Zcrenshaw nigereepps Final Game Design

Abstract: Describe the learning goals of your game, the premise, and the overall game design in just a few paragraphs.

Our game, *To Space and Back*, is a fraction learning game for 3rd-5th graders. The game is designed to introduce the concepts of fractions through a graphical representation of fractions as slices of circles and rectangles. The game is designed to accompany the initial steps in the fractions learning trajectory for the Common Core curriculum for our target age group.

The premise of the game is that Dr. Stevens, a rocket scientist, has been trying to get their rocket into space for many years. They have just discovered a new fuel, Ingenium, that reacts with water to create an explosion. Dr. Stevens encourages the user to harness the power of this new found fuel to get the rocket into space. Dr. Stevens sets goals for the student in the game, starting by getting the rocket off the ground, then into space, then to the moon, and then all around the solar system. This increases the level of challenge as the game progresses. The user is also exposed to new resources as they explore the solar system and collect new fuel types.

To get the rocket off the ground, it must be filled with both solid and liquid fuel. The user partitions these fuel types and then adds some to the rocket. With the right ratio of solid to liquid fuel, the rocket will get where it needs to go. If the rocket fails to attain its goal, the user is encouraged to try a different ratio of fuel. It is not a guarantee that every fuel ratio will complete the task, so there is some conflict between gravity and user.

Users are given near immediate feedback on the success of their launch, as the rocket does not spend too much time off the ground before it falls back to Earth. This helps the student know the effectiveness of their methods, and helps to guide game play. Once the user leaves the Earth, they are encouraged to play with new fuel types and explore for more. This feedback is enhanced by the binary outcome of a launch: it reaches its target or it does not. That said, the user can see how close they get to their target, and how much fuel is in the rocket during a launch. Using this data, the player can improve their fuel ratio and achieve the goals set out by Dr. Stevens and maybe even the player themself. Dr. Stevens not only provides challenges for the player, but also hints. Dr. Stevens drives the user the right direction, and acts as a “guide on side”, there to nudge the player in the right direction when they may be struggling.

User Profile: Summarize your user profile in 1-2 paragraphs, making sure to point out aspects that influence your game design.

Our user profile is a 3rd-5th grader who has basic arithmetic skills (addition and subtraction). They also understand gravity (intuitively, just enough to understand that things that go up must come down). The user is at the beginning stages of learning about fractions. Our game appeals to all different player types with different motivations and goals. Through universal design, we accounted for different demographics and cultures. Our user has the ability to use keyboard at a basic level with optional mouse playability. Ideally, the user is interested in rockets and science.

<u>Skills: Describe what skills you are going to teach your user. Make sure that these are skills, not just content. These need to be specific - not just "math" or "memorization" - exactly which math skills are expected or exactly what level of memorization is expected to be built? You also need the skills to show some range from easier to harder.</u>

The first math skill the users learn is to recognize how a circle looks when cut into different numbers of equal parts. Graphical equipartitioning is the first step to understanding fractions. The game starts with a circle, because many students may be familiar with pizzas or pies being cut into equal parts. This knowledge of equipartitioning of other, more familiar objects may assist their learning. For students that may not have this cultural background, the different shapes of an equipartitioned circle are easier to distinguish than those of a rectangle, and is a good introduction to fractions. The next step is to show the equipartitioning of a rectangle. This provides the students with another visual vocabulary they can use to help with fractional math later on. Many calculation tools in early fractional math depend on a visual representation of an equipartitioned rectangle, so recognizing how these fractions look graphically will assist the student in later math.

Furthermore, when the slices of solid fuel are placed into the rocket, they are simplified into an equivalent fraction. This may not be obvious to the user, but for those that do see it, it may get them to question why, for example, 2/4 looks about the same as ½. This lays the foundation for equivalent fractions in later math. The game also provides a textual representation of of the fractions, so the student can see the written fraction alongside the graphical fraction in order to build a connection between the two forms of representing congruent concepts.

This game also encourages the student to manipulate variables, which is an invaluable skill in STEM. The student is primed with the idea of a variable by being able to change the levels of each fuel, although the word “variable” is never mentioned. This exposes the student to the concept without intimidating them with new vocabulary. Also, encouraging the practice of experimentation, prediction, and trial and error, prepares the student for more advanced scientific learning and provides them with the cognitive tools to engage in constructivist learning later in life.

