component, skip those items and move on to FSMD Components.**

Written Narrative Components	Status	
Rules	0	1
Physical Objects	0	1
Physical Space	0	1
Timing	0	1
Physicality	0	1

Drawing Components	Status	
Rules	0	1
Physical Objects	0	1
Physical Space	0	1
Timing	0	1
Physicality	0	1
FSMD Components	**Status**	
Rules	0	1
Physical Objects	0	1
Physical Space	0	1
Timing	0	1
Physicality	0	1

Finite State Machine Diagram (FSMD)

A Finite State Machine Diagram (FSMD) is used in computer science to visually describe the behavior of a system. This diagram does so by documenting the changes in the output that occur throughout the game. In the context of this coding scheme, "output" will be defined as *what is seen by the user's screen*. **Before** coding this section please read the following introduction to Finite State Machine Diagrams below to give you a better understanding of the concepts.

A Finite State Machine Diagram is a visual representation of the behavior of a system. In the context of game design, the game itself is the system. A sample Finite State Machine Diagram can be seen below in Figure 3.

Figure 3 represents a Finite State Machine Diagram. In the above diagram, the **circles** represent **output states**, the **arrows** represent **transition states**. **An arrow is defined as a solid line with an end that represents a direction. Note: double-ended arrows count as two arrows.** A line with no direction is NOT considered a transition.

An output state is a representation of what the system displays at a specific point of the game. For example, at the start of the game when neither team has made any form of input, the game prompts the teams with some output i.e. "Team A, Team B waiting". After receiving input, the system responds by displaying a different output state.

A transition state represents a conditional input that is necessary to bring about a discrete change in the output state. For example, at the output state "Team A, Team B waiting" the conditional input needed to change from this state is a countdown timer. When this condition is met, the change in output state can occur. The countdown timer represents the transition state.

Figure 3. Sample Finite State Machine Diagram for ClassATeam3Day3

Presence of Finite State Machine Diagram

This assesses whether or not students have a Finite State Machine Diagram(s). **If you choose 0, skip the rest of the questions in this document.** A Finite State Machine Diagram is a visual representation that specifies the behavior of technology used in the game through boxes and arrows. To be considered a FSMD, the diagram must contain arrows that point to boxes or a block of text. **If you select 1 and there are multiple diagrams, choose the primary diagram to answer the remaining items in this document.**

0	1
There is no representation of a Finite State Machine Diagram.	There is some representation that resembles a Finite State Machine Diagram.

Input Types

This refers to what type of input results in a change from one output state to another. **RFID (Radio Frequency Identification Device)** refers to technologies that incorporate the use of radio waves to read and capture information stored on a tag attached to an object such as a Near Field Communication (NFC) scanner. **Buttons** refer to physical buttons on a device. **GPS (Global Positioning System)** refers to technology that tracks position and can change states depending on player location. **Keyboard** refers to a physical keyboard. **Touch Interface** refers to any input made on a touch-screen device that could not be done with buttons or keyboard (i.e. dragging an object or drawing). **Timer** refers to any transition based on a preset timer. For example, a player that enters an incorrect answer must wait 10 seconds before answering again. **Other User** refers to any transition based on an action from another player or game manager. For example, a player only receives a problem when an opponent crosses the line onto their side of the playing field. Mark **0** for not present and **1** for present.

Type of Input	Status	
RFID	0	1
Buttons	0	1
GPS	0	1
Keyboard	0	1
Touch Interface	0	1
Timer	0	1
Other User	0	1

Output State Representation

An output state is a representation of what the game screen represents while the game is being played. This question assesses whether or not outputs are represented within drawn outlines such as boxes or circles of the Finite State Machine Diagram.

0	1	2	3
Never, or mostly never	Sometimes	Most of the time	Always, or Almost Always

Transition State Representation

This refers to the extent to which arrows represent transitions between states within the Finite State Machine Diagram. These can be triggered by any form of input such as RFID scans, GPS, Buttons, Touch Interface, Timers, Keyboard and input from another player.

0	1	2	3
Never, or mostly never	Sometimes	Most of the time	Always, or Almost Always

Finite State Machine Diagram Consistency with Specified Rules

This is the extent to which the Finite State Machine Diagram is consistent with the rules (written or pictorial) as stipulated by the students. For example, if the written rules dictate that players must participate in teams and the Finite State Machine Diagram shows that team play is optional, then the Finite State Machine Diagram is inconsistent with the game rules.

