Project Thumbnail
Teaching children algebra through a narrative driven game. The player must escape the maze they have fallen into by learning and demonstrating their algebra skills in a series of puzzles. By engaging the player in this way they will be able to effectively learn and practice the concepts needed to advance in algebra.

Target Users
Children aged 8 - 10 who are just beginning to learn algebra. Users will already have an understanding of how to do addition, subtraction, multiplication, and division.

Delivery Platform(s) and justification(s)
The game would be easiest to make in Flash or HTML5 using the <canvas> tag due to the widespread use of web browsers in schools and at home. The controls and gameplay don't require anything more then what Flash offers by default and there is no additional cost incurred in development. Use of HTML5 would not require a license, but is not yet fully standardized and thus would involve more time in the debugging phase.

Learning Goals
Through playing the game the users should acquire and be tested on their understanding of

- Single variable Algebra
- Balancing out equations
- Order of operations

Single variable algebra consists of problems such as 2 + x = 5 and are solved by getting the variable alone on a side of the equals sign while keeping the equation balanced. When -2 is added to the left side of the equation to eliminate the 2 next to the x variable, the right side of the equation must have -2 added as well. This results in x = 3 which is the solution to the problem.

Balancing out equations consists of taking problems such as 2 + x = 5 and ensuring that no matter what operations are done to the equations the resulting equation is equal to the one before it. If -3 is added to the left side of the equation then -3 must also be added to the right side of the equation.

Order of operations is the correct sequence of operations to evaluate when solving an equation and follows PEMDAS which stands for parenthesis, exponents, multiplication, division, addition, subtraction. The game will involve all of these except exponents. A sample problem would be (2 + 4) * 3 = X. Since the operations inside the parenthesis must be evaluated first the addition must come before the multiplication.

The users will not be tested on their math vocabulary, speed with which they solve problems, or multiple variable algebra.

Instructional Design - (outline, to be continued)

Shaping:

each section of puzzles starts out easy and becomes more difficult
difficulty resets when each new type of puzzle starts

Flow:

The puzzles are designed to provide help if the player is having difficulty and to also scale appropriately if the player is doing well such that they don't get stuck in frustration or boredom.

Scoring:

While there is no overt scoring mechanism, the player's learning can be gauged through their progress through the ruins. The player's learning can also be gauged by their performance on the final stage which is a cumulative test.

Narrative

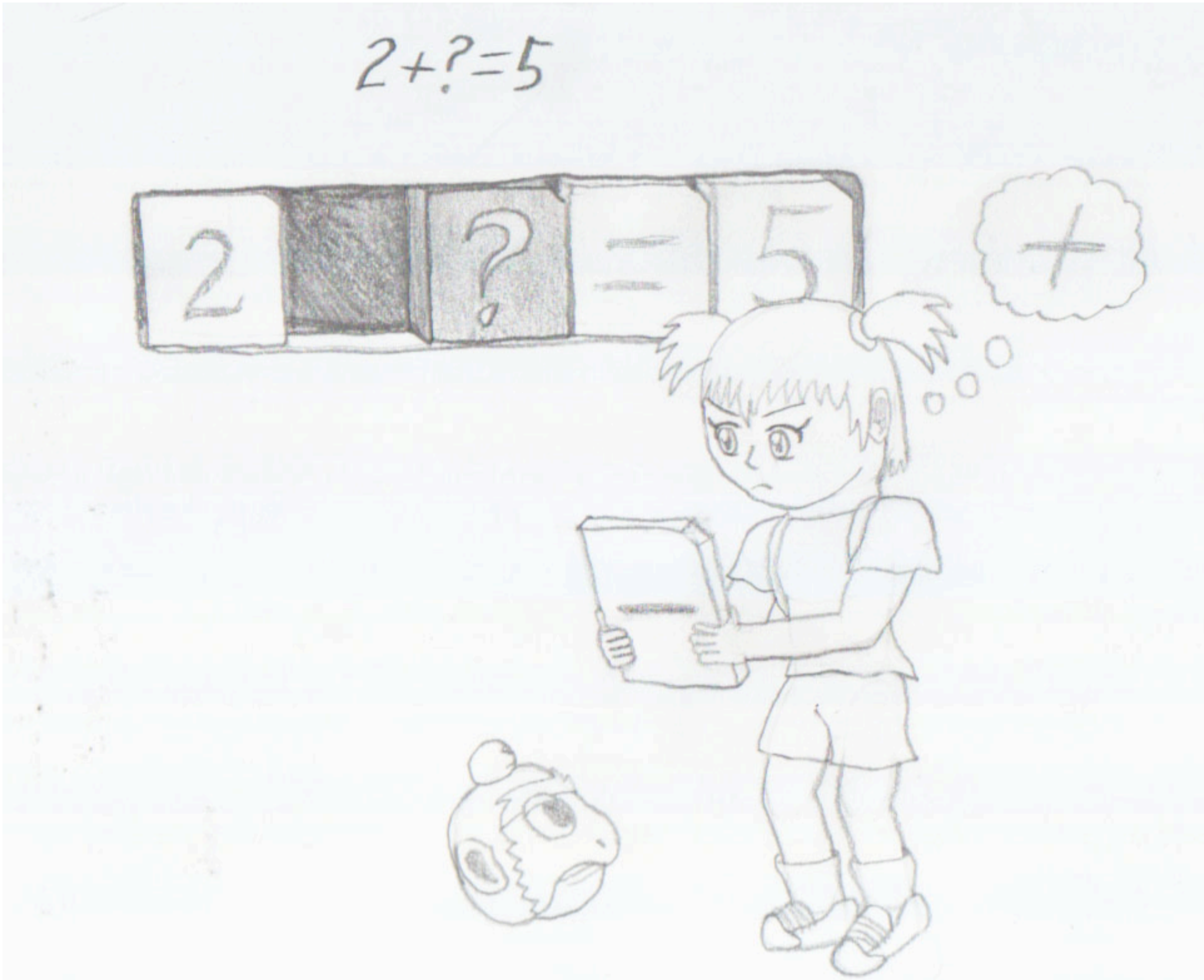
You, the player, were out in the jungles of South America with your parents, world famous archaeologists, when you fell through a hole in the ground and ended up in a strange maze full of numbers and odd symbols. It was a good thing you had a flashlight. There was what looked like the head of a strange stone statue in the dark room with you. As you began to explore, looking for a way out, the statue called out. "Hey, kid, I can get you out of here, but you'll have to find the rest of me first." Will you listen? Will you aid this strange creature? Why are the walls covered in numbers?

Its up to you to navigate through the maze, solving the mathematical problems and puzzles, in order to find the missing pieces of your stone guide and hopefully rebuild him so he can provide you with the way back out of the ruins.

Gameplay

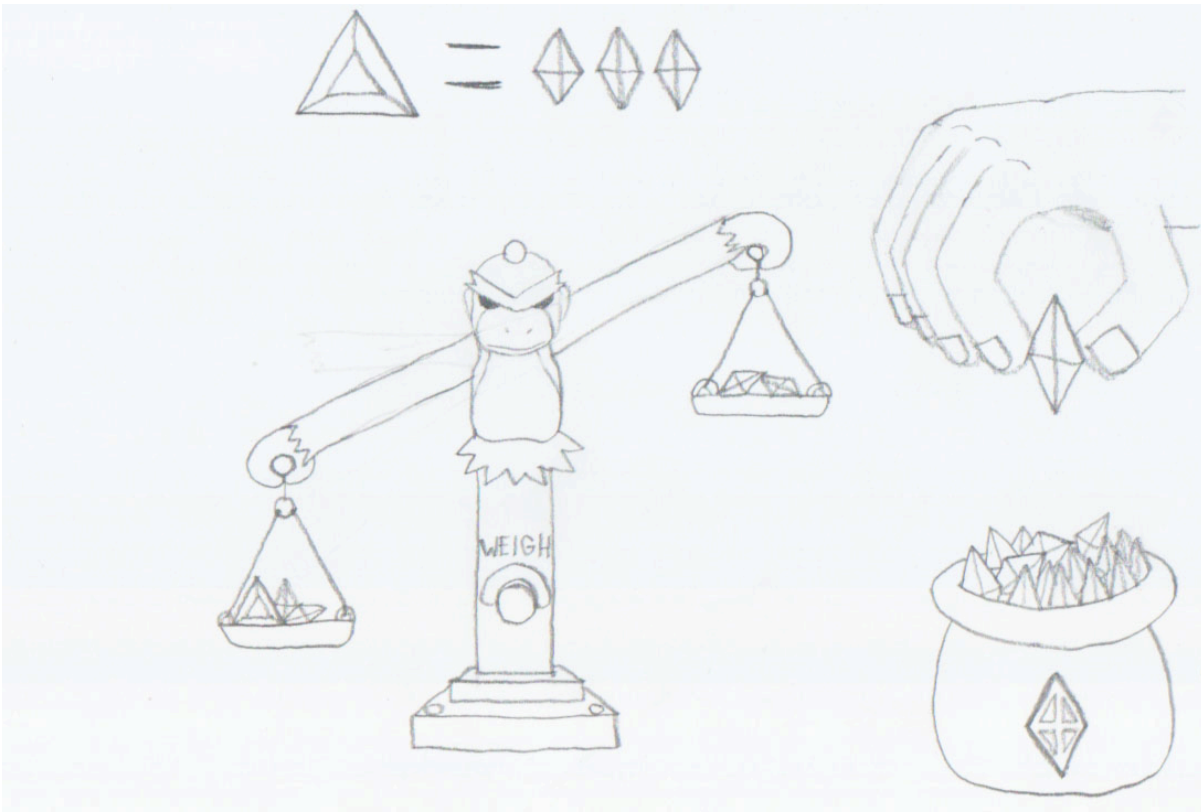
The game is navigated in a 2D top-down adventure style where the player explores rooms and discovers puzzles to solve. Upon nearing a puzzle the game will transition into a "mini-game" state where player movement is restricted to simply exiting the state and mouse interaction is enabled for any objects in the puzzle that require it. The stone statue is utilized as a mentor who will explain any necessary information including how to solve the various puzzles throughout the game.

Tile Puzzle: On the wall, there is a missing number equation. It is written twice: once in carvings on the wall itself, and once in various tiles on the wall or on the floor among the tiles. All of the tiles on the wall can be removed from the wall and slid around in it. There are also markings on the backside of each tile that displays the opposite meaning of what is written on the front. In other words, the backs of the numbered tiles contain the negative of that same number, and the tiles with the operators have their opposing operation (plus vs. minus and times vs. divided by). Equal sign tiles have the equals sign on both sides, and there is a black tile in the wall that bears a question mark.
The player's goal in these puzzles is to replace the question mark tile with one of the ones on the floor to open the next room. Only one of the tiles on the floor is able to unlock the door, and that is the correct answer to the problem. The player is able to move the tiles around and flip them over so that he or she can play around with the problem. In order to keep the original problem from being lost in this rearrangement, the original problem is marked out above the slots for the tiles. Being able to flip the numbers and operations to their negative forms will also allow the player to see that you can solve algebra problems like these by moving the numbers and reversing the operations. With an appropriate arrangement, the player should be able to see a problem that can be solved or filled in with one of the tiles on the floor.



Jewel Puzzle: You know the values of these small red jewels that you have, and each of them is the same value. There are, however, inscriptions on the wall that depict these triangular blue gems. Though each of these blue ones look alike, they oddly have different weights to them that correspond to a certain number of red gems. The door to the next room is locked by a scale weighed down on one side by a blue gem, whose value is cryptically given on the inscription above. (For example, it may show 2 blue gems on one side of an equals sign and six red ones on the other.) Weigh red gems on the scale to balance out the scale. (No, you may not take the blue gem off the scale. Your guide will warn you that it will set off a trap.) Through this method, players should be able to figure out that he or she can solve algebra problems of multiplication by thinking of it as a division problem. The inscriptions may show at first that the red gems are already grouped into the same number of lines as there are blue gems. Later puzzles, however, will show the red gems in less organized patterns (like in a triangle or a circle). This way, the player might see the arrangements and be clued into them at first, but later the player will have to arrange the gems himself or herself.

Later on, you will also encounter scales that contain green hexagonal gems. Like the blue ones, these green ones oddly have different weights to them. However, the inscriptions above the scale depict the green jewels broken into a few equally-sized pieces, and it reveals that each piece of the green gem weighs a certain number of red ones. Here, the player is learning how to reverse division problems with missing values into multiplication problems. Again, the arrangements of red gems in the inscriptions might be laid out in a straight line the first few puzzles the player goes through, but later on, the red gems in the inscription will be arranged into patterns.