<u>Learning Trajectory: create a hypothetical learning trajectory for how student skills / knowledge will be built. The left edge should be the skills you assume students start with (lower anchor points). The right edge are the most advanced skills you will teach (upper anchor points). If there are concrete skills in the middle, you can highlight those with a different color. If you think it is</u>

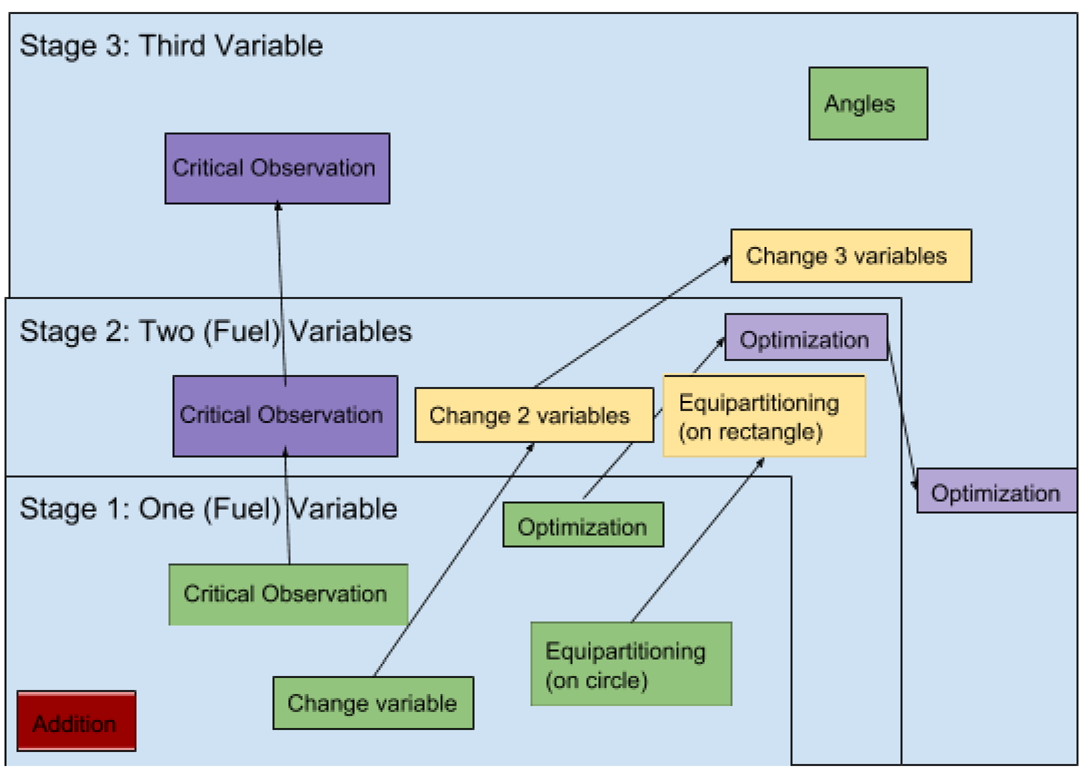
more appropriate to split this into multiple trajectories, you can do so. Where available, cite sources for either the learning goals themselves or the relationships between learning goals. Much of what you are teaching has research behind it, so you should not be making all of it up.

The purpose of this game is to introduce basic mathematical concepts. More specifically, we intend to demonstrate fractions, variables, experimentation, optimization, and angles in a very informal setting. The focus will be on variables, fractions, and angles. The other concepts will follow intuitively as a consequence of play. In the first portion of the game, we will focus on experimentation and fractions (in a graphical representation). The second portion of the game will focus on reinforcing the skills in part one in a different setting, and expand the skills of the user in the realm of the game. The third portion of the game will focus on changing two variables at a time, and optimizing the ratio. The fourth portion of the game will focus on angles and trajectories. In learning trajectory below, Portion One and parts of Two make up Stage 1, Portion Two and Three is Stage 2, and Portion Four is Stage 3.

A reformulation of our learning trajectory is in Figure 1. Another, slightly more detailed version is in Appendix A.

Figure 1: Three tier learning trajectory

Key: Red - Assumed Skill, Green - New Skill, Purple - Reinforce Skill, Yellow - Expand upon skill



Some of the learning trajectory is based on the Fractions and Equipartitioning trajectories from the following source:

https://turnonccmath.net/index.php?p=map&m=2

These learning trajectories are broken down by topic and grade level, and we have picked portions of the trajectories are grade appropriate for our target demographic.