0	1	2	3
Never, or mostly never	Sometimes	Most of the time	Always, or Almost Always

State Consistency (Boxes)

This refers to how consistently the boxes (states) represent what players should be seeing on the screen of their mobile device. Some of the boxes might represent something else, such as logic of the program, or roles of the players, or general state of the game, etc. that does not correspond to what players see on the screen. How often do the states represent what players should be seeing on their screen?

0	1	2	3
Never, or mostly never	Sometimes	Most of the time	Always, or Almost Always

Transition Consistency (Arrows)

This refers to how consistently the arrows (transitions) are labeled to represent an event that triggers a switch from one state to another, or whether some of the arrows might represent something else. For example, if the students generally labeled the arrows with the type of input needed to trigger the transition, but sometimes they did not specify which input was associated with a given arrow or labeled the arrow with the action of someone other than the player using their mobile device, this would mean that the students "Sometimes" had transition consistency.

0 1 2
3

Never, or mostly never Sometimes Most of the time
Always, or Almost Always

Specification of Mistakes

This refers to whether or not the Finite State Machine Diagram contains states that are transitioned to when a player makes a mistake. Mistakes can include incorrect answers and failure to submit an answer within a specified time constraint.

0	1
The Finite State Machine Diagram does not account for possible mistakes that players might make while playing the game.	The Finite State Machine Diagram accounts for possible mistakes players might make while playing the game.

Domain Level: Management-Level

Does the diagram contain any references to managerial roles such as a teacher or game manager that coordinates teams or players?

0	1
The Finite State Machine Diagram does not contain references to game management.	The Finite State Machine Diagram does contain references to game management.

Domain Level: Team-Level

Does the diagram contain any references to teams as a whole? If the diagram represents all possibilities for all teams within the inputs, outputs and transitions, then the Finite State Machine Diagram is specified at the team-level for each team (1). If the Finite State Machine Diagram only represents an example for one team, then it is specified for a single team (2).

0	1	2
The Finite State Machine Diagram is not specified at the team-level.	The Finite State Machine Diagram is specified for a single team.	The Finite State Machine Diagram is specified for each team at their respective levels.

Domain Level: Player-Level

This refers to level of specification within the Finite State Machine Diagram. If the Finite State Machine Diagram represents an example of output/transitions for one player, then it is specified for a single player (1). If there are one or two diagrams that represent possibilities for more than one player, then the Finite State Machine Diagram(s) are specified for multiple players (2).

0	1	2
The Finite State Machine Diagram is not specified at the player-level.	The Finite State Machine Diagram is specified for a single player.	Multiple Finite State Machine Diagrams are specified for multiple players.

Finite State Machine Diagram Completion

This refers to the extent to which the diagram makes logical sense as a complete finite state machine diagram. This includes properly labeled and positioned states and transitions. Looking at the diagram, how accurately are the above components assembled to form a logical, complete diagram?

0 1 2

3

Never, or mostly never Sometimes Most of the time

Always, or Almost Always

Quantitative Analysis of FSMD

For this section write the total number of each category in the space provided on the answer sheet. Use only the primary diagram included.

Category

States/Boxes
Transitions/Arrows
Labeled Arrows (includes input to transition; excludes numbers)
Numbered States

Evidence of Programming Language Knowledge

Mark **if any** of the Finite State Machine Diagrams included any kind of programmatic thinking; specifically, if-then conditional statements or loops. Did the students specifically write “If-then” statements in their diagram(s)? Did they include arrows that loop back to a previous state in the diagram? Did they specifically refer to “while” loops? These loops refer to a sequence of instructions that is continually repeated until a certain condition is reached.Loops refer to Choose all that apply.

