I. Abstract:

Our content area for our game will be mathematics, specifically taking as our focus the transition from an understanding of arithmetic and basic operations to an understanding of algebra and algebraic thinking. We focus on building to the ability to understand and model simple numerical relationships between quantities and objects in the world mathematically, such as use of combinations of operators, ratios, combinations of operators, proportional relationships and draw conclusions from these relationships.

Beginning learners in our content area will have an understanding of the four operators in arithmetic and be comfortable using them. Intermediate learners will have an understanding of expressions using combinations of operators, an ability to solve word problems, a familiarity with more complex operators, and exposure to fractions. Advanced learners will have an understanding of creating expressions and equations which describe numerical relationships, an understanding of functions and how to build them, and a more complex understanding of proportional relationships such as ratios. Our content area and learning trajectory are selected in order to emphasize these concepts of numerical relationships, eventually building to complex ideas about functions and proportional relationships and allowing for smooth transitions from one building block to the next.

Haunted House Escape is a puzzle adventure game in which, while exploring a deserted house in your neighborhood, you become trapped. Your goal is to get to the ground floor of the house and escape by solving puzzles and collecting keys. You navigate a top down 2d environment ***bounded*** by the walls and doors of the floor corridor. The critical ***rules*** are that each key is opened by a door, and you must acquire that key before unlocking the next step in the progression represented by the door. After you get the floor level key, you can advance to the next level. Keys are unlocked in each room by completing minigames, the rules of which we intend to be ultra discoverable given they use the same key controls as movement. The ***obstacles*** are represented by these unopenable doors, the maze-like network of halls and doors, and the minigames

themselves, which players must surmount. ***Conflict*** emerges naturally in the single-player setting given the intuitive goal of escaping the house and the requirement of finding keys unlocked by completing minigames. *Uncertainty of outcome* is achieved by difficulty of the minigames which require the skills we build.

Character Misty about to encounter a mathematical puzzle piece minigame. She's on the last level and already has two keys.

II. User Profile:

Our users will be of ages 8-12 (3rd to 6th grade). This will situate them in between a basic knowledge of operations and a basic understanding of numerical relationships such as ratios, proportional relationships, and simple functions. We assume only that the user will be able to recognize and use basic operators, and understand whole numbers and their relationships as on a number line and as a baseline seek to build upon these concepts.

