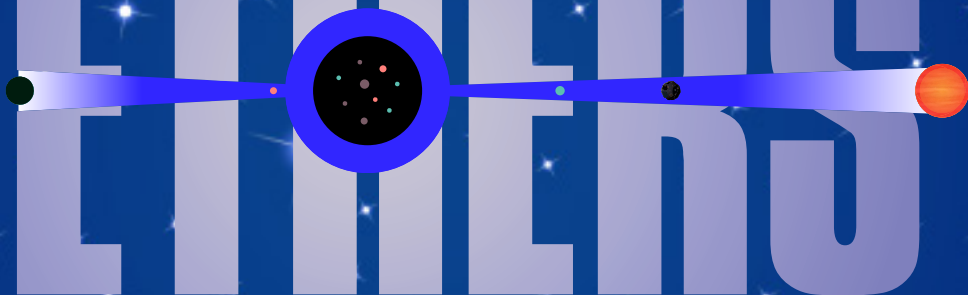


the gravity ether

ETHERS



Educator Resource Packet

A part of **ETHERS** series

Powered by **iridescent** with **INSTITUTE of PLAY**

This game and the resource packet are made freely available to teachers with the generous support from:



Packet Design:
2121.LA

CONTENTS

Introduction

What is the Gravity Ether?	3
How do I use it in the classroom?	3
The Educators Resource Packet	3

Concepts

Force and distance	4
Orbits	5
Mass, inertia and gravitational force	6
Level editors and game simulations	7

Sample Lesson Plans

1. Using games for science literacy	8
time 60 minutes	
directed at literacy skills	
standards: 	
2. Teaching force and distance	13
time 60 minutes	
directed at content	
standards: 	
3. (Mini Unit) Conduct an investigation about mass with the level editor	17
time 4 hours	
directed at content and scientific skills	
standards:  	

Appendices

Engineering design process diagram	32
Linking the games to standards	33

What is the *the gravity ether* ?

The Gravity Ether is a physics simulator, or game, for middle school students to learn about space. Unlike many educational games, the Gravity Ether is designed through use of implicit learning theory. This means that students must learn the underlying physics concepts present in the game to progress through the levels.

DOWNLOAD THE GAME



learn more about learning in the game



The game has 3 unique features

Game Content

Students have to learn about gravity to play the game better.

Gravity is taught implicitly through play, to be coupled with explicit instruction.

Freeform exploration is broken up by directed challenge levels that test knowledge through puzzle-like tasks.

watch a tutorial



PLAY

Level Editor

Kids can make their own levels in the game. Student created levels are great for project based learning.

This can be used to demonstrate the engineering design process.

watch an example



CREATE

In-game Assessment

The game collects data about student performance as they play.

That data is made freely available to teachers through a web interface: ethersoftheworld.net/teacher/login.php.

Teachers can follow student progress in gameplay and level design.

LOG IN

How do I use it in the classroom?

- To extend student learning in areas of force, orbits, inertia and mass
- Give students the opportunity to virtually manipulate gravitational forces and watch how mass interacts in space (this environment is difficult to set up in a lab!)
- Have students play at home as an introduction/hook to topics in astronomy and physics
- Allow students to use the level editor to create inquiry-driven explorations about space
- Subsidize learning from informational texts about space

The Educators Resource Packet

This packet will provide examples for how educators can use the Gravity Ether to teach different skills and concepts. Sample lesson plans are given as a starting point for teachers to make their own lessons.

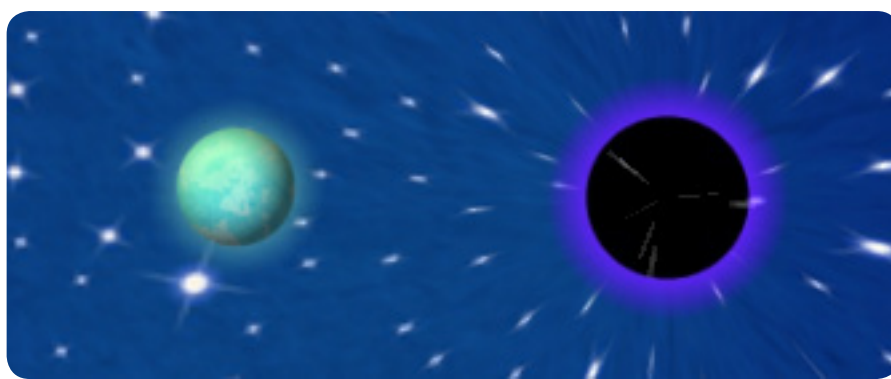
CONCEPTS

Force and Distance

The first part of the game addresses the relationship between force and distance; in particular through the Universal Law of Gravitation:

$$F_g = G \frac{m_1 m_2}{R^2}$$

Gravity Ether gameplay reinforces the idea that distance (r) gets bigger force will get smaller. By playing through the first few levels of the game, students will see that planets move fastest (experience the most force) when they are very close to a blackhole.



screenshot from the game: planet and blackhole

Implicit Learning in Action: The first challenge level tests a student's understanding of force and distance by asking him or her to accelerate 3 planets to a high speed. The student must add a black hole some distance from the planets and then remove the black hole when the planet gets close, at its maximum velocity. This implicitly requires an understanding that high forces are created at close distances to planets, and that high forces lead to high velocities.

Sample Questions the Game Can Teach and Reinforce:

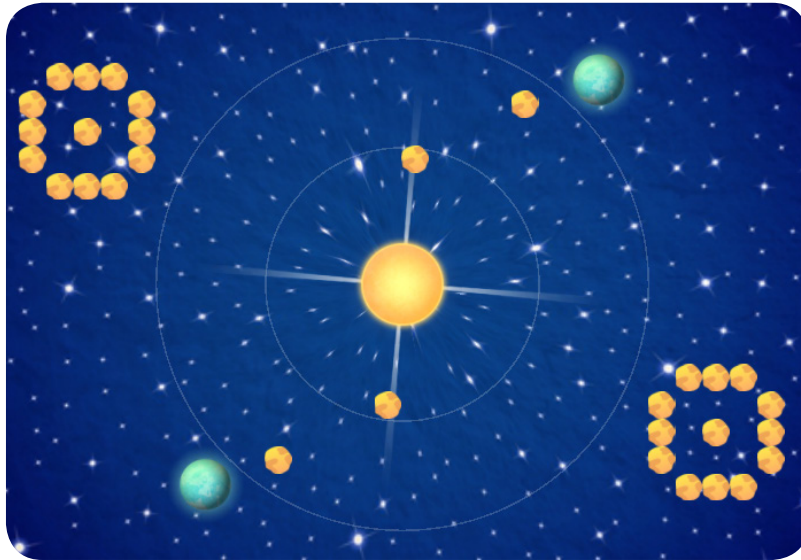
- If there is a black hole to the right of a planet, where does the planet go?
- How can you make a planet move a certain distance and then stop moving?
- How would you move a planet towards a corner and keep it there?
- How does the distance of a black hole to a planet affect the force on a planet?
- How does the distance from the blackhole impact the speed of the planet's motion?
- Can you design a plan to move the planet from the bottom right hand side of the screen to the upper left hand side?

More information about which force and distance standards are addressed by the Gravity Ether can be found in [Appendix 2](#).

CONCEPTS

Orbits

The second set of three levels involve orbits. Students will learn how the distance and speed of a planet from a sun impacts a planet's ability to orbit around the sun.



screenshot from the game: planets in orbit

Implicit Learning in Action: In levels 4 - 6 and the Orbit Challenge, students will learn how a planet can orbit a sun or a black hole and how the distance and speed of the planet impacts this orbital motion.

Sample Questions the Game Can Teach and Reinforce:

- What type of motion does an orbiting planet exhibit?
- What happens to an orbiting planet if the blackhole is removed?
- How can you get an orbiting planet to stop orbiting?
- How do you get a planet to orbit around a sun?
- Describe your plan to get a stationary planet to begin orbiting around a sun.

More details in regards to specific orbits standards are addressed by the Gravity Ether can be found in [Appendix 2](#).

CONCEPTS

Mass, Inertia and Gravitational Force

The third set of levels addresses mass. Planets differ in size and density, which will in turn affect their total mass. These levels are designed to specifically call their attention to three features impacted by planet mass.