The above trajectory is based on the common core standards, outlined in the link below:

http://www.corestandards.org/Math/Content/NF/

Furthermore, this game concept was derived from experiments that Zack Crenshaw has done at his summer job working as a camp counselor at the Franklin Institute. In his job he conducted these experiments with children of the target age. These experiments were designed by STEM curriculum experts. A link to the write-up for this experiment is below.

https://docs.google.com/document/d/1Z2X_EshoiDT-9yy0wCousQFS4oboMJHa1e9n6anQ9do/edit

This game centers around the Core Four of STEM education (https://www.edelements.com/hubfs/Core_Four/Education_Elements_Core_Four_White_Paper.pdf):

The Core Four of STEM education, four basic qualities of successful STEM educational methods are: Flexible content and tools, Targeted instruction, Data-driven decisions, and Student-reflection and ownership

In this game, the user is free to experiment with the variables as they please, while still within the targeted confines of the game (as the user only has at most three variables to experiment with). As the user plays the game, their future decisions will build upon the experience they gain, and upon the data they collect from watching various trials of the rocket launch. In that way, they have complete control to drive the gameplay, and reflect upon past decisions to inform future ones.

Additionally, an expansion of this game could be applied for a chemistry learning trajectory. The game could be extended to include an exploration of pressure and reaction speed.

This could occur on multiple levels (different versions of the game could be developed based on varied learning tracks/grade levels). However, we do not intend to develop this curriculum, as we will be focusing on the math portion. There is a draft of this learning trajectory in Appendix B.

Game Design: Describe your game, taking care to describe the different elements such as premise, rules, etc. This needs to be a complete description that will allow the reader to understand the game play.

The characters in our game are the narrator and the player/user. The narrator (the user can choose between a few possible narrators), a rocket scientist, has always dreamed of going into space, but they've never been able to find the right rocket fuel. However, they have has recently learned of a new fuel combination: Ingenium and water. But, they need to learn how to use this new type of fuel to get his rocket into space. They need the user's help to do it. Your job is to help him find out how this new fuel works, and find the best recipe to get their rocket into space. You are recruited by the narrator to find the best fuel to get a rocket into space. As you're floating through space, you crash into the moon and lose one of your thrusters. The only way to get back to Earth is to find better fuel on nearby asteroids and use them to return back home.

The rules and procedures of our game are as follows: To launch into space, you must use a combination of Ingenium (solid rocket fuel) and water in the correct proportion to reach optimal altitude. Once in space, you must use angles to launch fuel and resources that you find from nearby asteroids, back to your spaceship. You return to Earth by figuring out the best fuel combination given these new resources (different fuel types).

Conflict is implemented because it takes the correct fuel ratio to launch the rocket successfully, and correct angle to get resources to the spaceship once on the moon. Failure to do so correctly, results in failure of the mission.

The boundaries in the game are the constraints of how to operate the rocket, and how far the rocket can go on a certain fuel type.

The outcomes at various points in the story include: Launch rocket successfully, or, it crashes before making it to space. Successfully deliver fuel and resources to the spaceship, or have to explore for more. Make it back to Earth or be stuck in space forever. This last point is particularly dramatic, and will act as a significant motivator for the user.

Skill Building: Describe how the game gets more challenging as users learn skills, using vocabulary from game design.

Initially the player adjusts 1 variable, the amount of solid fuel type. One circular piece (of Ingenium) is split into equal parts to show the user fractions and what they look like as the circle is divided. Through adding more pieces, the user will learn addition of fractions. Then the user can choose how many parts to split the solid fuel into, and this will show how these other fractions look as well as if they add fractions that combine, it will be simplified to teach fraction equivalence (for example ¼ + ¼ -> ½). The next step will be changing the water levels which will also be split into fractions similar to the solid fuel but on a rectangular rocket. Then both variables will be manipulated for a greater challenge and to explore optimal proportions and the relations between two fractions.

In the next phase, once the player has found the optimal solid fuel to water ratio and has successfully launched to the moon, the player will begin to explore angles when launching resources and fuel back to the spaceship. Using this new fuel, the user will begin to experiment with fuels of different strengths (i.e. coke and mentos, etc) and optimize ratios for those as well. This will be more difficult due to the manipulation of multiple variables: Fuel type, fuel ratios, and angle of launch. The user will need to master this in order to make it back to Earth.