III. Skills:

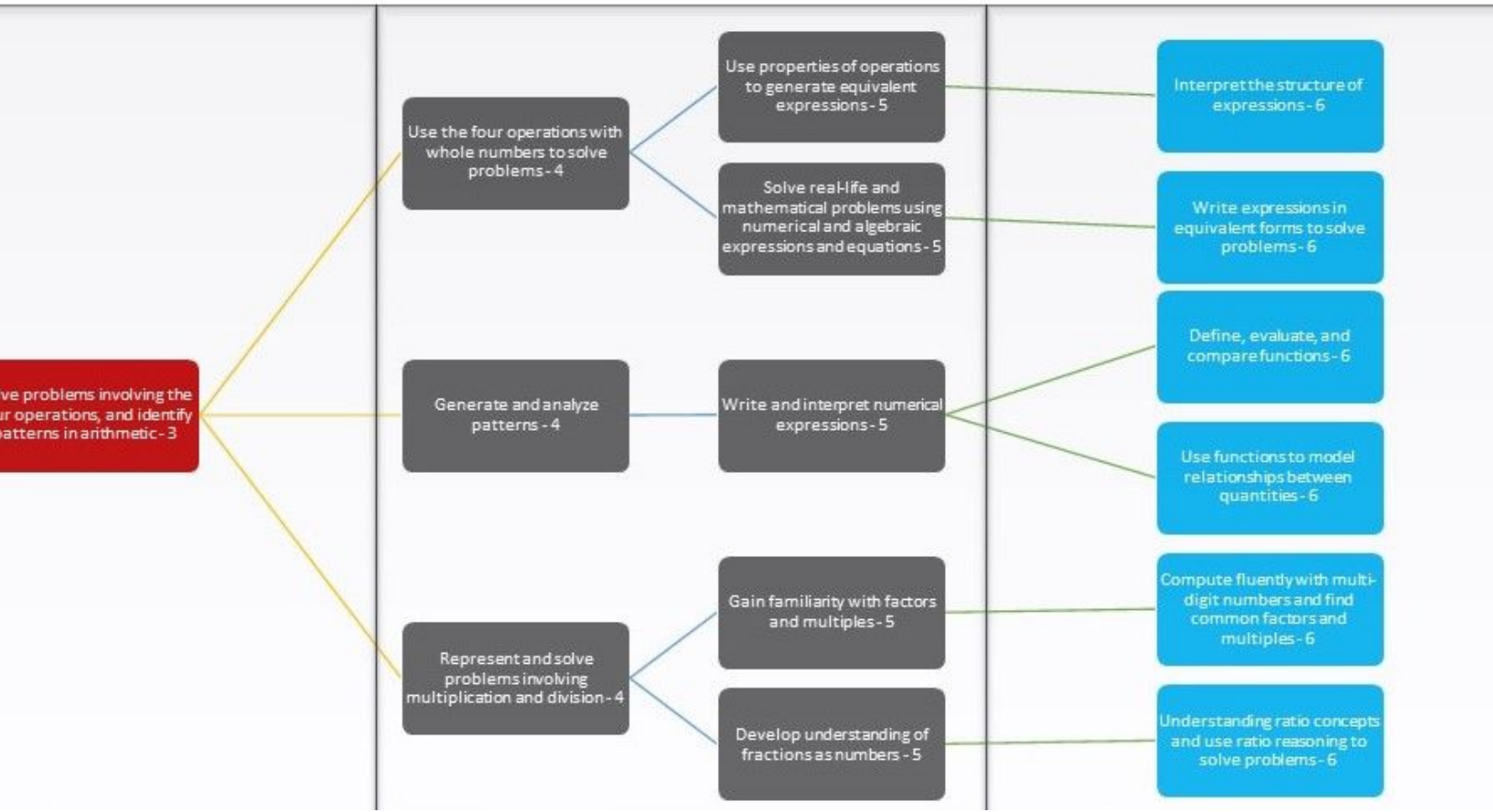
In this game, we seek to teach our users a variety of skills that revolve around numerical relationships applicable in understanding and modeling real world phenomena. Given a user who possesses only the minimum knowledge required to play our game, beginner level skills we seek to teach include: using combinations of operators, generating and analyzing patterns, and representing and solving problems involving arithmetic operators. Given a user with beginner level knowledge, intermediate level skills we seek to teach include: generating expressions, solving real-life and word problems using expressions, basic solving of equations, modeling relationships, and understanding ratios and proportional relationships. Lastly given a user with intermediate level knowledge, we will seek to teach skills such as creation of equations to model relationships and analysis of proportional relationships to represent and solve real-world mathematical problems.

IV. Learning Trajectory

We were able to derive ideas regarding content area and our learning trajectory from investigation of the standards for mathematical practice for each grade level in the Common Core State Standards. These skills mainly consist the transition from simple arithmetic to more complex algebraic equations from 3rd grade through high school, and the building blocks which compose this process. This trajectory was pieced together emphasizing a logical transition from one building block to the next, centered on themes such as numerical relationships in functions and proportional relationships discussed in our content area. Additionally, some sequential steps reference the same topics; we believe that repeated presentation with increased complexity that can be related to past presentations is an extremely effective learning strategy (See: Veladat, Spiral Learning).

According to the Common Core Standards website, teachers from all different backgrounds developed the standards to meet the needs of a growing and increasingly diverse student population in the United States (See: Common Core, Development Process). Opponents of the Common Core Standards claim that the standards have failed to produce adequate results, while proponents say that there has not been enough time in the program and lack of consistent implementation hinders results. We believe that the skills recommended by the Common Core math standards are vital for a robust mathematics education and can be applied in novel ways to approach education and problem solving. Additionally, because the program is impacted dramatically by implementation, and it is impossible to create a program which is applied uniformly by different educators and in different classroom settings, we believe that the core principles and benchmarks are still very useful. Therefore, we have chosen to implement these skills in our learning trajectory, with the understanding of the imperfections of the Common Core, and a determination to build flexibility in our ultimate design that allows for scaling of concepts to the displayed competence of our audience.