- 1 More massive planets have more inertia. This makes it easier for more massive planets to break obstacles in the level, and to slow down less when they do so (since they have more total momentum).
- 2 The likelihood of a planet breaking is related to (inversely proportional to) its mass. Therefore, in a collision between a more massive and less massive planet, the less massive planet is more likely to break.
- 3 A planet's acceleration depends on it's own mass and the mass of the object pulling it. This means that if you put a light and heavy object nearby each other, both feel the same force but the lighter object will accelerate faster. This also means that if you put a light and heavy object nearby a black hole, both will feel different forces, but accelerate towards the black hole at the same rate. This is a relatively advanced concept, but is illustrated in the third challenge level.



screenshot from the game: variety of planets.

Implicit Learning in Action: By playing levels 7 through 9 and the Mass Challenge, students will gain a better understanding of the relationships between mass, inertia, and gravitational force.

Sample Questions the Game Can Teach and Reinforce:

- What happens when two planets with the same density collide at the same speed?
- What happens when a dense planet collides with a less dense planet?
- Can you compare the difference in motion between a light planet and a heavy planet?
- How would a heavy and light planet move if they were placed some distance apart from each other?
- How does the density of a planet affect it's movement?
- What would happen if a heavy and light planet were placed some distance apart with a blackhole between them?
- How can you distinguish between a light planet and a heavy planet?
- Create an investigation (using the games level editor) to sort the planet's by mass, from the most massive to least massive.

More information in regards to what specific mass and inertia standards the Gravity Ether addresses are listed in [Appendix 2](#).

CONCEPTS

Level Editor and Game Simulations

Gravity Ether's level editor allows students to practice creating a level that has certain goals and constraints within this simulation of space. When the student is using the level editor, the student is directly practicing skills in the engineering design process ([Appendix 1](#)). Student can then use the game as a simulation space to conduct experiments and practice science inquiry.



screenshot from the game: the Create button, gives the students the opportunity to apply what they learned.

Sample Questions the Game Can Teach and Reinforce:

- What was your thought process when you were developing this level?
- How does the game relate to the motion of real objects in space, like planets or satellites?
- What are the specific challenges in the level you designed? Are they in varying difficulties?
- Can you design a challenging but not too challenging level for other students to play, using playtesting feedback from other students as data to inform your design?
- What are some concepts you applied in your designed level that you brought from previous levels you played?
- Can you develop and use a model in the level editor to mimic the earth and moon (or some other planets in our solar system)?

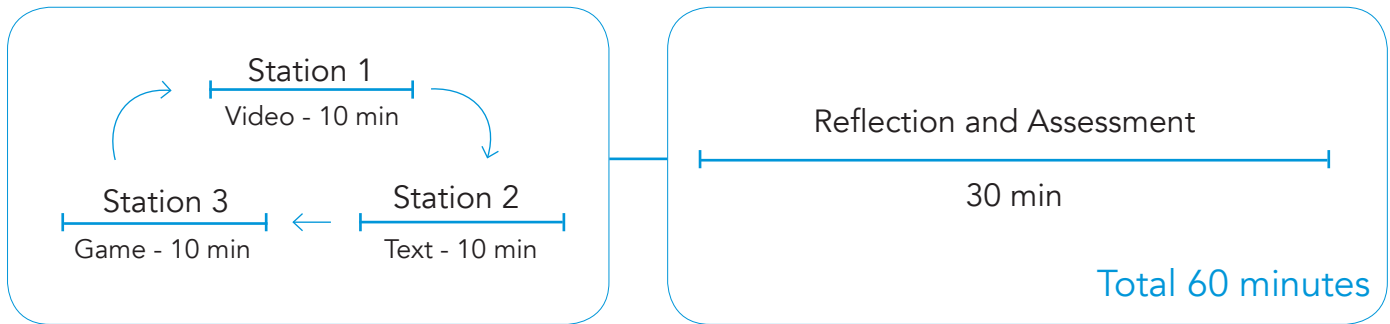
The level editor of Gravity Ether provides a unique platform for teachers to address the Next Generation Engineering Design and Common Core standards. More about how the Gravity Ether aligns to specific standards is provided in [Appendix 2](#).

LESSON 1

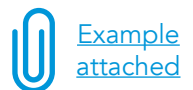
Using Games for Science Literacy

Standards addressed: Common Core Literacy in Science Lesson for 6-8th grades.