Types	Status	
A reference to "If-then" Statements	0	1
A reference to "While" Loops; or "Do this… until …"	0	1
Arrow(s) that loop to a previous state	0	1

Answer Sheet

3 Digit Code_______________ Day _____________

Category				Pag e
General Game Characteristics				21-2 3
Game Descriptor	0	1	2	21
State the **name of the game** specified by the students or that you believe it to be.				
Content				21
Counting and Cardinality	0	1		
Operations and Algebraic Thinking	0	1		
Number and Operations in Base Ten	0	1		
Number and Operations with Fractions	0	1		
Measurement and Data	0	1		

Geometry	0		1			
Ratios and Proportions	0		1			
The Number System	0		1			
Expressions and Equations	0		1			
Functions	0		1			
Statistics and Probability	0		1			
Targeted Grade Level	0	1	2	3	4	23
If specified, state the grade level.						
Progressive Levels	0		1			23
Content Adaptability	0		1			23
Game Facilitator	0	1	2	3		23
End-Goal	0		1			
Technological Descriptors						24
Technological Incorporation	0		1			24
If you selected **1**, list all technology here.						
Technological Dependency	0		1			24
Team Descriptors						25-26
Presence of Teams	0	1	2			25

Team Dynamics No Teams	0	1		25
Team Size	0	1	2	25
If you selected **1** or **2**, write the team size here.				
Number of Teams	0	1	2	
If you selected **1** or **2**, write the number of teams here.				
Team Dynamics Between Teams	0	1		26
Team Dynamics Within Teams	0	1		26
Collaboration and Competition				27-28
Player Competition	0	1		27
Player Collaboration	0	1		27
Team Competition	0	1		27
Team Collaboration	0	1		27
Facilitator Competition	0	1		28
Facilitator Collaboration	0	1		28
Kinesthetics and Physicality				29-30
Physicality	0	1	2	29
Physicality Option	0	1		29

<table>
<tr><td>Sweat Factor</td><td colspan="2">0</td><td colspan="2">1</td><td colspan="3">2</td><td>29</td></tr>
<tr><td>Physical Contact</td><td colspan="3">0</td><td colspan="4">1</td><td>29</td></tr>
<tr><td>Style of Physical Contact</td><td colspan="2">0</td><td colspan="2">1</td><td colspan="3">2</td><td>30</td></tr>
<tr><td>Physical Space Diagram</td><td colspan="3">0</td><td colspan="4">1</td><td>30</td></tr>
<tr><td>Physical Environment</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>30</td></tr>
<tr><td>(ii) If you selected 0, select one of the codes.</td><td colspan="3">1</td><td colspan="4">2</td><td></td></tr>
<tr><td>(iii) If you selected 6, write the specified environment here.</td><td colspan="7"></td><td></td></tr>
<tr><td>List any secondary locations here.</td><td colspan="7"></td><td></td></tr>
<tr><td colspan="8">Mathematical Relevance/Importance to Gameplay</td><td>31</td></tr>
<tr><td>Motor Action/Math Relationship</td><td colspan="2">0</td><td colspan="2">1</td><td colspan="3">2</td><td>31</td></tr>
<tr><td>Mathematical Importance</td><td colspan="2">0</td><td colspan="2">1</td><td colspan="3">2</td><td>31</td></tr>
<tr><td>Mathematical Utilization</td><td colspan="2">0</td><td colspan="2">1</td><td colspan="3">2</td><td>31</td></tr>
<tr><td colspan="8">Game Representation Components</td><td>32</td></tr>
<tr><td>Written Narrative Components</td><td colspan="7"></td><td>32</td></tr>
<tr><td>Rules</td><td colspan="3">0</td><td colspan="4">1</td><td></td></tr>
<tr><td>Physical Objects</td><td colspan="3">0</td><td colspan="4">1</td><td></td></tr>
<tr><td>Physical Space</td><td colspan="3">0</td><td colspan="4">1</td><td></td></tr>
<tr><td>Timing</td><td colspan="3">0</td><td colspan="4">1</td><td></td></tr>
</table>

Physicality	0	1	
Drawing Components			32
Rules	0	1	
Physical Objects	0	1	
Physical Space	0	1	
Timing	0	1	
Physicality	0	1	
FSMD Components			32
Rules	0	1	
Physical Objects	0	1	
Physical Space	0	1	
Timing	0	1	
Physicality	0	1	
Finite State Machine Diagram			33
Presence of State Diagram	0	1	34
If you selected **1**, write the number of Finite State Machine Diagrams here.			
Input Types			34
RFID	0	1	