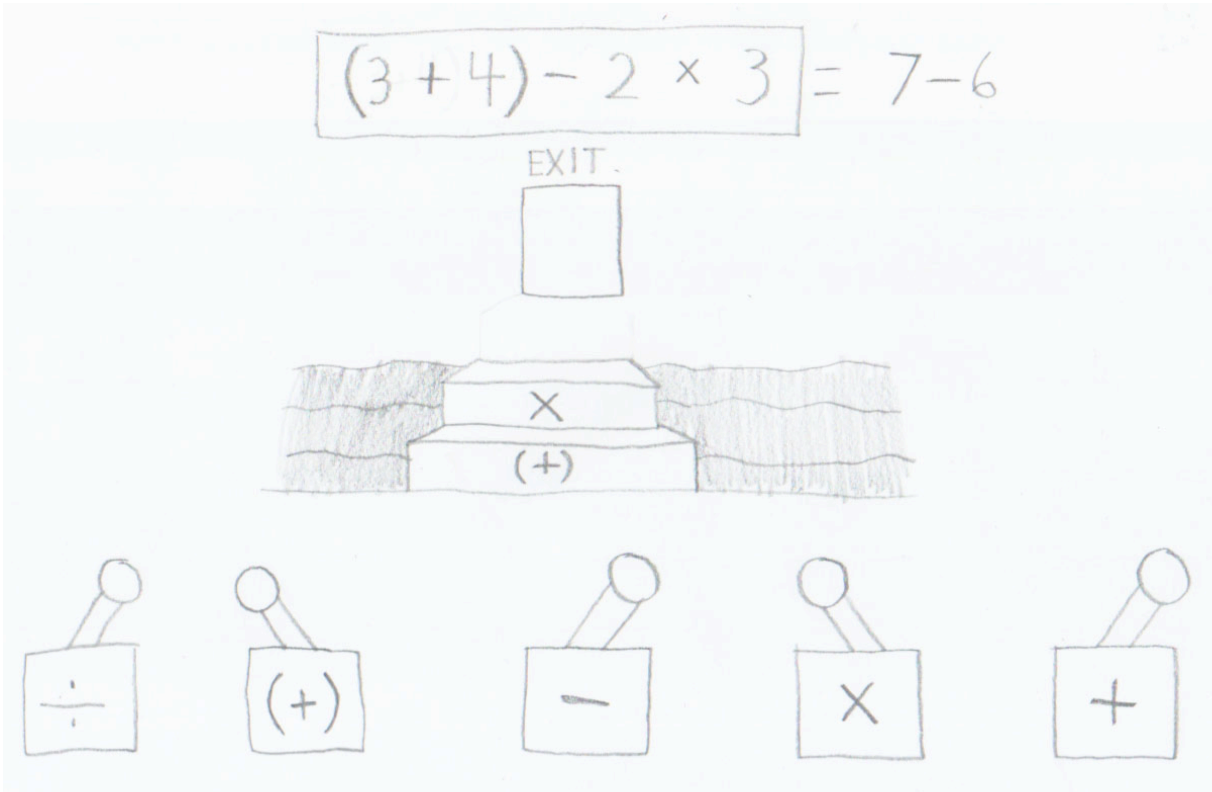


<u>Order of Operations</u>

Order of Operations problems are done through problems that would be displayed like this:

(3+4)-2*3

And there would be levers displaying different mathematical operators such as +, -, (), etc, which when pulled solve that section of the problem. On mistake, it resets the entire problem. When each lever is pulled, it causes platforms to move and doors to open so that the player can progress.



Final boss: The final assessment is the last series of problems the player will solve in order to prove that they have learned the concepts being taught in the tile puzzles and order of operation puzzles. The player will receive advanced problems from the stone statue involving one variable but multiple operations and parenthesis. The game is played by placing tiles on the stone statue itself to put the correct tile in the missing space. The statue at this point will offer no additional support (maybe you are arranging tiles to fix his brain in some way?) and the player must demonstrate mastery of these two concepts to solve the problems.

User Interface and Environment

The main character will be controlled using the "WASD" keys for the corresponding up, left, down, and right direction. The mouse serves to allow for interaction with the menu's during the exploration state and interaction with the puzzles during the "mini-game" state.

In the exploration state a mini map is present on the bottom left of the screen to indicate where the player is in relation to other discovered puzzles. Should not be required to play the game but used as additional help to prevent players from becoming lost even in simple levels.

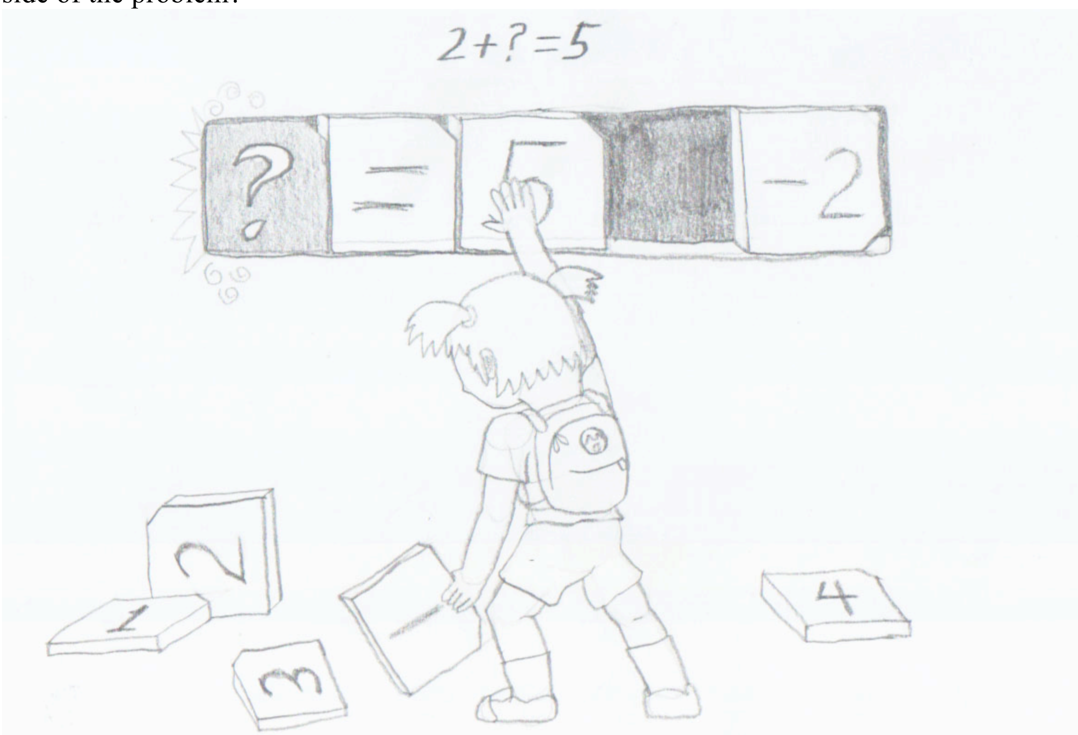
The puzzles are self contained and are where the learning goals of the game are taught. The exploration state is used to connect puzzles in a cohesive story.

Gameplay Examples

Tile Problem 1:

Player sees a wall with some inscriptions: "2 + ? = 5". Each symbol is marked on its own square tile. The whole inscription is in smaller print on the wall above these marking. The guide screams in confusion as to what this could mean, and the tile saying “5” falls out of the wall. The other side of the “5” tile has “-5” marked on the back of it. The guide then remarks, “Look at that! That tile came right out of the wall. And it has something written on the back. If that one came out of the wall, then I wonder if we can take them all out? Maybe if we rearrange these things, we can find our way out of here.”

At this point, the player will be able to interact with the wall. The same inscriptions as before are here. Underneath the inscriptions are four more tiles that display the numbers “1”, “2”, “3”, and “4”(which should be a different color than the ones in the wall). The player can take any tile from the wall and drag it into a new spot on the wall, as well as putting tiles on the ground. However, the player may also move the tiles on the floor into a blank spot on the wall. If the player puts one of the colored tiles into the wall and it is not the answer, nothing noteworthy happens. If the player puts the “3” tile in the wall, a fanfare plays, and the player will be notified of her success, proceeding to the next room. “Nice going, kid,” the guide says, “so how did you figure that out? Did you try moving those numbers all to one side of the problem?”



Tile Problem 2 (this will not be the very next problem, but it will come):

The player sees a similar situation to what he found before: some glyphs on the wall in tiles, the same inscription marked above, an empty square on the wall, and a few colored squares with numbers on the floor near this wall. This time, the problem reads “? - 2 = 4”. The colorful tiles on the floor are marked with the numbers “5”, “6”, “7”, and “8”. The player’s avatar approaches this wall to investigate the plus sign, and she finds that the minus tile bears a “plus” mark on the other side. “Plus and minus, addition and subtraction”, the guide notes. “Opposite operations. If we rearrange this problem, maybe we’ll see it in a more familiar form along the way. Remember, if you’re lost, the problem you wanna solve is above this window.”

The player will now be able to interact with the wall again. Hold the left mouse button over a square, and the player can drag the tile to another square (either swapping places with the tile in the wall or sliding the tiles to one side). Through this, in addition to the information the guide just stated, the player should be able to rearrange the problem into something that can be solved easily, like “? = 2 + 4”. Once the player puts the “6” tile in the question mark’s place, she will hear the fanfare and be brought back to the exploration. The guide will then exclaim, “Now that wasn’t so hard, was it? In fact, the way you rearranged that problem almost looked like you made it an addition problem. Maybe by getting the numbers all on one end, we just end up making the opposite kind of problem. Might be neat to know."

Jewel Scale Problem 1:

The player now faces a more unusual kind of puzzle. Again, near the top of the wall are some pictures. This time, it shows two blue triangles on the left of an equals sign, and six red diamonds to the right of the sign, formed in a 3 x 2 rectangle. Below these markings is a large indent in the wall. Within this indent is a scale, weighed down on one end by a blue triangular gem. Nothing sits on the other end of the scale right now. However, your guide points out a pot holding many red diamonds. The guide looks around the room briefly to find another blue gem to no avail. "Looks like only have one of these to work with. But we probably only need one anyway. So, how many of the little ones does it take to match one of the blue jewels?"

Now the player can interact with the scale. She can click and drag diamond gems to the raised end of the scale. Doing this places red diamonds on the scale. Once the player has placed their wanted amount of gems on the scale, she can push a button on the scale to see the result. If the player has put too few or too many diamonds on the scale, the end with the diamonds will either stay risen or drop lower than the triangular gem, and a quick buzz will sound. This means the player is incorrect. The player may continue to weigh different numbers of red diamonds until she finds the solution. Once the player figures out that she should put three diamonds on the blank end of the scale, then the fanfare will play, and the next room will open. "Nice going! Did you figure it out by dividing the diamonds among each triangle?" asks the guide. "Because that's how I would've done it."

Jewel Scale Problem 2:

This time, the player faces another locked door with a scale in it. There are two blocks of inscriptions this time. One displays a roundish green gem split into three pieces, and the other shows that one piece of the round gem displayed is worth four red diamonds. On the scale, however, appears to be a green jewel like the one drawn above perfectly intact. "Did these people actually break their gems to figure out a piece's weight? That's pretty drastic," notes the guide. "But it looks like they split the gems into equal pieces, at least. So if one piece is that much, how many diamonds will balance the whole thing?"

Here the player sees the green gem split into three pieces and that one piece equals four diamonds. Therefore, for each piece, there should be four diamonds on the scale. Since there are three pieces, the player would be expected to place twelve diamonds on the scale. Once the player does this, again, the lock releases, and the player can move on. "Great job back there. I have to wonder, though, why didn't these guys just weigh the whole thing instead of breaking it?"

Order of Operations Problem:

The player faces a set of low stairs, a door high up on the wall and some levers bearing mathematical operators. There is a problem inscribed on the wall saying (3-1)*5-4. The guide says "I'm pretty sure pulling the levers in the right order will make the stairs come out so you can get out that door." The player then pulls one of the levers. If for example, the player pulls the subtraction first, the stair begins to move and then falls back down because that is incorrect. If the player were to pull the paranthesis lever instead, then the stair would move up to door and lock in place. This proceeds through the rest of the problem, slowly simplifying to show the player how it works, until they can proceed out the door.

Final Boss Problem 1:

The player has finished collecting all of the items the stone statue has asked of them and now asks the player to repair him. Pieces of the statue start to magically come together but a number of tiles are missing from across the statue revealing familiar problems like the ones in previous mini-games. The player sees a number of tiles stating this problem: $(2 \times ?) + 4 = 10$:Since the player has passed the order of operation mini-games they know that in this problem numbers inside the parenthesis are evaluated first, multiplication comes second, and addition is last. Then because they have learned how to balance equations they recognize that you must reverse the typical method in order to put the missing number on the correct side of the equation. Now the player will remove the addition first by subtracting 4 from both sides of the equation and remove the multiplication by dividing both sides by 2. This leaves the player with 3 which they must find in a tile lying on the ground and bring to the ? spot.