Goal of this lesson: This lesson uses the Ether game as a simulation that subsidizes student learning from scientific texts. It is a station-based lesson that asks students to analyze information from multiple sources and synthesize this information into a system showing interactions between benefit/problem relationships present in space exploration.

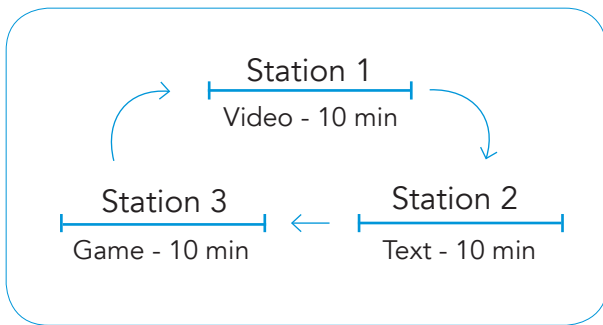


Lesson Plan	Compare and contrast the learning scientists have been able to achieve from using space probes with the problems they may encounter exploring space.
Standard	CSS: RST 68.7: Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.
Learning Target	Students will compare and contrast the learning scientists have been able to achieve from using space probes with the problems they may encounter exploring space by reading the CCSS exemplar text "Space Probe," playing the Gravity Ethers game, and viewing the video "Wringing out Water on the ISS" and citing each of these sources in a flow chart.
Assesment	Students will create a flowchart that addresses these points: - 4 examples of the learning accomplished by scientists in space - 4 problems encountered by scientists exploring space - 4 relationships between phenomena (could be relationships between problems, learning connected to problems) - Each piece of evidence cited by source (text, video, game or combinations)



LESSON 1

Lesson Structure



Students will be at each station for 10 minutes. Prompt students to take notes about the information they are learning at stations with instructions to focus specifically on the learning and problems scientists encounter while exploring space.

Station 1

Video “Wringing out Water on the ISS” 10 minutes

link: <http://www.youtube.com/watch?v=o8TssbmY-GM>

Possible guiding questions for students to consider while watching video:

- How does running this experiment in space differ from how we would do it on earth?
- Besides the water acting strangely, what else do you observe being different about the space environment?

Station 2

“Space Probe” Text 10 minutes

Students will read and take notes on “Space Probe” text. Teacher may ask students to incorporate different strategies for enabling comprehension, such as Talking to the Text, KWL chart, etc.

Station 3

Gameplay *the gravity ether* 10 minutes

Download at <http://iridescentlearning.org/programs/the-gravity-ether/>

Students will play the Gravity Ether for 7 minutes, taking notes on learning for 3 minutes.

Questions to ask students in regards to game play: What did you like about the game?

- What was the most challenging?
- What strategies did you use?
- What did you learn about gravity, density, the properties of planets?

Teacher may want to brainstorm guiding ideas to frame learning, such as:

- Note how the density of planets impacts their movements
- Observe how the lack of gravity in space affects different objects
- Note problems a space probe may encounter as it tries to move through space

LESSON 1

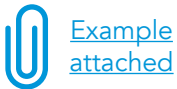
Lesson Structure (cont.)

Reflection + Assessment 30 minutes

Create Learning vs. Problems In Space Flowchart

Students will work independently or in groups to create a flowchart with 8 examples of the learning accomplished and problems encountered by scientists exploring space, noting the relationships between phenomena and citing which source (text, video, game or combinations) they have acquired this information from.

Note: Teacher will need to walk through process of creating flowcharts and delineating relationships if students are unfamiliar with task.



LESSON 1

Common Core Exemplar Text

"Space Probe"

A space probe is an unpiloted spacecraft that leaves Earth's orbit to explore the Moon, planets, asteroids, comets, or other objects in outer space as directed by onboard computers and/or instructions sent from Earth. The purpose of such missions is to make scientific observations, such as taking pictures, measuring atmospheric conditions, and collecting soil samples, and to bring or report the data back to Earth.

Numerous space probes have been launched since the former Soviet Union first fired Luna 1 toward the Moon in 1959. Probes have now visited each of the eight planets in the solar system. In fact, two probes—Voyager 1 and Voyager 2—are approaching the edge of the solar system, for their eventual trip into the interstellar medium. By January 2008 Voyager 1 was about 9.4 billion miles (15.2 billion kilometers) from the Sun and in May 2008 it entered the heliosheath (the boundary where the solar wind is thought to end), which is the area that roughly divides the solar system from interstellar space.