Arithmetic ==> Algebra



V. Game Design:

The premise of our game is as follows (ideally set with an opening cutscene either before or after the main menu). You and a few of your friends have decided to investigate a suspicious mansion in your neighborhood. You sneak in and hear a noise upstairs, so you climb up and up. As soon as you enter the attic, the door locks behind you. You must escape the house and get home. Players will navigate each floor as its own level and solve mathematically involved puzzles to attain keys and open doors with the goal of getting to the ground floor and escaping. The rules are simple and follow those of a typical adventure game. You, as the character, will have an inventory full of items you have collected. There are a set number of rooms you can navigate between on each floor and items to collect and locks to open. We will follow a one key one lock policy in order to make the game accessible to younger users. For instance, a player might be navigating through a hallway to a door marked in blue. The player must then solve a puzzle marked in blue in an available room. The puzzle will require manipulation of proportional relationships, and when solved, provides a blue key. The player can then navigate back to the door, open it and solve another puzzle to access a new room (simplified).

The game we will create will fall most closely within the bounds of an Adventure game. The user will navigate through the game world and solve individual puzzle instances in order to progress. Our game will be comparable to something like Myst, wherein the player explores an island filled with different paths, dwellings, rooms, and thematic locations uncovering a lore and solving puzzles which culminate in a dramatic end. The major differences will be the real time aspect of our game in that exploration of the varying areas will be more possible (Myst is an older game where each setting is just a frame), the focus on more involved puzzles with engaging mathematical relationships rather than just simple item collection, and the engaging subject material and environment which will be thematically relevant for the typical student user, with provisions to integrate majority and minority students alike.

The structure and elements described above lend themselves to these important aspects. Due to our adventure game genre and simple leveled setting, it will be easy to provide a clear and thoughtful increase in difficulty between each unlocked door on one level of the house, and between levels of the house, in order to create progression. Each level will cover a distinct topic area within our learning content, and each subsequent door on that level will add minorly in complexity in order to create a true building challenge which will not only engage but also scaffold. As players move between rooms collecting items and solving puzzles, they will collect additional essential items that reveal a history of the house and past inhabitants' haunted experiences. Additionally, there will be a scoring factor which will be composed of successfully solving puzzles with few attempts and with speed, which will drive engagement for more competitive players or those who tend to minimax.

VI. Skill Building:

The collection of each key will involve solving a puzzle which requires some simple mathematical expression or model. For instance, envision two rotating columns, each with 4 symbols on the sides. Rotation one column makes the other turn 2 symbols forward, and rotating the other makes the first turn 3 symbols forward. Thus, the player will have to investigate mathematical relationships such as proportions and ratios in order to make both columns face the same way. This engagement builds in concepts of these relationships rather than asking players to solve them explicitly, creating strong interactive elements that appeal to many player types while never asking the player to confront math directly. We have brainstormed numerous such puzzle types and are confident in their teach ability due to research on *learning trajectories*, the potential for employment of *spiral learning*, and the natural interactivity and engagement that comes from puzzles in the *zone of proximal development* (See: Veladat, Spiral Learning). New and different elements will be added between rooms and between levels in order to add complexity. Thus, if a player succeeds in traversing an entire floor and moving to the next, we know that they have understood the concepts required to pass that level and can be introduced to new ones, provided familiar concepts to cement those ideas, or provided familiar concepts with increased

complexity to build upon them. A simple example going off of that which we present above might be multiplicative elements between the ratios of column movements, or perhaps an increased number of relationships such that different columns rotate proportionally based on the orientation of the others (in essence, complexity can easily be added when a design is intuitive and engaging).

VII. Motivation:

Many different player types will find engaging elements in this game. We appeal very directly to the explorer, who will find it exciting to uncover new areas of a level, new kinds of challenges, and navigate the world we create; the collector, who will enjoy acquiring the different pieces of knowledge and items the world has to offer and identifying and organizing what kinds of puzzles he can solve with what information; the achiever, who will appreciate the tiered design and the inherent motivation of hitting subgoals; and certainly the craftsman, who will be excited by the design and confrontation of puzzles, as well as building an understanding of what skills and knowledge need be involved to theorize about the puzzle solutions. There are also certainly elements for other players like the competitor, for whom we we build in a timing aspect so they may compete with themself or others even across instances of a singleplayer game; the artist, who will appreciate strong interactive elements and smooth and flashy design of the puzzles; and the storyteller, who will appreciate uncovering the mysteries of the eerie house along with the characters themselves. We will also drive the engagement of players who take educational experiences less seriously through strong interactive elements of the puzzle design; the joker type will ideally find a place in our game in the play that is possible regardless of objectives through manipulating pieces and feeling the impact of his choices.