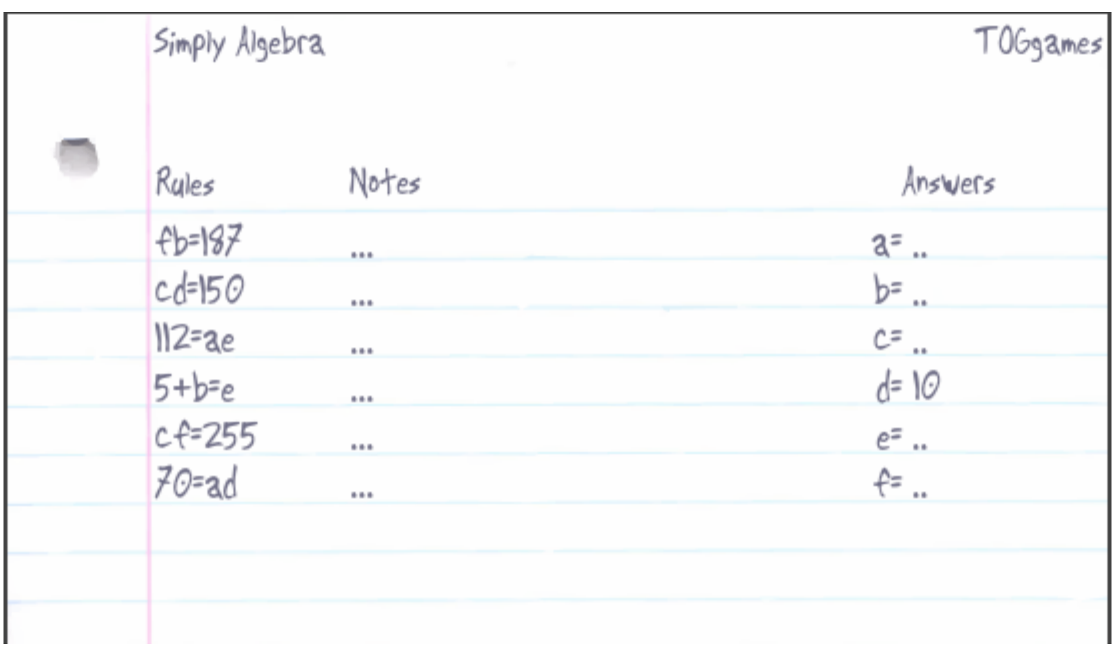
Project Testing and Iteration

In order to conduct a proper analysis of this game, it should be tested in a quasi-experiment using classroom groups of students in the 8-10 year old age range. There should be written pre and post tests for the students involved to gauge their learning. The comparison should be against another math learning game or activity, rather than against classroom and book learning. The game should be evaluated both for teaching value and entertainment since if the students aren't engaged, they won't learn. Also, the players should be evaluated a month and three months later to see if they have retained their learning. The evaluation should not look like the play environment from either game and should not contain the exact problems given in the pretest.

Comparative Assessment

http://www.kongregate.com/games/TOGgames/simply-algebra?acomplete=simply+algebra
http://www.mathdork.com/mathgames.html

A search for games related to algebra on the Internet revealed two games trying to cover the same sort of topics that we are intending to cover. These games were Simply Algebra and MathDork.com's Asteroids. Simply Algebra is a game based on solving multiple algebra equations at once on a screen that looks like lined paper. The interface is friendly, for those of us who have taken an algebra class. It has that familiar handwritten and paper feel. But this is not going to keep the attention of a child, nor does it do anything to teach basic algebra concepts. This game hinges on the idea that you already know algebra and simply need practice.



The MathDork.com Asteroid game is a Flash implemented game where the goal is to shoot the asteroid that has the same value as X. While this could teach the basic ideas of algebra, this game's main problem is that the numbers aren't randomized. In fact, every single play through gives you the exact same problems in the same order and with the asteroids following the same preset paths. This removes any possibility of educational value.

Comparative assessment shows that our game is a better teaching game than these two games, which were the only algebra based games found on an Internet search.

Questionnaire that would be used for assessment.

<u>Questionnaire:</u>

1.) How familiar are you with algebra?
2.) How much time do you spend a week playing video games? Math games?
3.) Are you interested in algebra?

1.) 2 + ? = 6
2.) 3 * ? = 12
3.) 2 * ? = 6

4.) (? - 2) * 3 = 12

1.) Would you recommend the game to a friend?
2.) Was it challenging?
3) What was your favorite mini-game?

Needs Analysis:

What problem is stopping people from doing what they are supposed to be doing?
According to the Third International Mathematics and Science Study US test scores in mathematics are about average in 4th grade and decrease onward until high school. In order to increase student's academic standing in mathematics a stronger foundation in basic concepts and changed curriculum is suggested by the analysis section of the report [2]. The algebra component of 8th grade testing is 30% and students in the US begin learning algebra in 3rd and 4th grade.
What are the causes of that problem?
Problems include lack of interest, pace of classes (too slow or too fast), cultural stigma, lack of understanding / too abstract. We will seek to address the lack of interest with the engagement generated through gameplay in combination with narrative. The pace of learning is directly controlled by the player in a game so faster learners can naturally move more quickly. Women typically become disinterested in mathematics do to cultural stereotypes but in today's younger generation both genders play games equally. By turning the problems into gameplay the difficulty in understanding algebra as an abstract mathematical concept can be mitigated by the "realistic" framing of the problem. (This is a typical educational trick word problems are often used for, a train traveling 100mph…etc)
Within the training domain, what general skills and knowledge do we need to impart to make the problem go away?
Key steps in solving an algebra problem are:
Order of operations, identifying opposite operations (+ & - and / & *), getting the unknown variable alone, balancing equations
Can we simulate the performance of those skills?
Put it into context that would interest kids. Go at own pace / no time limit. We are actually solving problems, so simulation = performance.
…
Subject Matter Experts
Math teachers
3rd and 4th Grade students
Parents
…

Task Analysis:

Criteria for Performance Evaluation
1.) How fast they do algebra
2.) Get the right answer
3.) Identify correct operation
4.) Realize you must get a variable alone

Some of the steps taken are visible as the student must at least write the answer down and very often are taught to show their work as they solve problems. Other steps take place in the student's head as they work on a problem, such as identifying which operation comes next in the order of operations or what the opposite operation is in order to balance out an equation. If the student gets a problem wrong there is a break down somewhere in the steps being taken to solve the problem but it can be difficult to pinpoint exactly where the break down occurred and the student may not be able to articulate it. By keeping the problems simple enough it will be possible for a game to check after each step is taken in a problem and narrow down the step that the student misunderstanding.

Steps to take

1.) Solving 4 + x = 11
a. 1.) Seeing the problem
b. 2.) Identify operation being used
c. 3.) Identify opposite operation
d. 4.) Subtract 4 from 4
e. 5.) Subtract 4 from 11 (subtract 4 from each side)
f. 6.) Realize x = 7
2.) Solving 2x + 5 = 15
a. 1.) Identify operations being used
b. 2.) Identify opposite operations
c. 3.) Recall order of operations
d. 4.) Reverse "
e. 5.) Subtract 5 from each side of =, only from whole numbers
f. 6.) Divide each side of = by 2.
g. 7.) x = 5

Common Mistakes / Expectation Violations

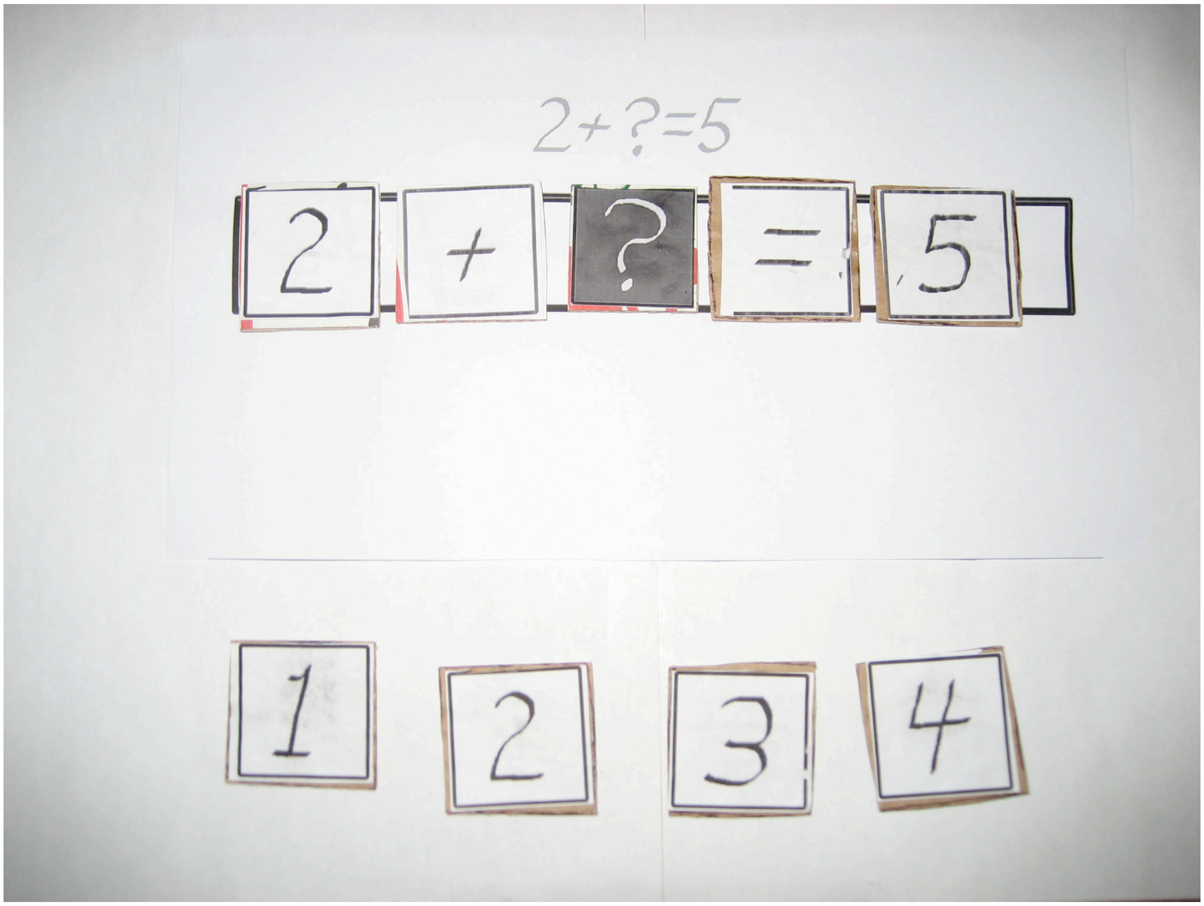
1.) Not getting variable alone
2.) Following / reversing order of operations
3.) Getting problem wrong

Sources

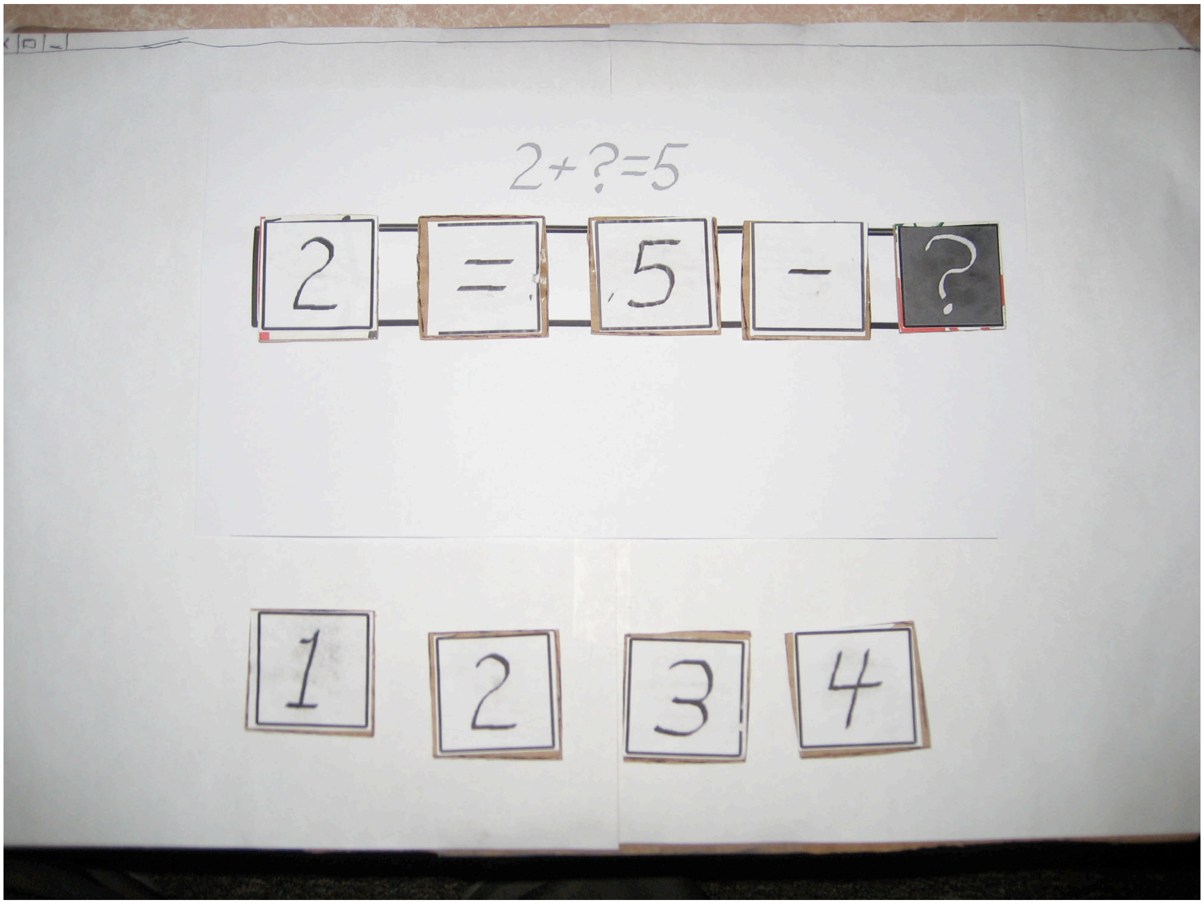
[1] Hands-On Equations; http://www.borenson.com/
[2] http://nces.ed.gov/pubs2009/2009001.pdf