Voyager 2 is not quite as far as its sister probe. Voyager 1 is expected to be the first human space probe to leave the solar system. Both Voyager probes are still transmitting signals back to Earth. They are expected to help gather further information as to the true boundary of the solar system.

The earliest probes traveled to the closest extraterrestrial target, the Moon. The former Soviet Union launched a series of Luna probes that provided humans with first pictures of the far side of the Moon. In 1966, Luna 9 made the first successful landing on the Moon and sent back television footage from the Moon's surface. The National Aeronautics and Space Administration (NASA) initially made several unsuccessful attempts to send a probe to the Moon. Not until 1964 did a Ranger probe reach its mark and send back thousands of pictures. Then, a few months after Luna 9, NASA landed Surveyor on the Moon.

In the meantime, NASA was moving ahead with the first series of planetary probes, called Mariner. Mariner 2 first reached the planet Venus in 1962. Later Mariner spacecrafts flew by Mars in 1964 and 1969, providing detailed images of that planet. In 1971, Mariner 9 became the first spacecraft to orbit Mars. During its year in orbit, Mariner 9's two television cameras transmitted footage of an intense Martian dust storm, as well as images of 90 percent of the planet's surface and the two Martian natural satellites (moons).

Encounters were also made with Mars in 1976 by the U.S. probes Viking 1 and Viking 2. Each Viking spacecraft consisted of both an orbiter and a lander. Viking 1 made the first successful soft landing on Mars on July 20, 1976. Soon after, Viking 2 landed on the opposite side of the planet. The Viking orbiters made reports on the Martian weather and photographed almost the entire surface of the planet.

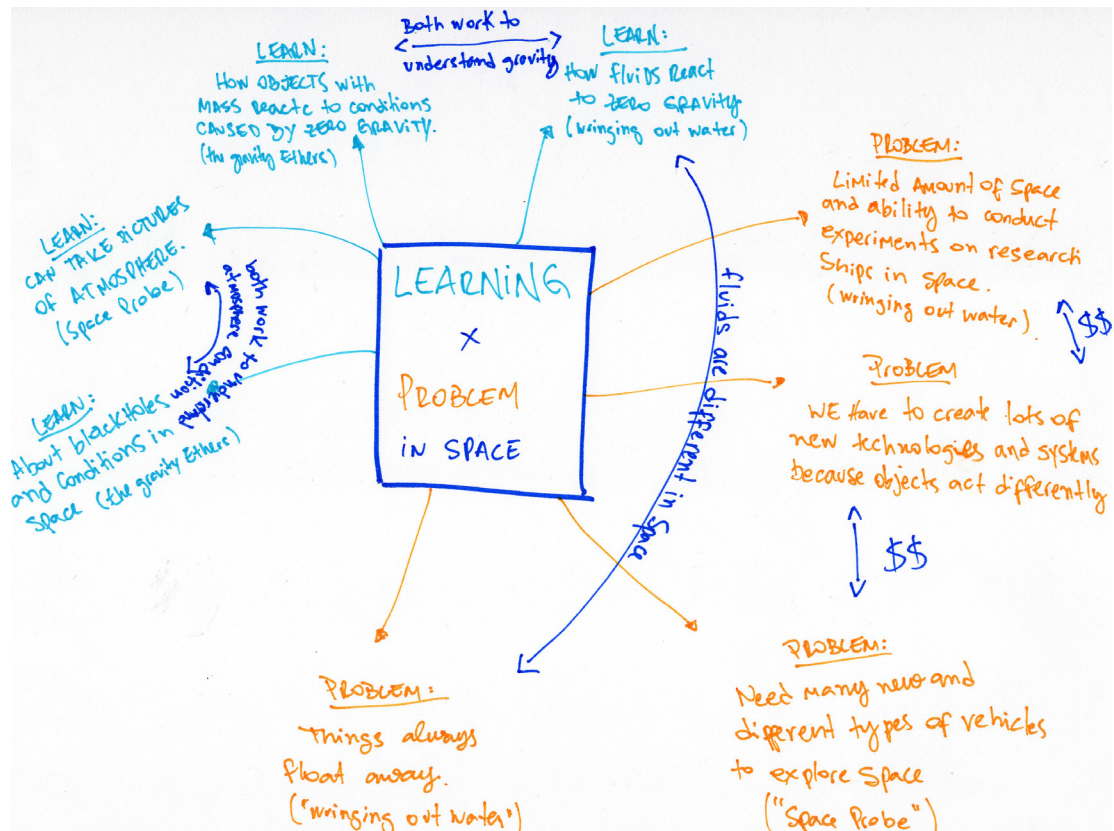
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Astronomy & Space: From the Big Bang to the Big Crunch. Edited by Phillis Engelbert. Farmington Hills, Mich.: Gale Cengage Learning, 2009.