Buttons	0	1			
GPS	0	1			
Keyboard	0	1			
Touch Interface	0	1			
Timer	0	1			
Another Player	0	1			
Other (Please write)					
Output State Representation	0	1	2	3	34
Transition State Representation	0	1	2	3	35
FSMD Consistency with Rules	0	1	2	3	35
FSMD State Consistency	0	1	2	3	35
FSMD Transition Consistency	0	1	2	3	35
Specification of Mistakes	0	1			36
Domain Level: Management-Level	0	1			36
Domain Level: Team-Level	0	1	2		36
Domain Level: Player-Level	0	1	2		37
FSMD Completion	0	1	2	3	37
Quantitative Analysis					37

States/Boxes (Total)			
Transitions/Arrows (Total)			
Labeled Arrows (Total)			
Numbered States (Total)			
Evidence of Programming Language Knowledge			37
If-then statements	0	1	
Loops	0	1	
Arrow(s) that loop to a previous state	0	1	

Appendix B.

WORCESTER POLYTECHNIC INSTITUTE

SOCIAL SCIENCE AND POLICY STUDIES DEPARTMENT

Estimados Padres, Junio del 2019

Nuestro equipo de investigadores del Instituto Politécnico de Worcester (WPI, Worcester Polytechnic Institute, Massachusetts, USA) viene a la escuela de su hijo a hacerlos usar un programa llamado JuegosMobiles.org, como parte de una experiencia piloto en Córdoba, una actividad de investigación dirigida por profesores y estudiantes de esta Universidad, en colaboración con la Universidad Blas Pascal y la escuela de su hijo.

Como parte de este proyecto de investigación, los maestros y los alumnos trabajarán juntos en actividades donde los chicos diseñan juegos de matemáticas (físicamente activos, para varios jugadores) y programan teléfonos celulares como parte del proceso, utilizando un software especial creado por investigadores del Instituto Politécnico de Worcester. Esta investigación es especial porque enseña a su hijo conceptos de ciencias de la computación que no se enseñan hasta la universidad, en particular el concepto de programación de dispositivos móviles como máquinas de estado finito.

Como parte de la actividad, los alumnos primero jugarán un juego de matemáticas usando dispositivos celulares como apoyo al jugador; después los chicos diseñarán sus propios juegos en papel, y por último, programarán los celulares con el software de programación de juegosmobiles.org durante varias semanas, durante las clases de matemáticas y computación. También contestarán un cuestionario antes y después de la experiencia. Su hijo podría ser elegido para una entrevista grabada en video para hablar en voz alta explicando los juegos que han diseñado. Los videos son solo para fines de investigación y para comprender el pensamiento computacional y el proceso de diseño de los alumnos, y se guardarán en la computadora de los investigadores. No se publicarán en la web ni se mostrará al público sin permiso extra.

La grabación de video es solo para fines de investigación y se guardará sólo en las computadoras de los investigadores. El nombre personal de su hijo NO se guarda, y los datos recopilados y las respuestas que proporcionan no se pueden vincular a ellos personalmente. Todos los datos se analizan en base a números anónimos, y cualquier referencia personal se destruye poco después de que los estudiantes usen el programa. También, su hijo puede optar por dejar de participar en cualquier momento.

No dude en contactarme si tiene alguna pregunta sobre esta investigación , que está regulada por la Junta de Revisión de Investigación Institucional de la Universidad (Worcester Polytechnic Institute) para proteger los derechos de los participantes humanos en las investigaciones, el Dr. Kent Rissmiller (correo electrónico: kjr@wpi.edu, +1 508-831-5019) si tiene alguna duda, o simplemente mándeme un email a mí personalmente.

Dra. Ivon Arroyo
Programa de Technologia Educativa y Ciencias del Aprendizaje
Laboratorio de Tecnologías Educativas Avanzadas
Worcester Polytechnic Institute, WPI, Worcester, MA
Email: iarroyo@wpi.edu

Hacer una cruz (X) en lo que corresponda:
___ SÍ autorizo a mi hija/o a ser grabado en video como parte de la investigación
___ NO autorizo a mi hija/o a ser grabado en video como parte de la investigación

Firma del padre, madre o tutor: ____________________

508-831-5296 (TEL) 508-831-5896 (FAX)

100 INSTITUTE ROAD, WORCESTER MA 01609-2280 USA
WPI.EDU