Paper Prototype:

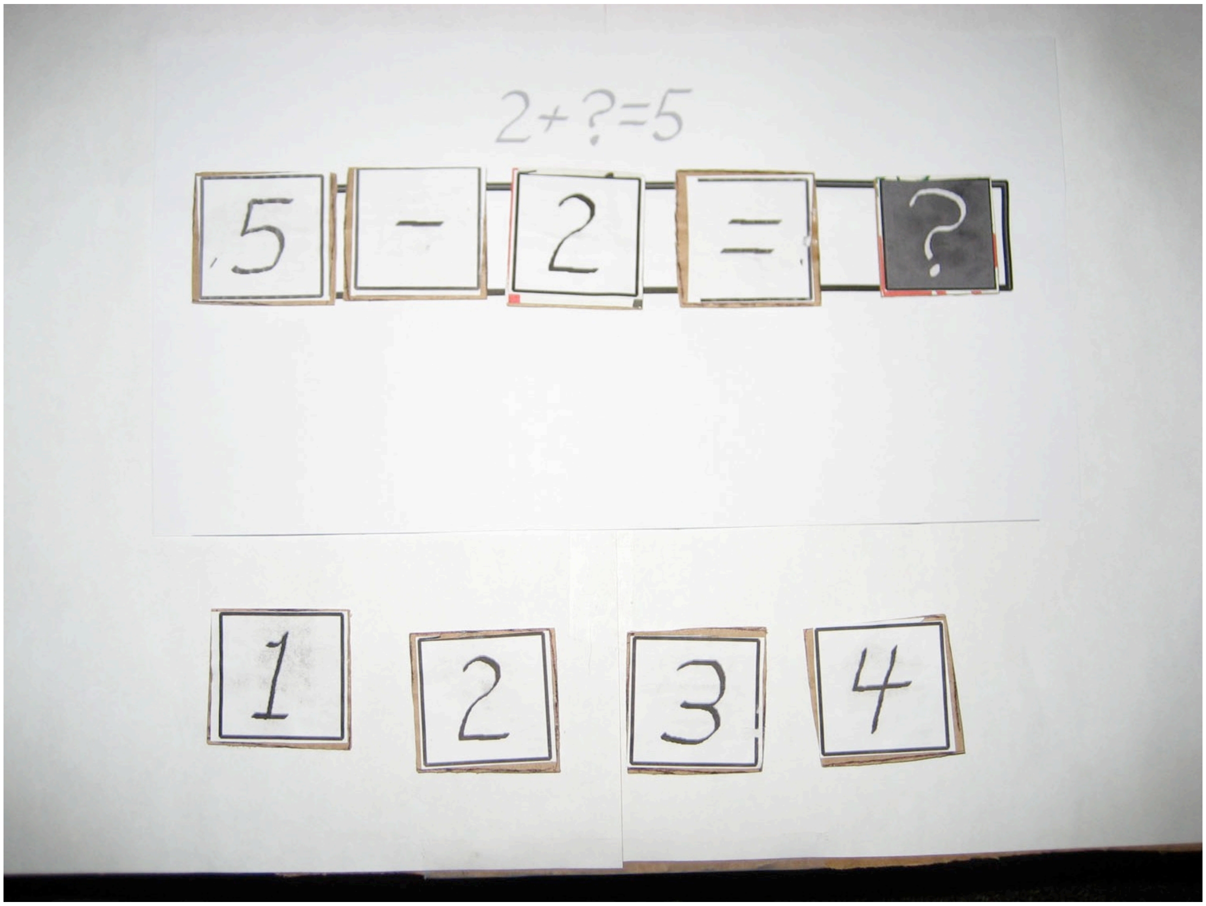
Tile Game 1:



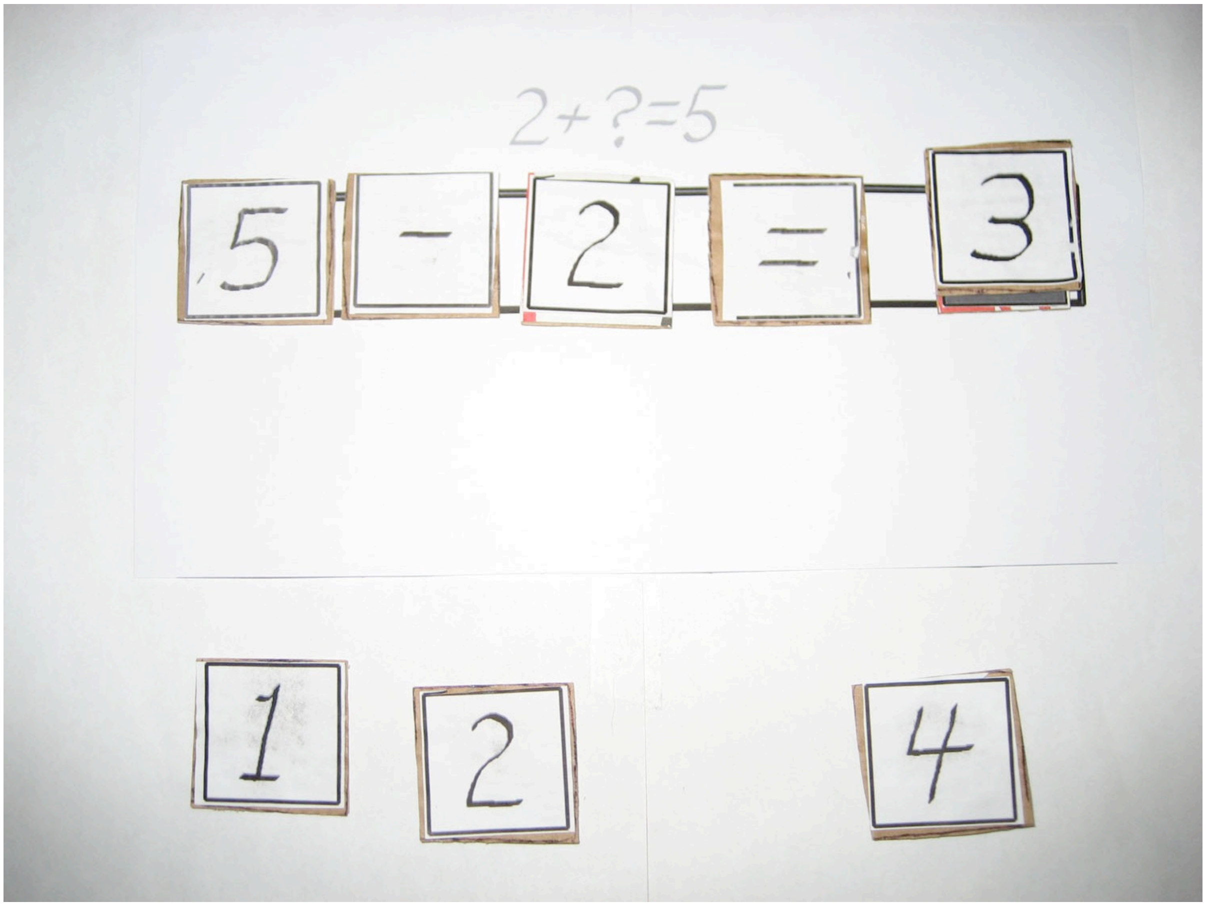
Start of Problem



Player drags “?” tile from left side of equation to right side. Other tiles change to reflect user action.

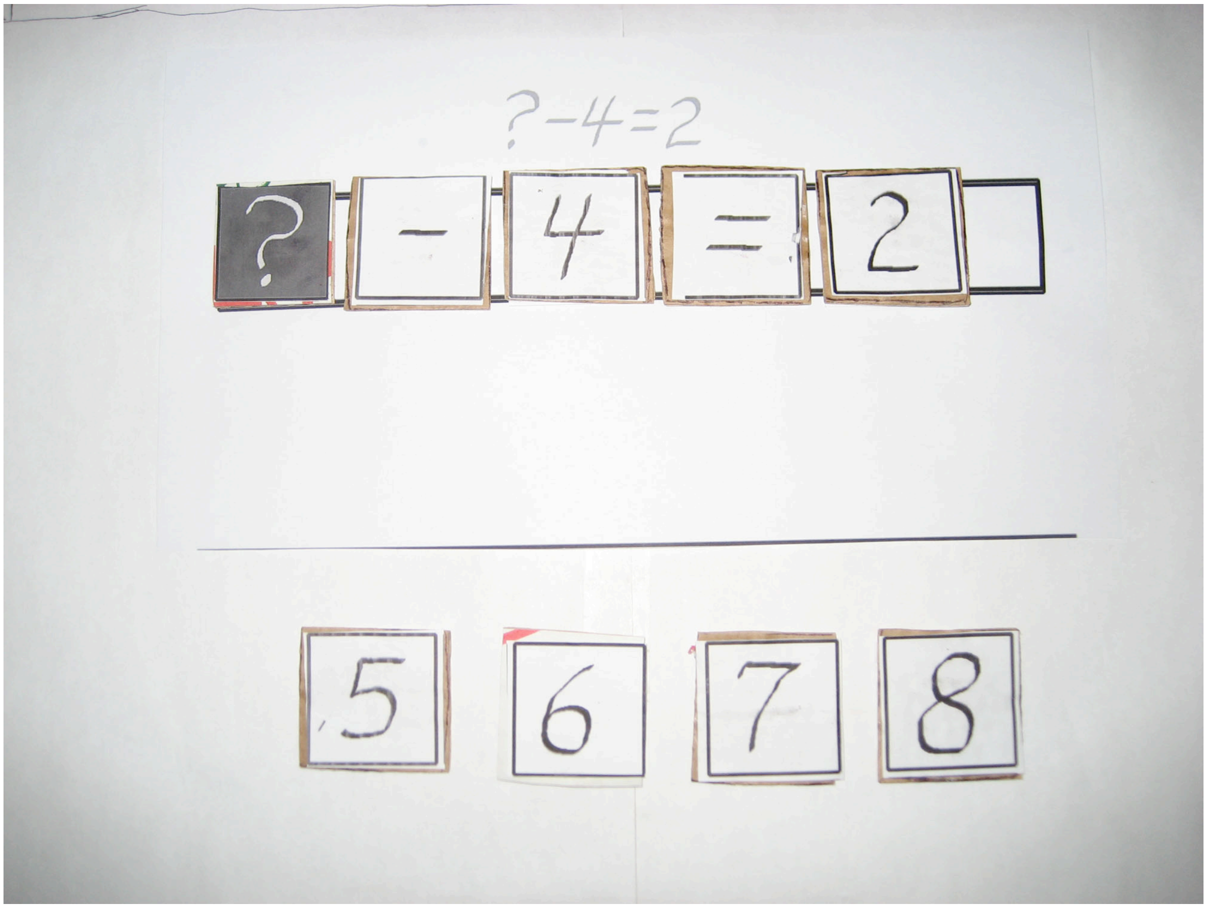


Player drags 5 from right side of equation to left side. “-” operation keeps equation balanced.