<u>Motivation: Describe what elements you included to engage the reader, again using vocabulary from game design. Describe how different "player types" will find something that engages them.</u>

To engage the reader we have a number of dramatic elements, such as premise, story, and conflict. The premise is simple but driving: the user's goal is to get the rocket into space. They have a helpful companion, Dr. Stevens, who assists them in their journey and moves the story along. In terms of story, with each launch stage, the user gets closer and closer to their goal. The closer the user gets to their goal, the more game elements are added. This keeps the user in the Flow of the game, by increasing the difficulty of the challenge as the game progresses. The user has to fight with gravity and the hidden mechanisms of the fuel types in order to figure out how to advance the story and the game. The user is extrinsically motivated by Dr. Stevens to help them with the rocket design, and there is an extrinsic element to the end goal. The game also appeals to the achiever in the user, and once the goal of getting the rocket to the moon is set, this motivation can become internalized, and this intrinsic motivation to progress keeps the user focused on the game play. Once the user has made it to the moon, the map expands and allows the user to set their own goals to explore the solar system, while guided by the need to return to home as the story progresses. In this way, there are a number of dramatic, extrinsic, and intrinsic motivators in this game.

The Competitor can attempt to make it to and from space in the fastest / fewest attempts. The Explorer can explore the galaxy and fuel ratios. The Collector can acquire resources and knowledge about fuel types and combinations. The Achiever is engaged because the spaceship becomes more powerful / likely to succeed through resource management. The Joker is engaged because successfully making it to and from space isn't required, and experimentation is allowed/encouraged, thus the game doesn't have to be taken too seriously. Also, they can plan comical flight paths for their rocket. The Artist can creatively come up with rocket fuel combinations. The Director is in charge of controlling which fuels are used and what angle. The Storyteller plays in a world of space exploration, as a rocket scientist. The Performer can show success through resources and rocket launches. The Craftsman can craft rocket fuel combinations and engineer angle trajectory for successful travel.

Designing for the User: Explain how you took into account the limitations in skills of the user to influence your game design.

Our game is designed to allow the user to explore different concepts and actions such as splitting solid fuel into parts to understand fractions. Through this experimental focus, our game is less skilled-based in the beginning and more about understanding concepts. Thus, if the user has limited skills, they can still play the game successfully. As the game progresses, the user gains the skills and knowledge to be able to complete future stages. If the user lacks proficiency in the concepts, then the game can be played purely by understanding the game mechanics explained in the tutorial, and through trial and error. If the user is stuck, Dr. Stevens can offer a hint. Also, gameplay is totally driven by the user; there is no timer, and the user chooses when to add fuel and launch the rocket.

Culturally-relevant Instruction: Explain how you designed the game to appeal to students whose cultures do not fall into dominant American culture. What specific game elements did this affect, and in what way does that follow strategies we learned about culturally-relevant instruction?

We designed our game for students of various backgrounds through the implementation of customization and references. We will allow the user to customize what their character / sprite looks like, who Dr. Stevens is and looks like (by choosing between a few possible options), as well as choose between different settings and locations to begin the game. This allows students of different backgrounds and cultures to immerse themselves in the game and play as/with a character that they can relate more to. Rather than having a default background music, we will allow users to choose between various soundtracks as well, so that music doesn't turn the user away from playing the game. We will also have the game available in multiple languages. Lastly, we will introduce / reference role models of different backgrounds and minority groups throughout the game (i.e. Ellen Ochoa) to represent different cultures.

Badge System: Describe a badge system that could be integrated into your game. Take care to describe three categories of badges:

- Participation badges
- Achievement badges
- Badges that are for behaviors that lead to academic success (in between participation and achievement badges)

This game could include a number of types of badges. There are badges for complete game objectives and playing as the player must in order to continue to progress. Badges of this type could be for completing goals such as:

- Complete Tutorial
- Get the rocket off the ground
- Use solid fuel
    - Split solid fuel 3 different ways
- Use liquid fuel
    - Split fuel 3 different ways
- Try 3 different fuel ratios
- Try 3 different angles
- Get rocket to Moon
- Successfully return rocket

The badge system can also reward exploration and high achievement with a number of different badges, such as:

- Get rocket to certain heights
- Get rocket to certain number of other celestial bodies
- Unlocking certain number of fuel types
- Make certain number of successful missions
    - To another celestial body and back
    - To a certain body (eg: visit Moon certain number of times)
- Clear a level in a certain number of attempts

There can also be badges that reward behaviors that prime the student for academic success. Badges of this type may include:

- Discovering equivalent fractions
- Answering Dr. Stevens questions about how to use the rocket (for later, less supervised stages)
- Asking for hints
- Figuring out a problem independently

These badges can be displayed on their own menu, and be shown or shared with other students in the classroom. In a perfect world, students would be able to remotely share their badges with others, or be able to see others' achievements in order to motivate them to achieve more, like the Open Badge system.

Intelligent Systems: How could an intelligent system be used in your system to adjust game play based on user play? Hypothesize a design that would dynamically provide personalized feedback and choose the next level / task / etc.

An Intelligent System can be used in our system to adjust the game play through the use of hints. If the player is taking a while to understand the controls of the game or is struggling to reach certain milestones for a level, then we can design an ITS that gives hints to either how to progress through the game or suggestions (hot or cold type / add more fuel or less fuel type) for reaching the next milestone. We currently give personalized feedback on whether or not the rocket makes it to the set height or milestone, but the Intelligent System would give a more detailed feedback for improvement rather than “Try again” or “Congratulations”. Data from this system can also be used to reformulate the game’s milestones and to adjust the flow of the game while keeping the student relatively on track with the learning trajectory.

UDL: How would you incorporate universal design for learning to accommodate students with sight impairments, hearing impairments, and/or cognitive impairments?

We took into account users with various disabilities. For ESL users, we will have visual cues throughout the game, basic reading below grade level (not too complicated syntax and diction), a text-to-speech option (on by default), and have the game be available in different common second-languages. For auditory impaired users, we will ensure that sound is not required to advance through the game and that there is always a text option for instructions. For visually impaired students, we will have large text, have meaningful sound that helps to understand / highlight objectives (but isn’t required), highlight visually important aspects in the game, and we will make the game color palette colorblind friendly. Lastly, for members with cognitive impairment, attention deficit, or low motivation, we will include tips and hints, require user input to continue, and remove any time limits so that the game can be played at the user’s own pace. There is also the option to simplify the layout of the game and remove the stats box, should this prove distracting for the player.

Tangibles, Movement, Collaboration: What elements could you introduce that would use tangibles, movement, or collaboration into your system to increase learning? You only need to propose a single unplugged activity to satisfy this portion (and explain the relationship to the game).

This game is based on a tangible activity: alka-seltzer rockets. In this tangible activity, the user puts water and alka-seltzer into a film canister, seals it, and waits for it to explode, sending the canister into the air. The solid fuel in our game is like the tab of alka-seltzer, and the liquid fuel is like the water. In this activity, students can observe the reaction and launch in real time, play with the variables with physical objects, and they get to launch an actual, physical rocket. Doing an activity like this could increase engagement with the game, as it primes the user with the basic game mechanics, and only need to adapt how they put in fuel based on the constraints of the computer.

<u>Assessment / Transfer: Choose three learning objectives from your learning trajectory. For each of those three learning objectives:</u>

- <u>Create one assessment question that would assess student knowledge of that objective.</u>
- <u>Define one "real-world" learning objective that it helps teach.</u>

<u>Then, for one of the learning objectives, define a single "bridge" activity that would help connect the in-game learning objective to the "real-world" learning objective.</u>