VIII. Designing for the User:

Limitations in skills are taken into account through the creation of intuitive puzzles and interfaces for those puzzles. Regardless of skill and initial understanding of the core mathematical principles which underlie a puzzle, users will be able to develop that understanding through play due to both simple controls and clean

user interface. Additionally, because an introductory level will be included where the basics of our puzzle minigames are taught using only diagrammatic instructions with strong colors and textures, players will already be introduced to the basic mechanics, which will allow building of skills from there. We assume very little other than basic understanding of causality in movement, which should be understood by our target age and in most cognitively impaired players. Difficulty level differences between rooms and puzzles to allow for learning between instances, but the mechanics stay the same.

IX. Culturally-relevant Instruction:

In order to truly serve the needs of a relevant educational body of students, our game must address students from all different backgrounds and cultures. We eliminated the use of a default character (e.g. Mario), a remnant of mainstream culture that could alienate some students. Although well-known or recognizable characters are useful for branding purposes, they are not inclusive (e.g. Mario perpetuates stereotypes about Italian-Americans). Therefore, in a full game we would have a fully customizable character with independent attributes such as skin tone, clothing, height, body type, which are all irrespective of race or gender or any other potentially exclusive or stereotyped grouping. Also, any furniture or backgrounds that could be considered majority culture or exclusively Western will be replaced with those that are more equally represented (taking a page from popular video game Overwatch - universally applauded for its inclusion of diverse characters, storylines, and maps). For example, backgrounds of levels and choice in music will be purposefully crafted to match the player's initial choice in character. Sprites for characters will vary in skin tone and gender ambiguity to more accurately represent more people. By purposefully adding more inclusive cultural elements to the game, we can send a message that everyone is welcome to play and learn without the feeling of alienation that can come with mainstream cultural elements. In addition to incorporating elements from different cultures, our game will also borrow primarily from Japanese video games like Pokemon in terms of cartoon/anime-like sprites moving around rooms and spaces and collecting items in an inventory while the player observes the character and level from a bird's eye view, an acceptable global visual style.

X. Badge System:

Participation Badges:
- Explored all of level 1
- Explored all of level 2
- Explored all of level 3
- Bumped into walls 100 times

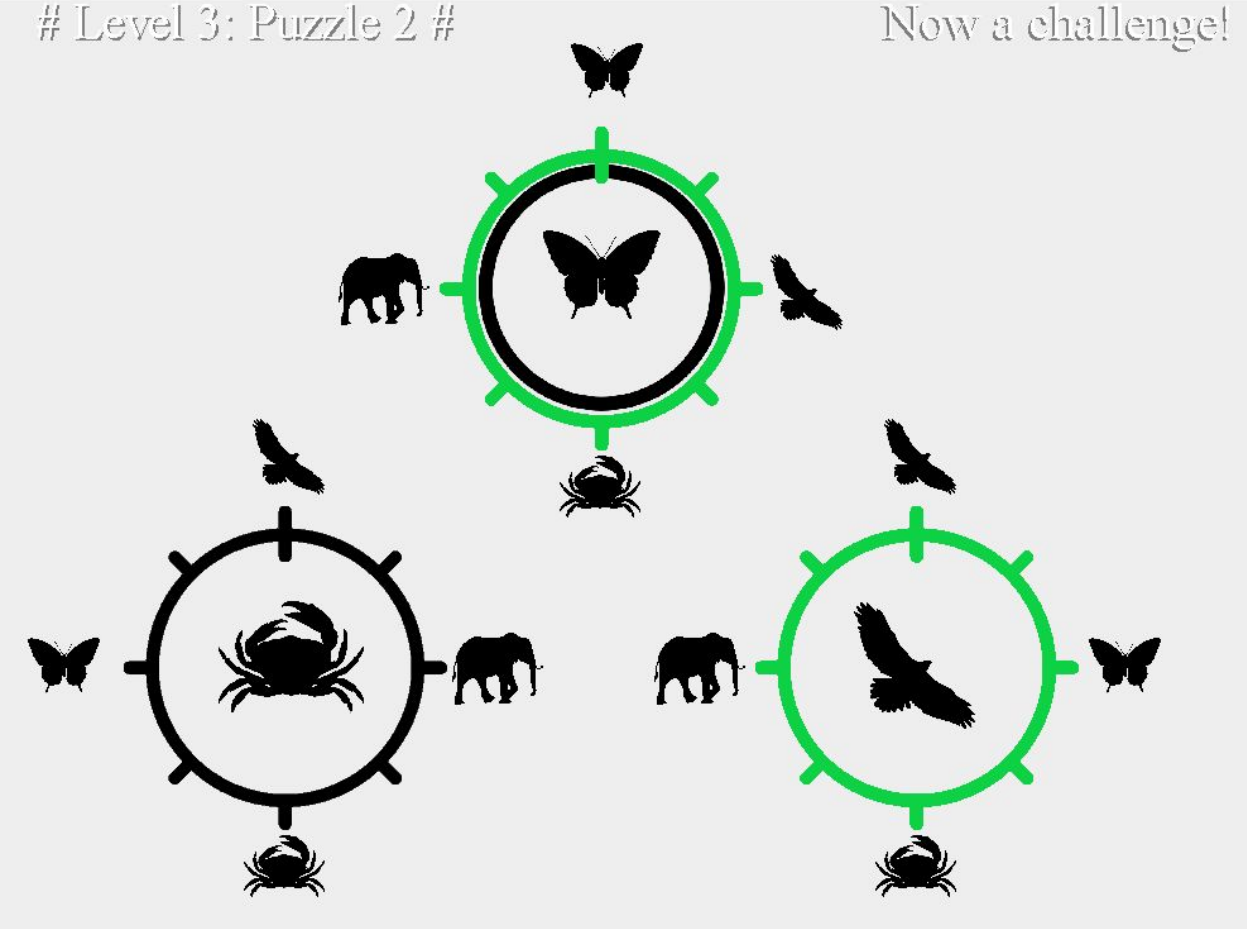
Achievement Badges:
- Solved a minigame
- Solved 5 minigames
- Solved 10 minigames
- Solved a minigame in less than a minute
- Solve a minigame in less than 10 seconds
- Unlocked all doors
- Completed the game
- Completed the game in less than 5 minutes
- Gathered every key
- Solved a minigame in the lowest possible number of moves