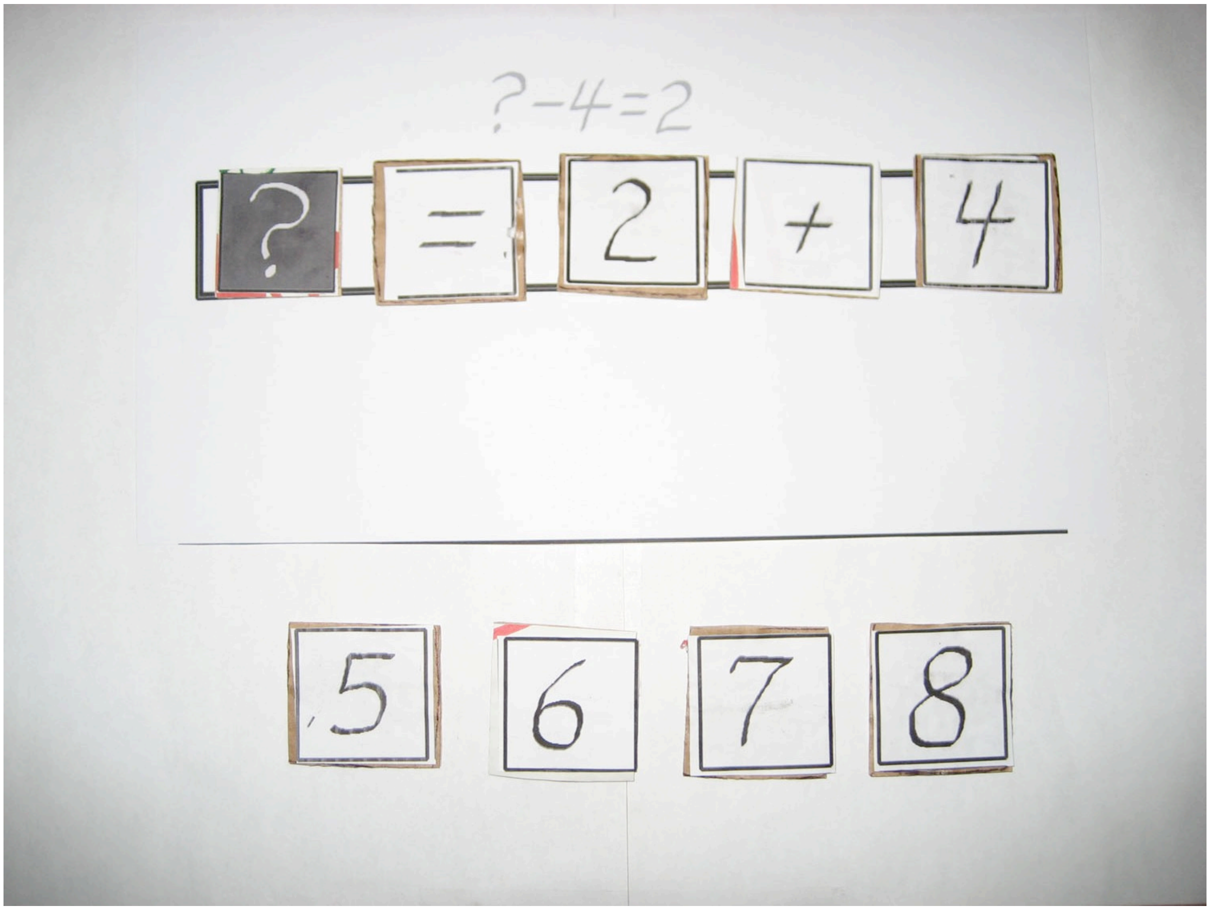


Player has solved 5 - 2. Placed answer over “?” tile

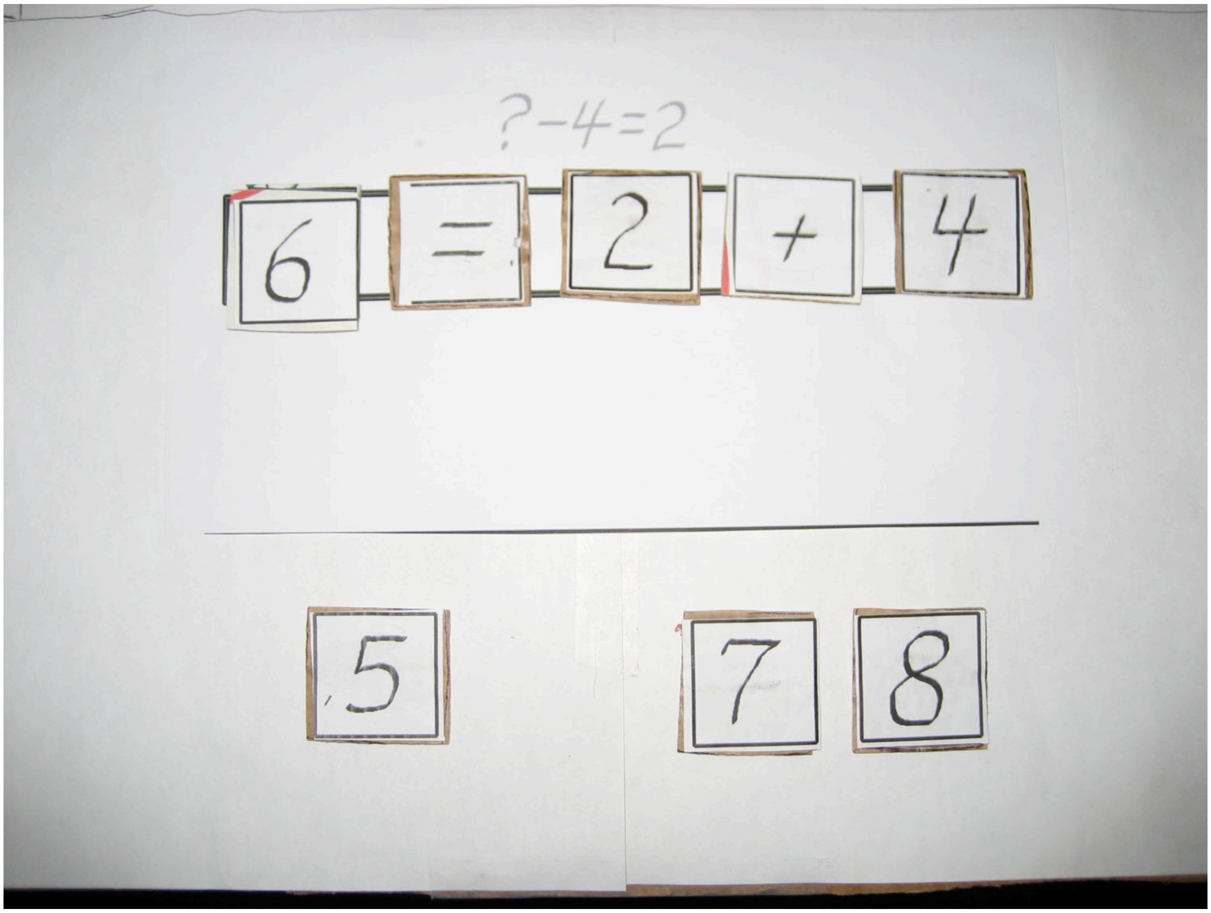
Tile Game 2:



Start of Problem.

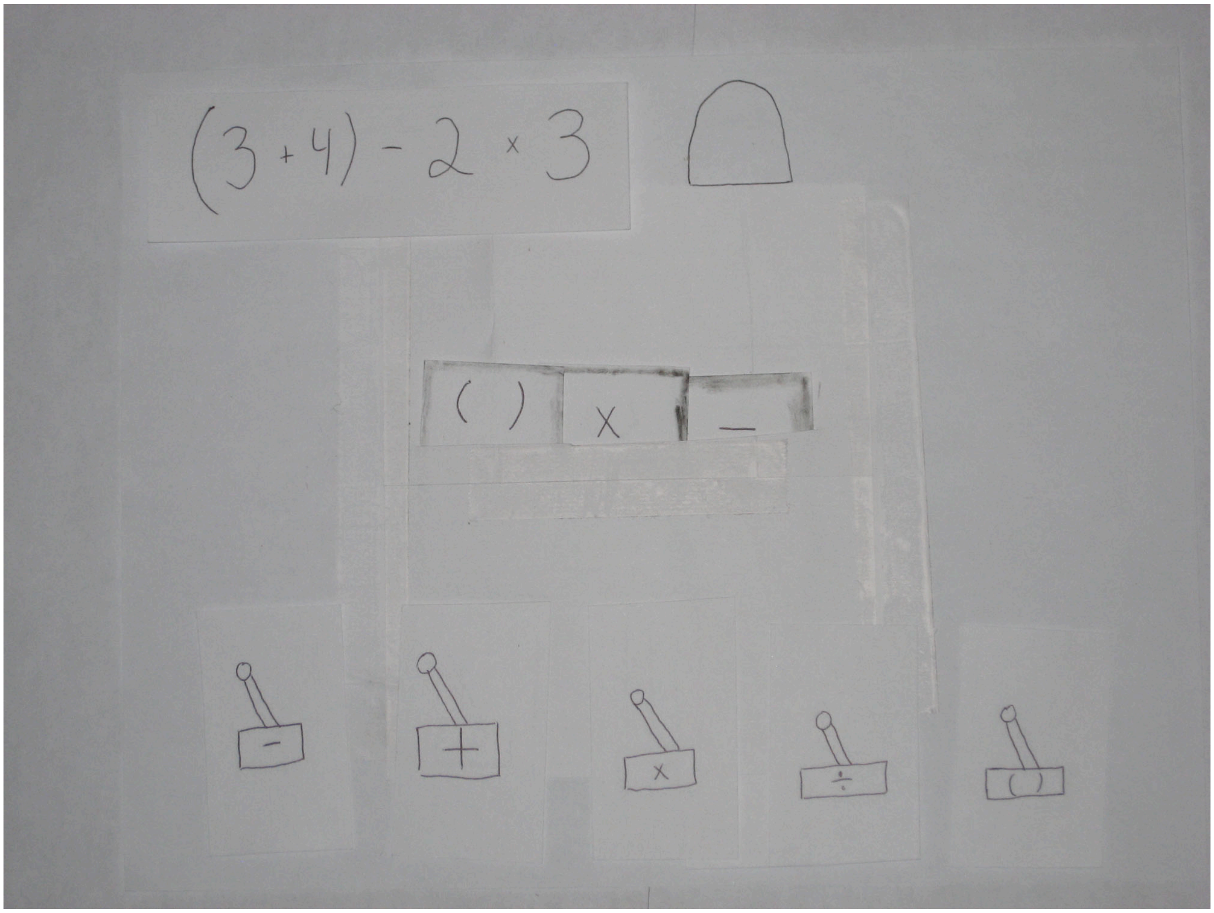


Player drags 4 from left side of equation to right side. “+” operation keeps equation balanced.

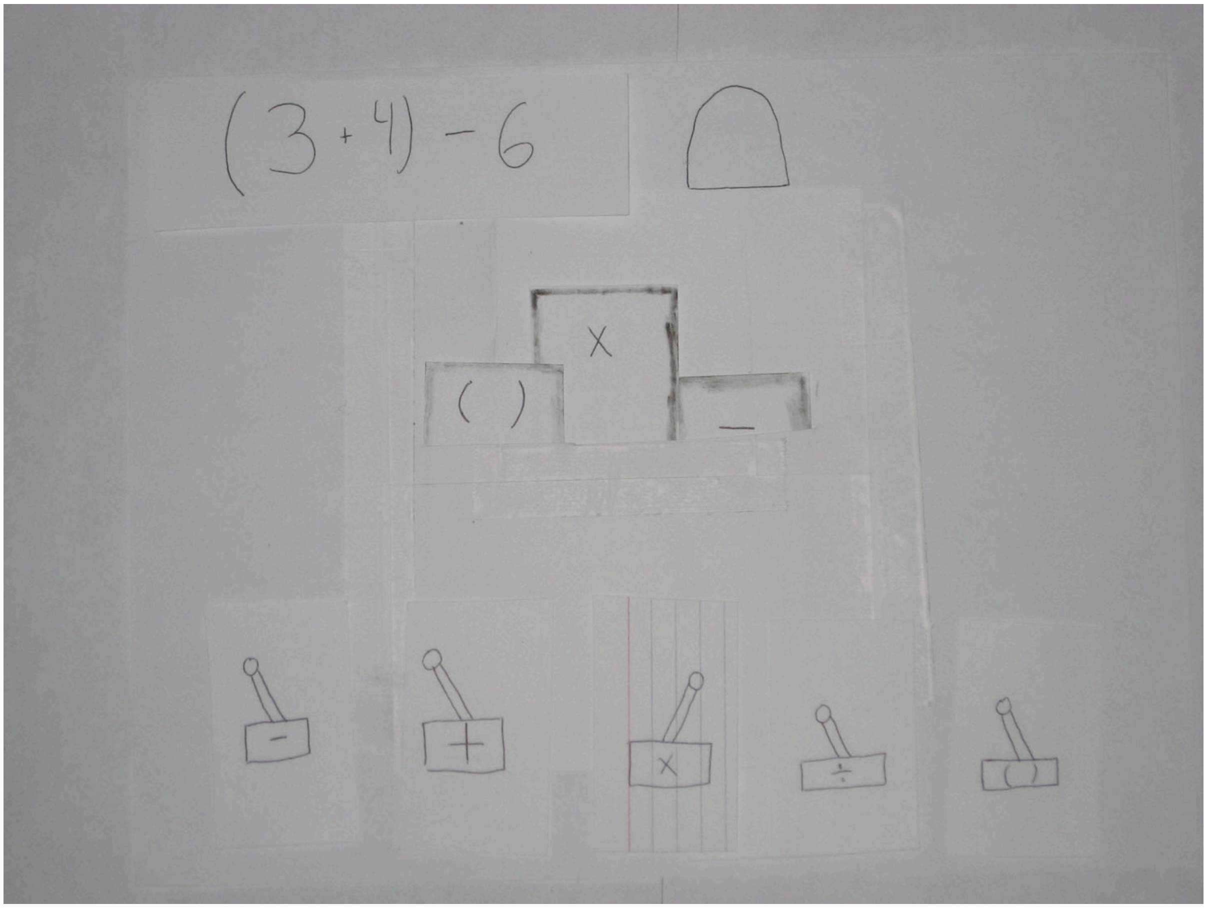


Player has solved 6 + 2. Placed answer over “?” tile.