LESSON 1

Learning vs. Problem In Space Flow Chart Rubric

POINTS	0	2	4	6
Examples of Learning	1 example of the learning accomplished by scientists in space	2 examples of the learning accomplished by scientists in space	3 examples of the learning accomplished by scientists in space	4 examples of the learning accomplished by scientists in space
Problems Encountered in Space	1 problem encountered by scientists exploring space	2 problems encountered by scientists exploring space	3 problems encountered by scientists exploring space	4 problems encountered by scientists exploring space
Source	Source (video, text, game) cited for a few pieces of evidence	Source (video, text, game) cited for a few pieces of evidence	Source (video, text, game) cited for most pieces of evidence	Source (video, text, game) cited for every piece of evidence
Relationships Between Evidence	1 relationship between pieces of evidence is noted	2 relationships between pieces of evidence are noted	3 relationships between pieces of evidence are noted	4 relationships between pieces of evidence are noted

Exemplar Flow Chart:



LESSON 2

Teaching Force and Distance

Standards addressed: Next Generation Science Standards: Physical Science Standard for Middle School.

Goal of this lesson: This lesson plan teaches force and distance through the workshop model. The lesson includes time for gameplay, class discussion of points related to Newton's First Law and assessment via differentiated exit tickets.



Lesson Plan	Using Gravity Ethers simulator to understand force and distance in relation to Newton's First Law
Standard	NGSS: MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
Learning Target	Students will answer questions independently about motion and forces.
Assessment	Exit ticket: focuses on how objects react when forces are applied, specifically in relation to blackholes.



LESSON 2

Lesson Structure

Warm Up 7 minutes



Ask students to pick three questions to answer independently from questions below:

What is a force?

How can you demonstrate force?

What will happen to an object when you pull it?

Where do you see different types of motion?

What is a "blackhole"?

What happens to planets and other space objects when it's near a blackhole?

Demonstration + Discussion 8 minutes



Ask varying students to demonstrate different types of forces and motions: lift (vertical movement) or sliding (horizontal movement)

After the demonstration, coordinate a class discussion with the students. This would ideally be a "Think, Pair, Share" or some other studentled conversation. Alternatively, this can be a teacherled discussion.

Discussion Points

- An object will stay at rest unless a force is applied.
- We will play a game called the Gravity Ether, where the blackhole produces force. Blackholes act as a force to pull an objects, like planets, towards them.
- Today, we are going to play a game and see what impact the force of a blackhole can have on space objects. Remember to think about the size of the object as well as the distance to/from the blackhole.
- Notice the direction and magnitude of how space objects move as you play this game and explore how blackholes work.

Game Play 30 minutes



Introduce the game as a simulation of space and gravity forces. Remind students to observe what happens in the game as they play, and be ready to share their observations. Then let them engage in free play, individually or in groups depending on the technology availability in your classroom. Playing in pairs is often ideal, as it encourages discussions during gameplay.

After 10 minutes of gameplay, break for a short reflection activity.

Mid Gameplay Reflection Activity (5 min).

Ask students to close laptops or turn off ipads for 5 minutes, and lead them in a reflection activity. The goal is for students to share their ingame observations with other students This can be done

LESSON 2

Lesson Structure (Cont.)

with any number of reflection activities, we would encourage them to be as student-led as possible. Possibilities include a Think, Pair, Share or generating a list of Game Strategies to compare with other students, or simply a teacher-led discussion. We give an example of potential Think Pair Share questions below.

Think Pair Share after 10 minutes of game playing

These questions focus on concepts addressed by Newton's first law:

- How can you make the object move in the direction you want?
- How can you make the space object move really fast?