Behavioral (badges for behaviors that lead to academic success):
- Beat your previous record for solving minigame in least number of moves
- Helped a friend solve a minigame
- Returned to and solved a level you previously couldn't solve
- Tried every level
- Tried one minigame for over 10 minutes
- Didn't ask for help before trying a minigame for at least 5 minutes
- Asked for help when stuck

XI. Intelligent Systems:

In order to adapt to a player's skill level, the game would record the amount of time and/or trials (number of spins made in an attempt to solve the "turn the proportional wheel" minigames). If the time required and the trials attempted are high enough, the game can assume that the player found the minigame excessively challenging, and that the player may have guessed and got lucky in solving the puzzle.

Look inside the puzzle minigames. Must move dial / wheel so the top symbol matches the middle one.



Using this information, the game can update its difficulty for the following minigame accordingly. The game will regress difficulty back to the difficulty of the last previously confidently solved problem. In order to avoid confusion in the relationship between level number and game difficulty, the game can add more puzzles in the same level right after an unconfident attempt. The green and black rings on the wheel puzzles (green indicating a solved wheel and black indicating an unsolved one) provide *immediate feedback* in a subtle way. Once the player solves all the proportional wheels, the minigame automatically ends and a golden key appears. Feedback like this after the difficulty decreases reinforces corrective behavior and ensures the player quickly forgets the previously overly difficult mathematical puzzle (while cementing learning about the current one).

XII. UDL:

To properly confront this question we should consider limitations in skills across numerous dimensions. By making sure our in game tutorial instructions and physical key commands and control structure are very accessible, we make sure that our game is as inclusive as possible in terms of a user's mental and physical abilities as far as grasp of controls. For instance, in our introductory tutorial level, the player will not even need to know how to read English in order to play. Pictures of the keys needed to do certain actions like movement will be displayed alongside animations demonstrating the actions corresponding to the keystrokes (arrow keys displayed while the character moves around the space to pick up to pick up items and unlock doors). Any commands necessary to enjoy the game in its entirety (as well as the learn the concepts) will be easy to understand.

Not only will the instructions to the game be intuitive in the true spirit of UDL, but the required controls will also be minimalistic, requiring as few keystrokes as possible to execute and relying only upon usage of WASD and QE (which in a full game could be remapped to a different controls scheme to be maximally inclusive). This conscientious design mechanic is done intentionally to make sure that everyone who could benefit from an educational game like this has the chance to succeed. In fact, the character in the game has no direct interaction mechanics other than movement, collecting items and opening doors by simply moving towards them with the arrow keys while also solving mini-game puzzles with arrow keys as well. These conditions ensure that not only will the commands necessary to play the game will be easy to understand but also easy to execute, providing everyone with an opportunity to learn the mathematical concepts the game hopes to convey.