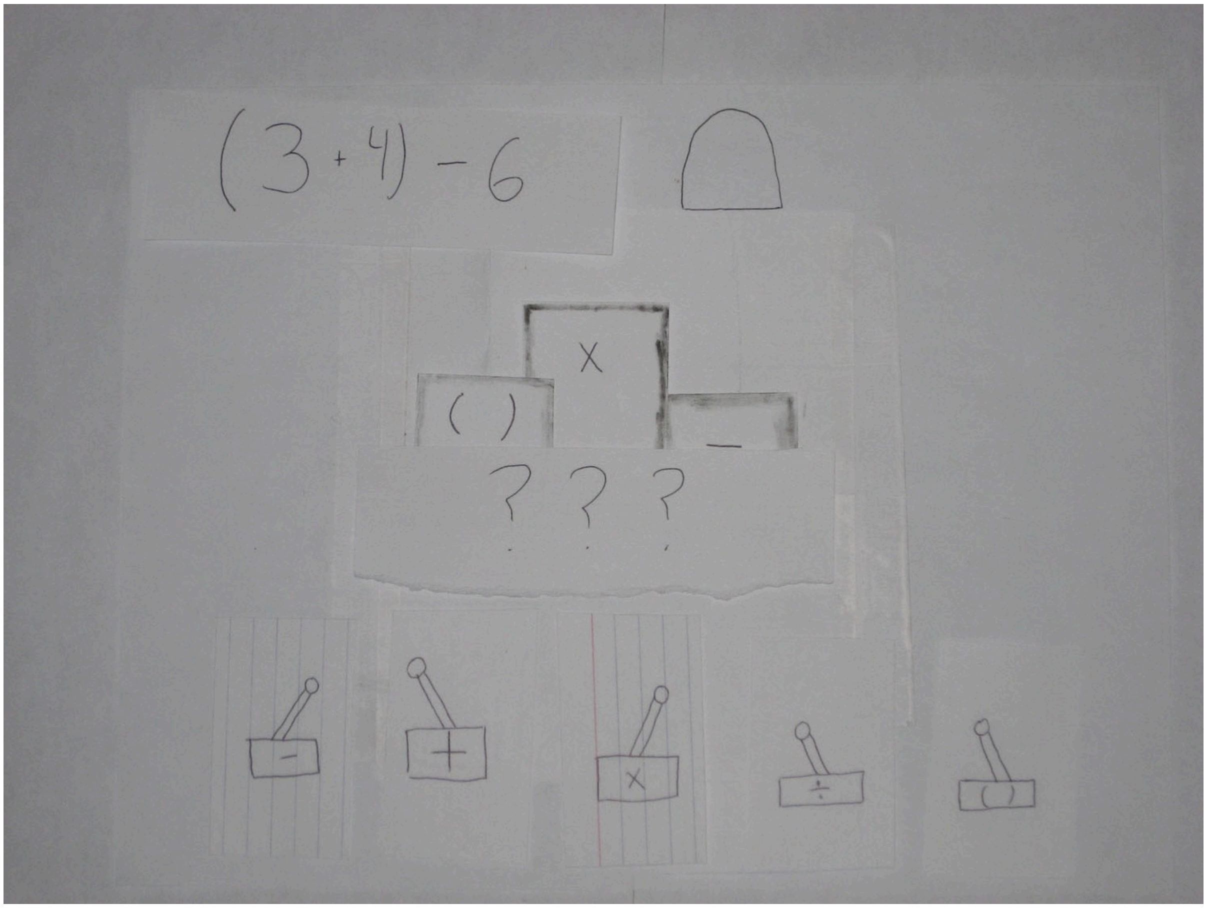
Order of Operations Game 1:



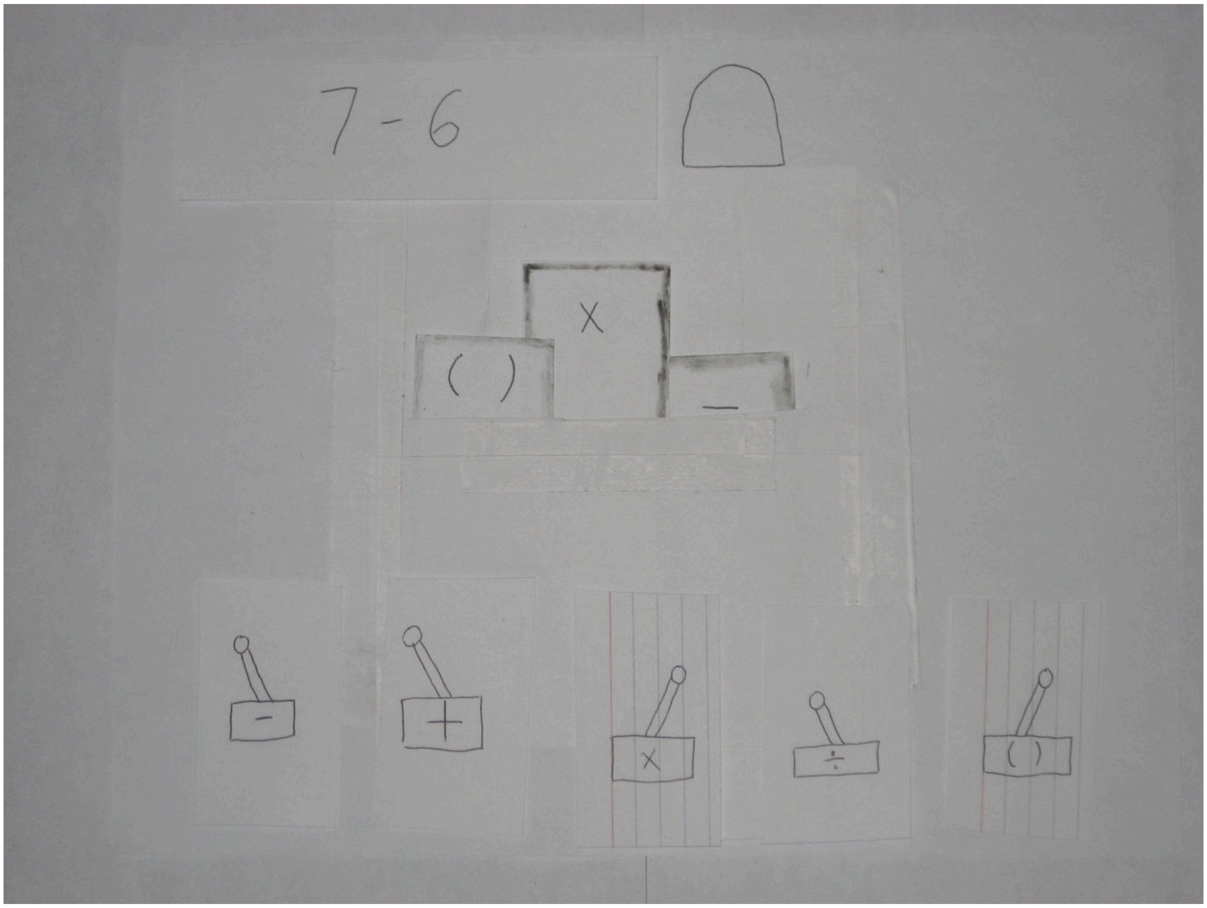
Start of Problem.



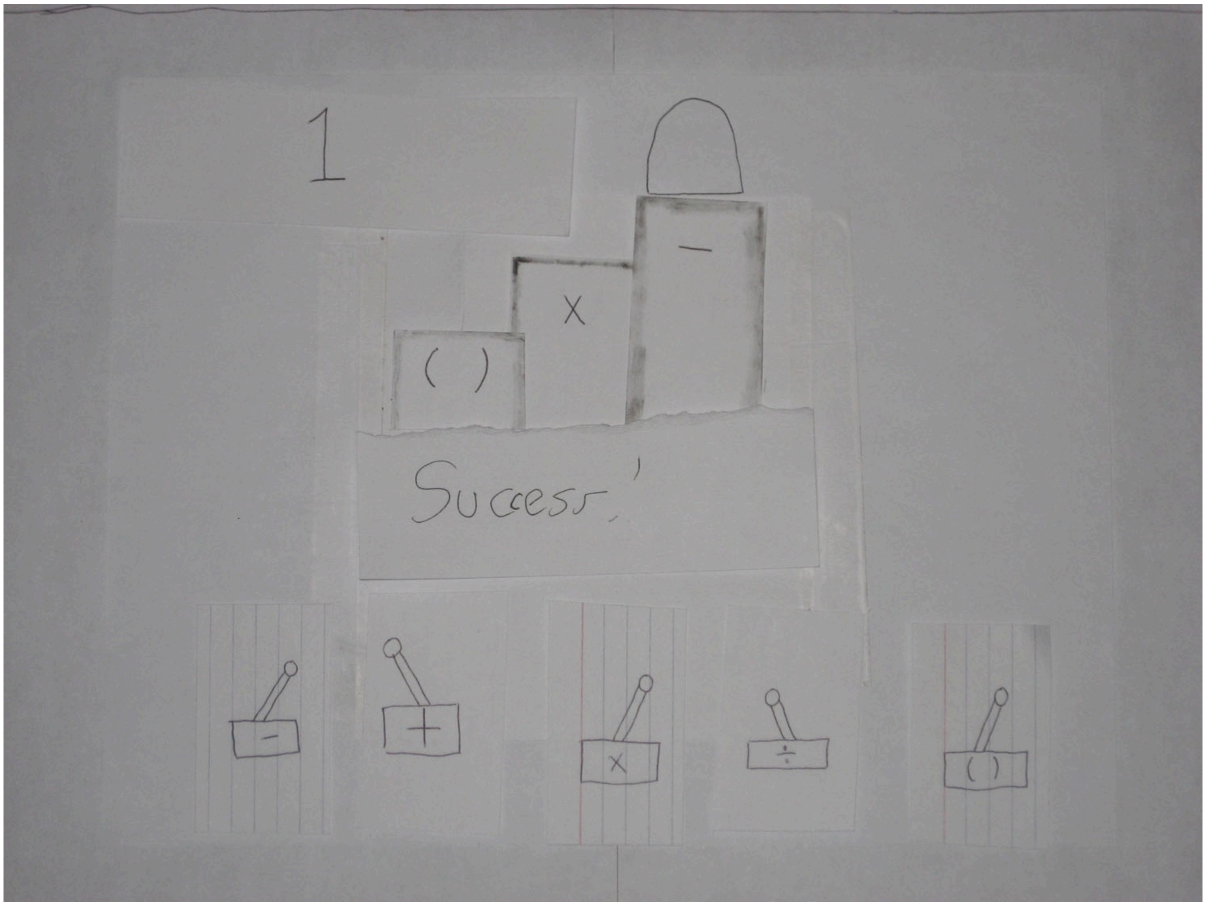
Player flips “x” operation switch. Equation performs the relevant operation.



Player flips “-” switch. Operation cannot be solved adequately so an error is given but equation remains the same.

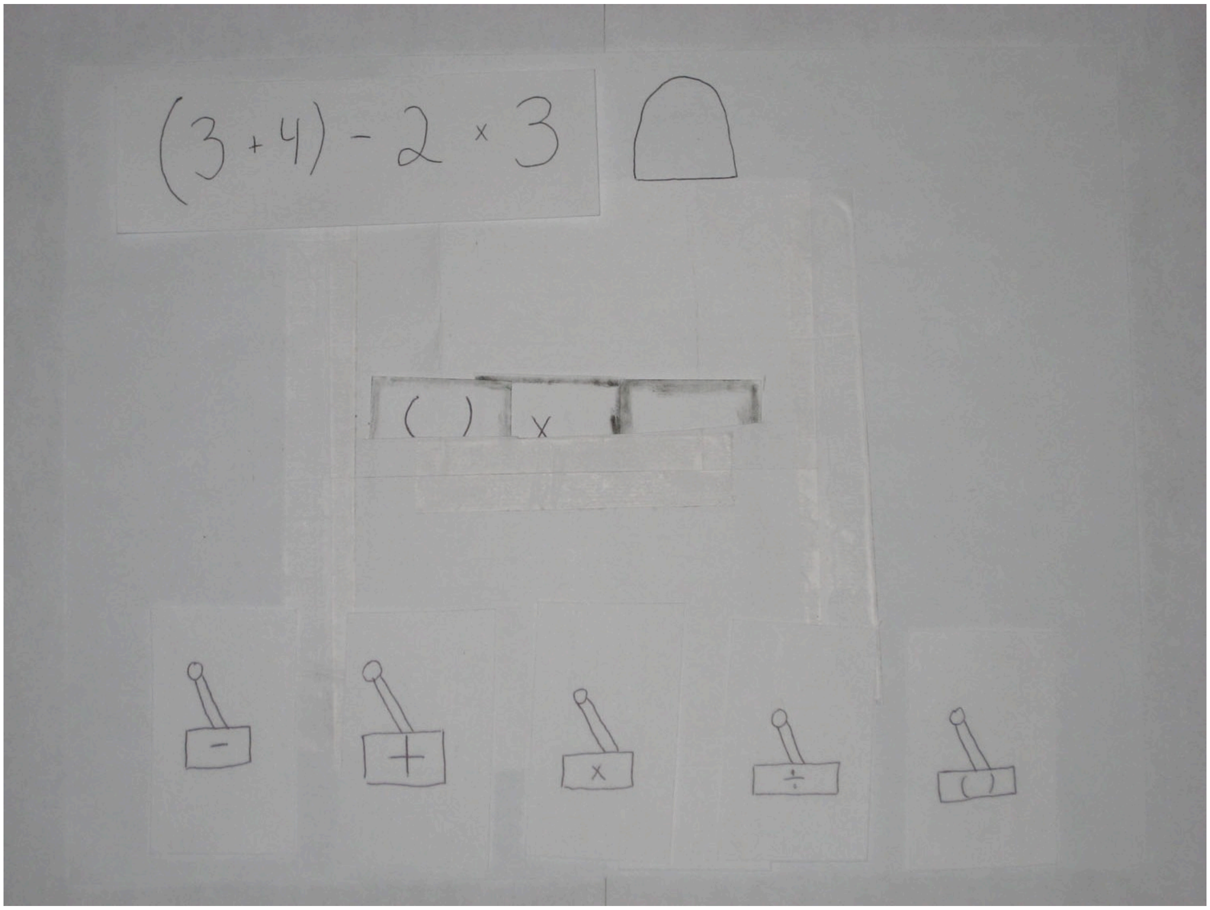


Player flips “()” switch. Equation performs whatever operation is inside the parenthesis.