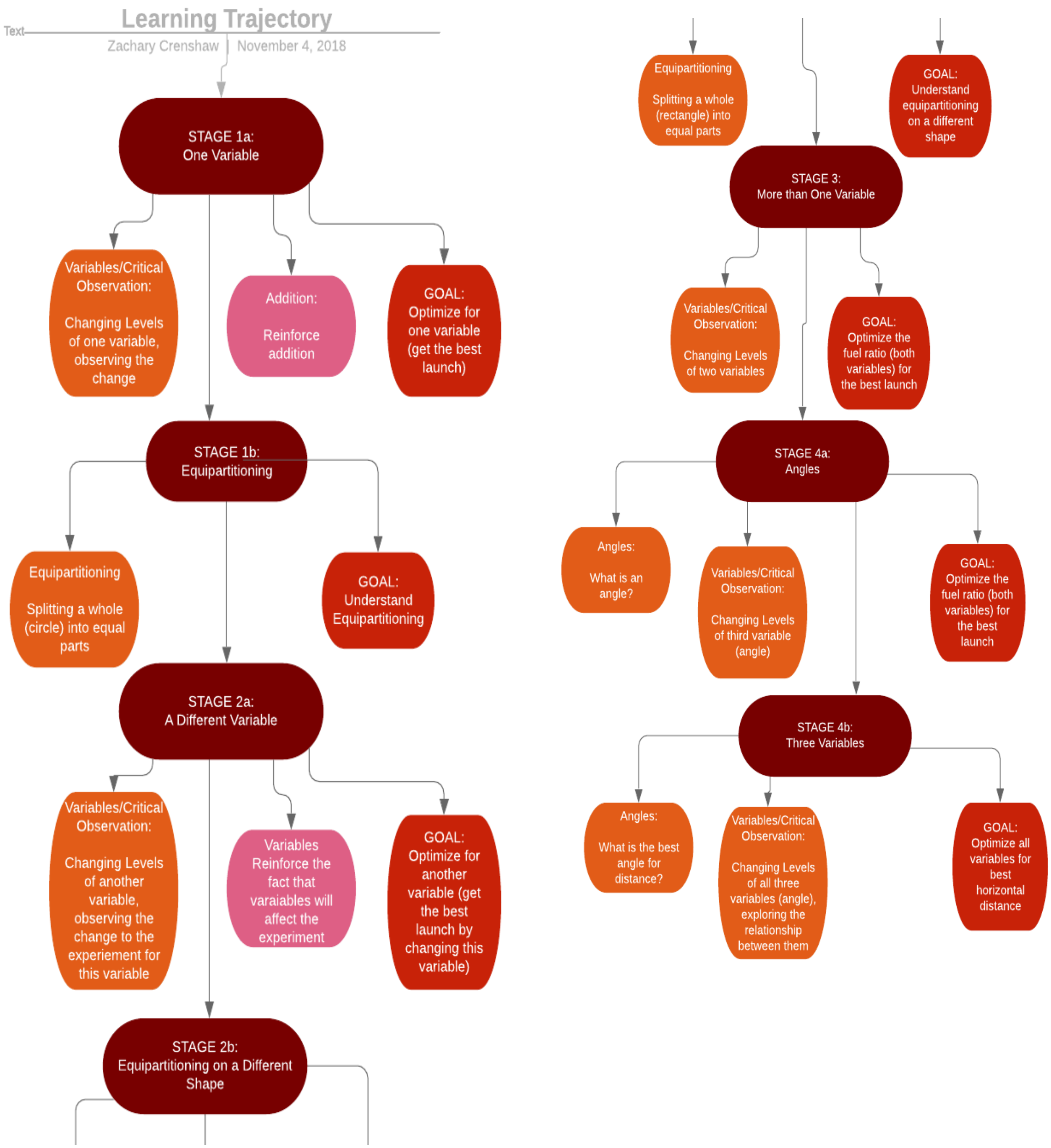
For our first learning objective, equipartitioning of circles, an assessment question could be: what does a circle split in to x number of piece (1-8) look like? Can you draw a picture of a circle split up like that? This reinforces an understanding of what an equipartitioned circle looks like in order to cultivate fraction sense.

For our second learning objective, equipartitioning of rectangles, an assessment question could be: what does a rectangle split into x number of pieces (1-8) look like? Can you draw a picture of a rectangle split up like that? This reinforces an understanding of what

For our third learning objective, controlling ratios of two different fuels (equipartitioned shapes), an assessment question could be: Can you draw me a solid fuel circle split into x number pieces and a liquid fuel rectangle split into y number pieces? Now can you show me how much of each fuel I need to get to the moon? This allows the student to build off of the cognitive tools developed from the first two learning goals in order to understand fractions of different types.

To demonstrate mastery of these skills, students can be asked to make a poster demonstrating their fuel ratio using cut up pieces of paper. Students can put fractions they made on a poster, along with the data from the game demonstrating that their ratio works. For fun, this can be made into a fun, creative, educational art project. Such a project also gives students a chance create and artifact and share their work with peers, just as constructionists would recommend.

Appendix A: More detailed math learning trajectory:



Appendix B: Chemistry learning trajectory