XIII. Tangibles:

Our game lends itself to the uses of tangibles without much alteration. Because the core mechanic in our minigames is the rotation and matching of wheel-or-gear-like elements, we could create a game board with pegs on which could be placed interlocking gears. When one is turned, the others react based on if they are connected, and their circumference, with the same goal of matching an image some side of the gear to its identifying image. I can envisions such a board with a set of compatible gears and a few decks of 'minigame cards' corresponding to three distinct levels of difficulty, where upon entering a minigame, a card is drawn which depicts a minigame, the minigame is set up by choosing and placing gears in the correct locations and orientations. Learners can then rotate the gears manually, moving their hands in corresponding ways to manipulate the system.

XIV. Assessment / Transfer:

(1) Understanding ratio concepts and use ratio reasoning to solve problems
   - If there are 99 3-leaf clovers: 1 4-leaf clover in a field, how many 4 leaf clovers are there in a 400 clover field?
   - Can help teach probability in genetics if given ratios on different traits and whether genes are dominant or recessive.

(2) Generate and analyze patterns.
   - What comes next in the pattern: 0, 1, 1, 2, 3, 5, 8, 13, __?
   - Sequences like the Fibonacci numbers are important in the computational run-time analysis of Euclid's algorithm to determine the greatest common divisor of two integers: the worst case input for this algorithm is a pair of consecutive Fibonacci numbers.

(3) Use functions to model relationships between quantities
- Give the equation for how the radius of a circle relates to the surface area of a sphere.
- Teaches physical relationships about the world. Flux is the luminosity of a star divided by its surface area. Given the radius and either the flux or luminosity, one can solve for the other variable. One learning goal is the understanding that an increase in radius decreases flux if luminosity is held constant.

XV. Game Bridge

To create a bridge activity, one could replace the animals on the minigames and put pictures and text for flux (brightness), luminosity, and radius. As one turns the distance or radius wheel, the flux or apparent brightness decreases by the square of the radius (flux wheel will spin opposite way of radius and at greater rate). This is all while the luminosity wheel is held constant. One could use a picture of the Sun, a light bulb, and a ruler for the symbols on the minigame wheel.

Minimum Viable Product:

MVP Specification:

- World and Navigation
    - The game world consists of a top down (tilted "bird's eye" view) 2-dimensional environment
    - The player will operate a player character sprite which navigates through the world
    - The main objects in the game world are doors, walls, and keys
        - Doors are barriers which the player collides with until they have the appropriate key. Upon collision a notification will appear indicating which key the player must obtain to open this door. If the player has the appropriate key and collides with the door, a puzzle minigame will commence. If the player is successful, the door will unlock, consuming the key and allowing entry to an additional room or the next level.
        - Walls are barriers which the player collides with. Upon collision, an aural and visual indicator will be displayed, but the player may not proceed.
        - Keys are objects found throughout the world. Upon collision with the player they are added to the inventory and a indicator notifying the player of successful pickup will be displayed

    - Each level will be one of these 2-dimensional spaces with walls, a set of doors, and a matching set of keys
    - Upon reaching a door where the corresponding key is in inventory, the screen will shift to a puzzle minigame

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- Mechanics
    - The player will move throughout the world using WASD
    - The player will collect items throughout the world by moving over them
    - Collected items will appear in the players inventory on screen
    - Players will unlock doors by moving to them
    - Players will manipulate puzzles by referencing objects with number keys and rotating objects with WASD and moving between objects to manipulate using Q and E
    - The player character has an inventory displayed on screen of currently possessed items
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- Level Design
    - Leveled design incorporating 3 levels, one *introductory*, and two *intermediate*, building in their challenge and demand of expertise.
    - Level 0 - "The Attic": **INTRO** - A single room with one simple challenge.
    - Level IV- "Main Floor": **INTER** This intermediate level will focus on exploring mid level concepts in our learning trajectory (recognizing patterns) - 2 rooms.
    - Level V - "Ground Floor": **INTER** This intermediate level will complete mastery of mid level concepts in our learning trajectory (creating expressions) - 2 rooms.

Works Cited

"Development Process." *Common Core State Standards Initiative*, www.corestandards.org/about-the-standards/development-process/.

"Mathematics Standards." *Common Core State Standards Initiative*, www.corestandards.org/Math/.

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