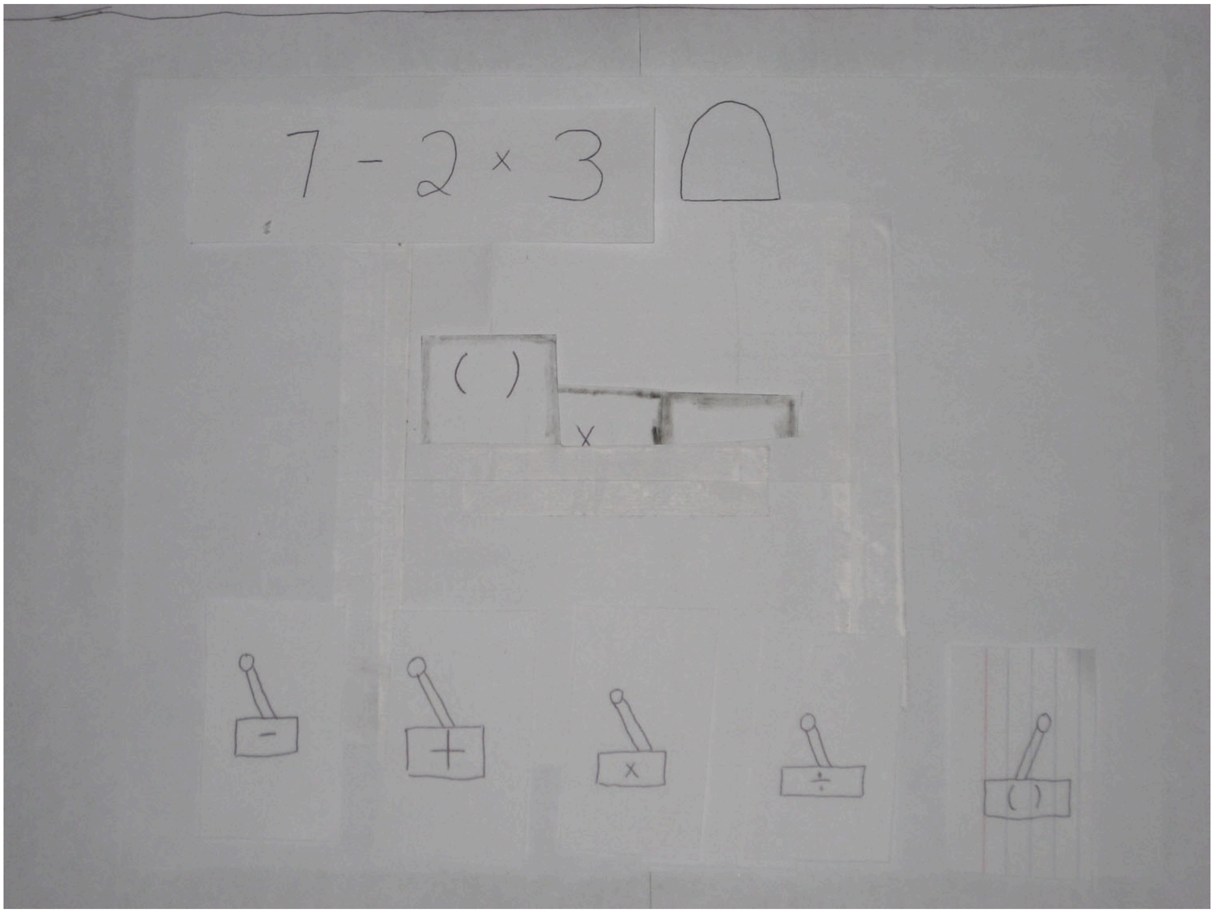


Player flips “-” switch. The equation cannot be simplified anymore so the player wins.

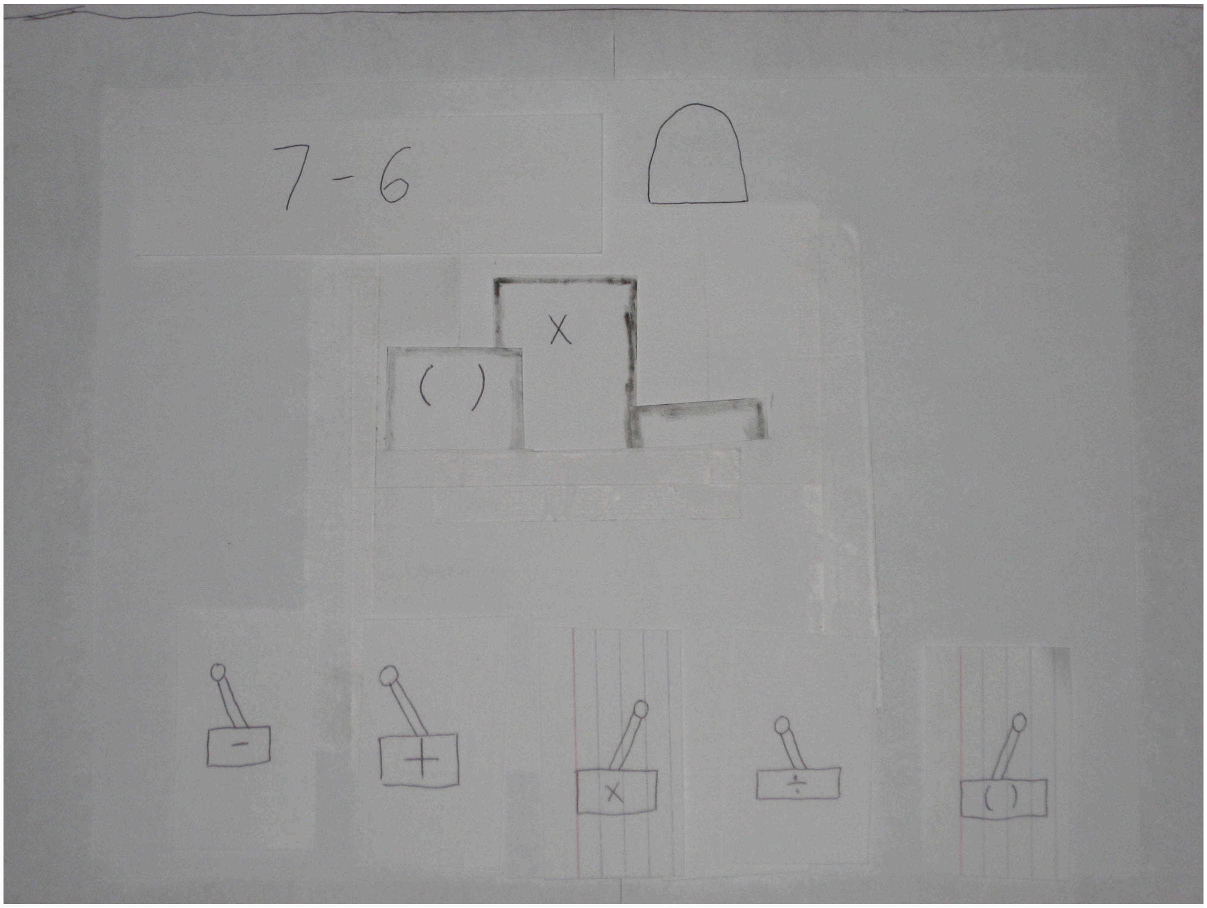
Order of Operations Game 2:



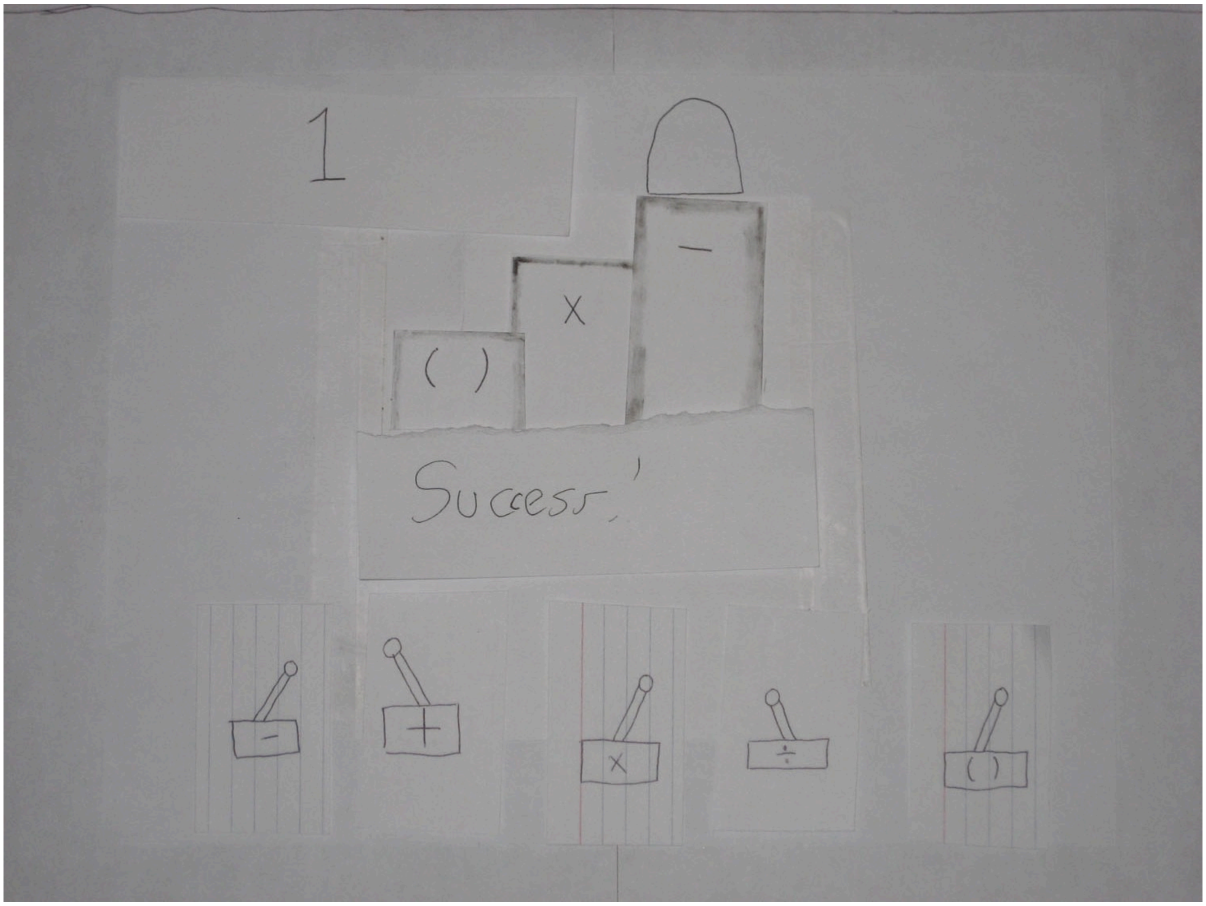
Start of Problem.



Player flips “()” switch. Equation performs whatever operation is inside the parenthesis.

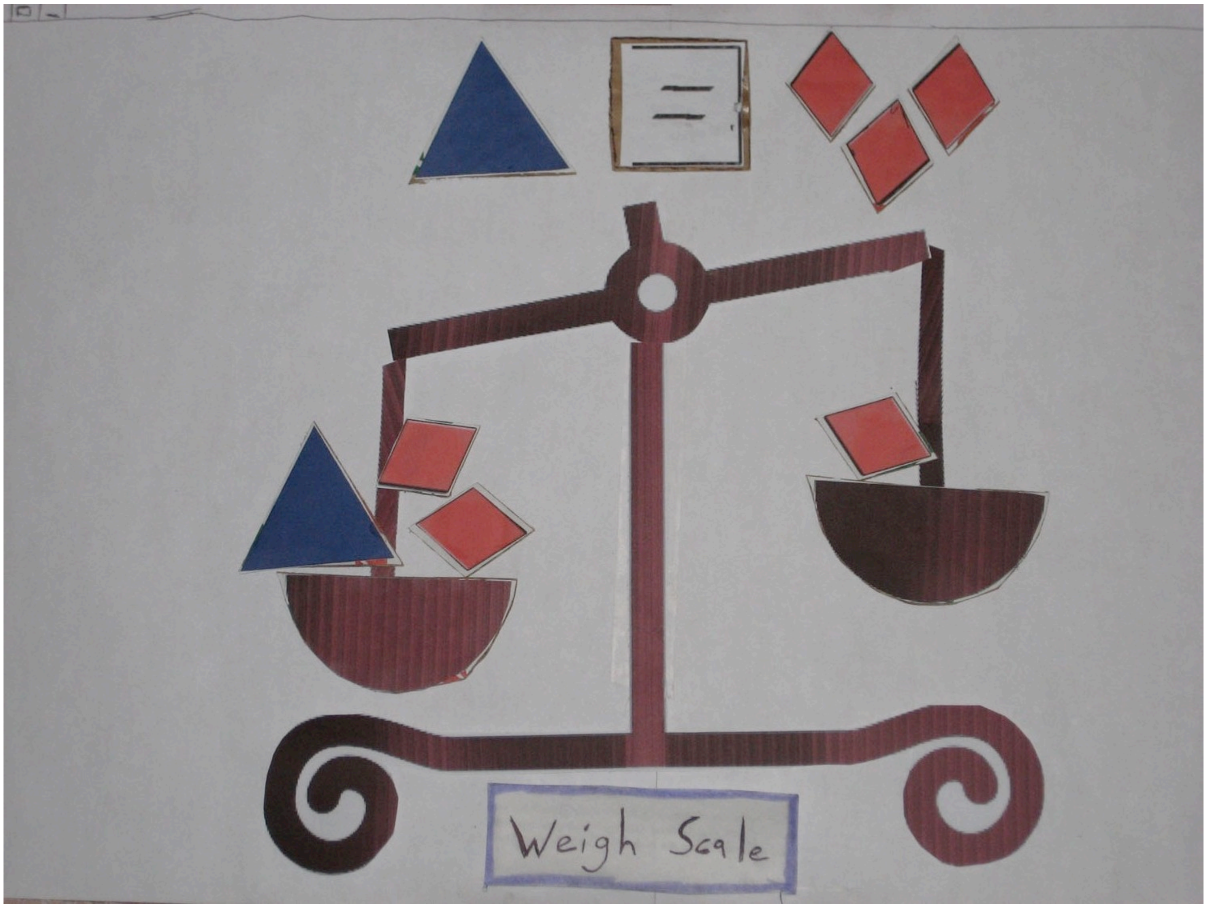


Player flips “x” operation switch. Equation performs relevant operation.

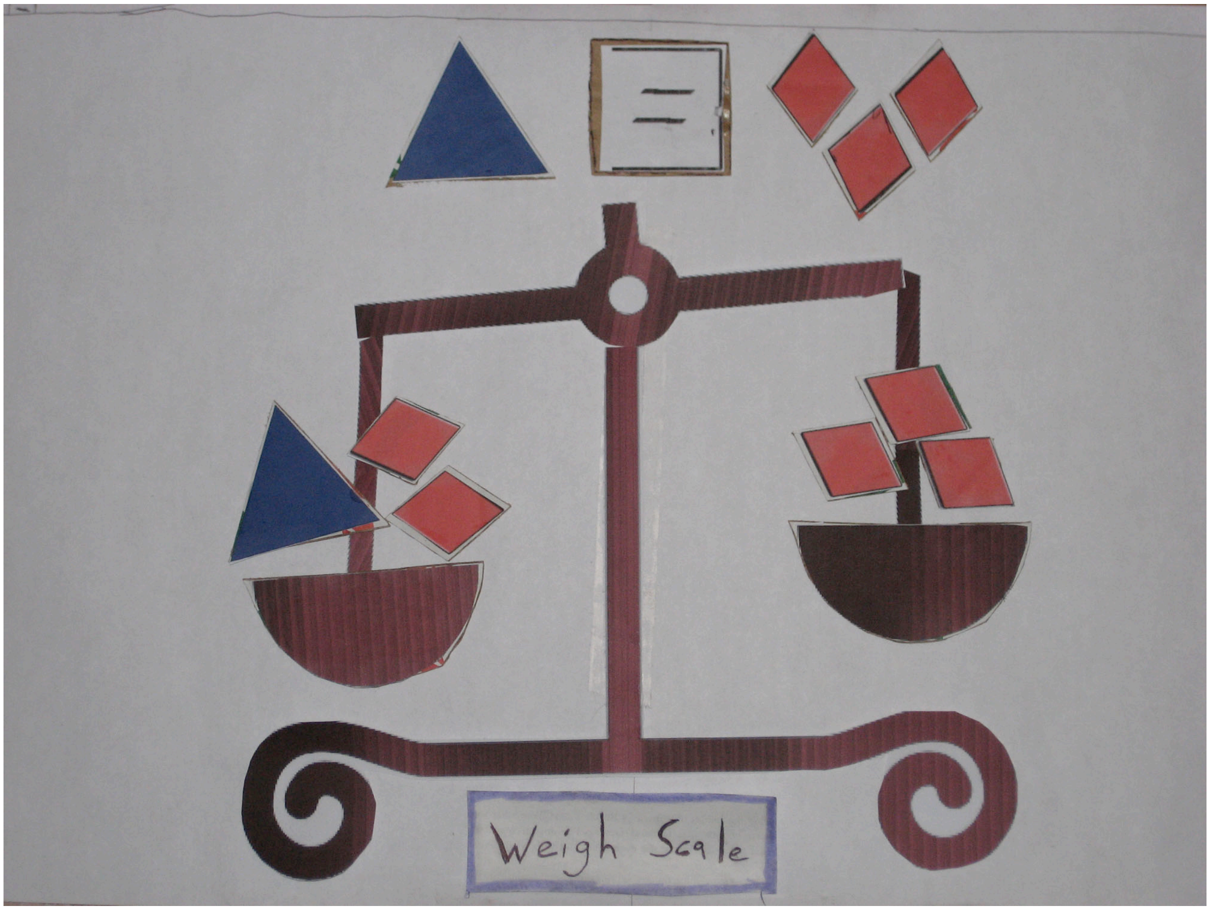


Player flips “-” operation switch. Equation cannot be simplified further so the player wins.

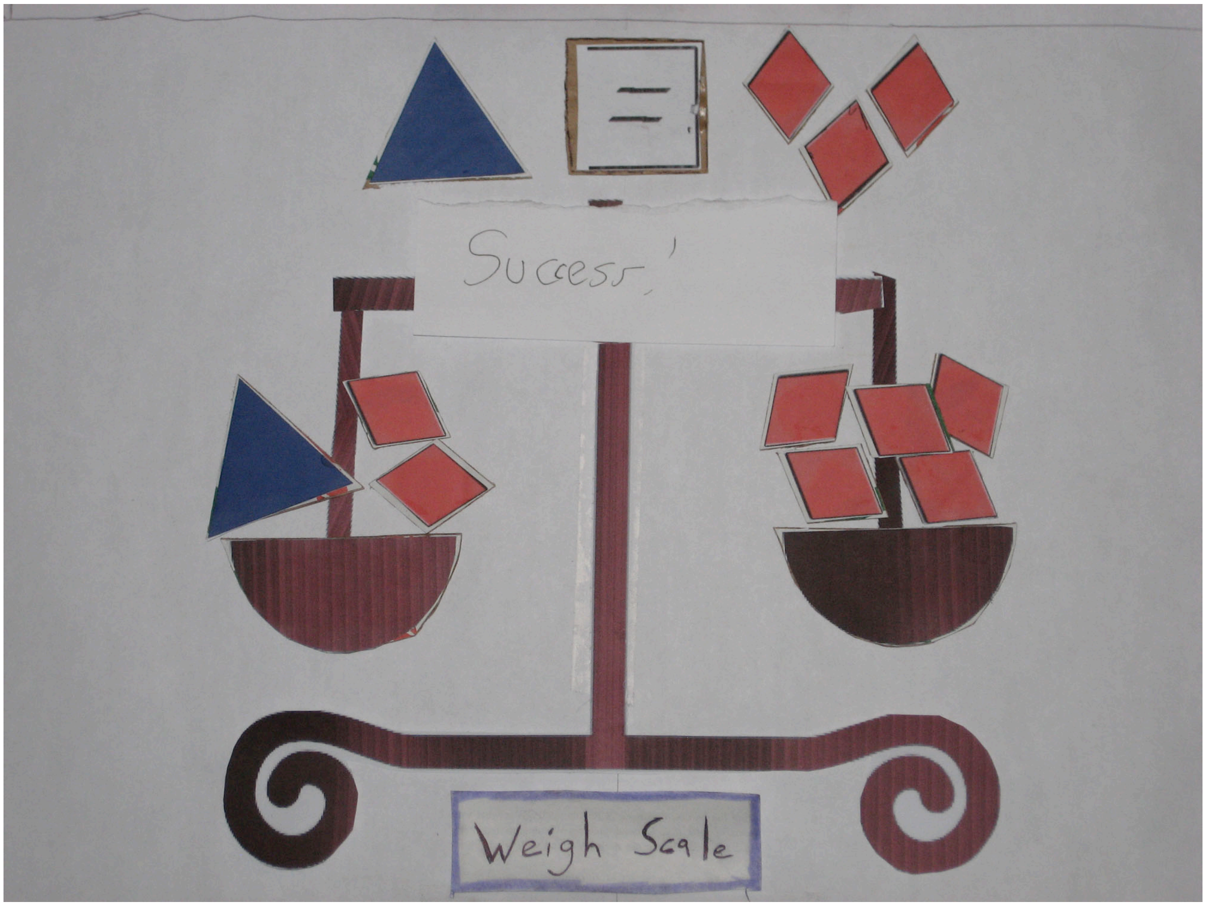
Jewel Game 1:



Start of Puzzle. Player can only place or remove fems from their side of the scale (right side).



Player places 2 red diamonds on the right side of the scale and hits weigh scale.

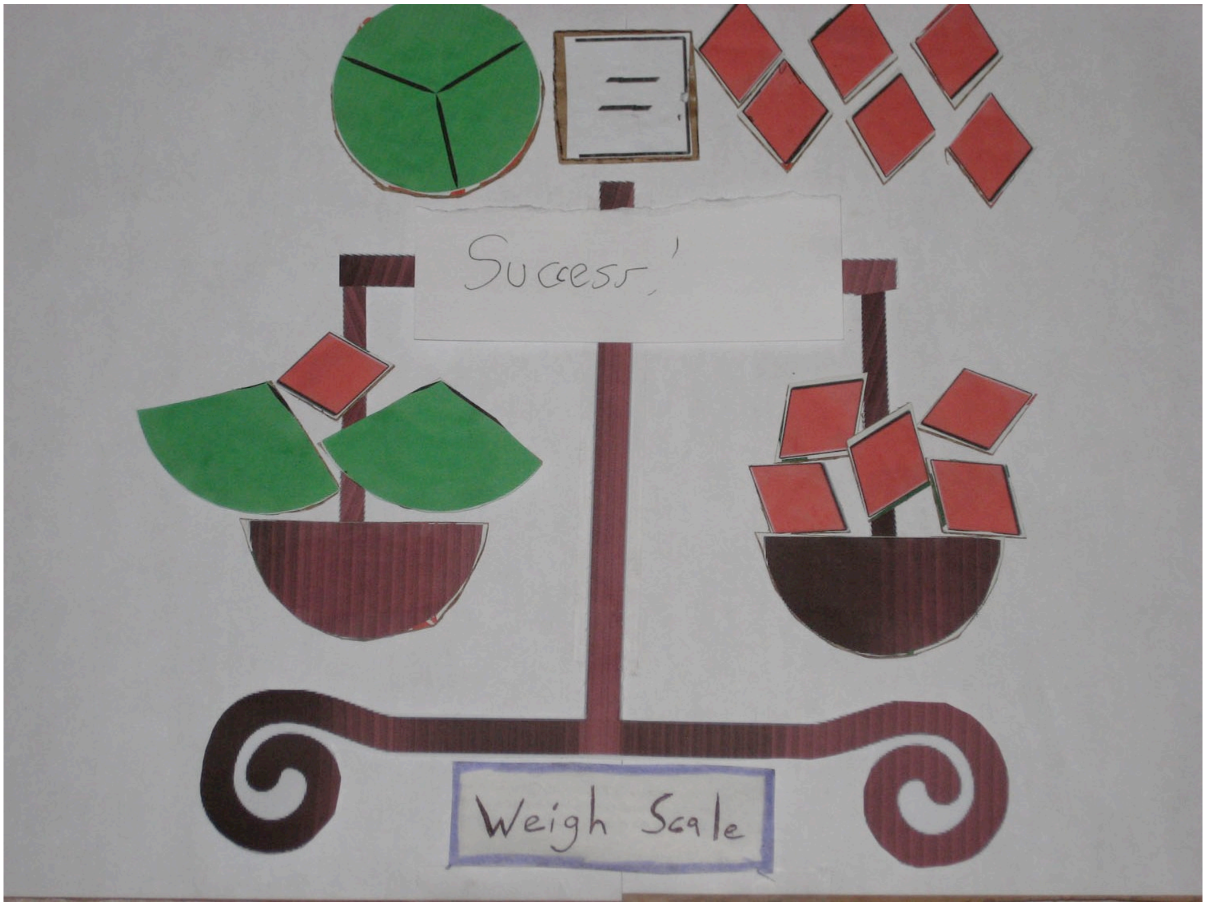


Player places 2 additional diamonds and hits weigh scale. Player wins.

Jewel Game 2:

Start of Puzzle.

Player places 4 additional red diamonds on scale and hits weigh scale.



Player removes 1 red diamond from scale and hits weigh scale. Player wins.