Reflection and Assessment 15 minutes



Class Discussion (10 minutes) Recap of gameplay.

Students can return to another Think, Pair, Share, or this can be a teacher-led discussion. Some sample points to reinforce:

- In space there are many blackholes. Space objects such as planets and asteroids can get pulled into the black hole.
- As objects get closer to blackholes, the force applied by the blackhole gets stronger. This will cause the object to move faster into the blackhole.
- When a space object is very far from the blackhole, it won't experience much force and therefore it won't move as much.

Exit Ticket (5 minutes) See next page for exit ticket attached.



LESSON 2

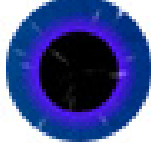
Exit Ticket A

Draw an arrow indicating how the planet will move:

1)

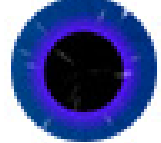
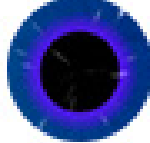


Planet



Black Hole

2)



Answer the following questions with complete sentences:

3) If a planet is located at equidistance from two blackholes, how will it react?

Exit Ticket B

Using arrows to indicate the movement of planets, draw a scene containing two blackholes and three planets. Each planet should have an arrow showing how the planet would move:

Answer the following questions with complete sentences:

2) How does distance from a force impact the movement of an object?

3) If an object is travelling through space at 65 mph and no outside forces act upon it, how will it react?

Mini Unit

Investigation About Mass with Level Editor

Standards addressed:

- **RST.9-10.7:** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
- **MS-ESS1-3:** Analyze and interpret data to determine scale properties of objects in the solar system.
- **Practice 3:** Planning and Carrying out Investigation
- **Practice 4:** Analyzing and Interpreting Data
- **Practice 8:** Obtaining, Evaluating and Communicating Information

Goals of Mini Unit:

Students will write a short reflection essay that analyzes the results of their investigation. It will ask students to evaluate and sort the planets from greatest mass to lowest mass including:

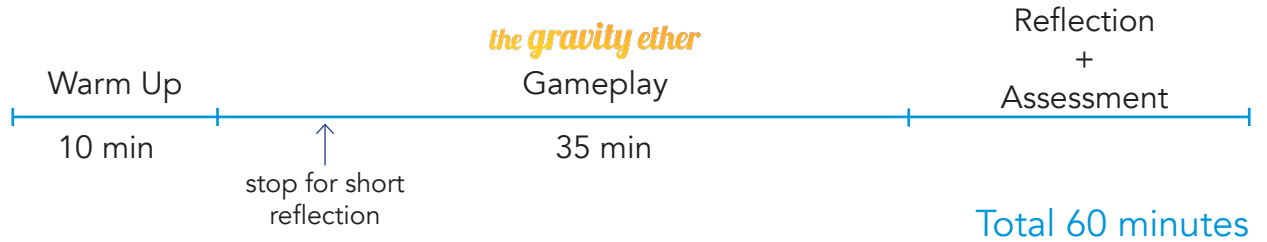
- A description and justification of the method by which they sorted the planets and came to their results;
- A synthesis of how data about planets was collected and analyzed;
- A justification of the validity of their results (how do they know their sorting is correct);
- An analysis of how their investigation results can be applied to determining mass in the solar system.

MINI UNIT

Investigation About Mass with the Level Editor

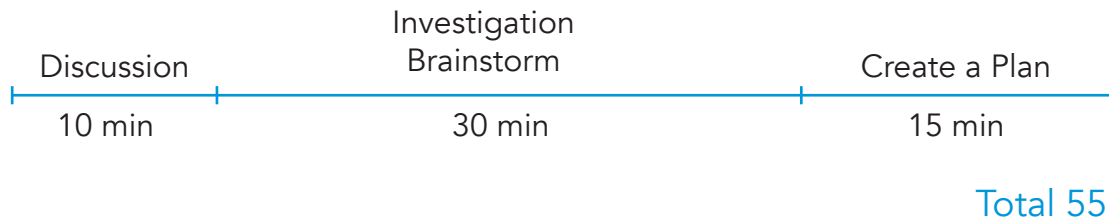
Day
1

Experience the game and think about the role of mass in the gameplay.



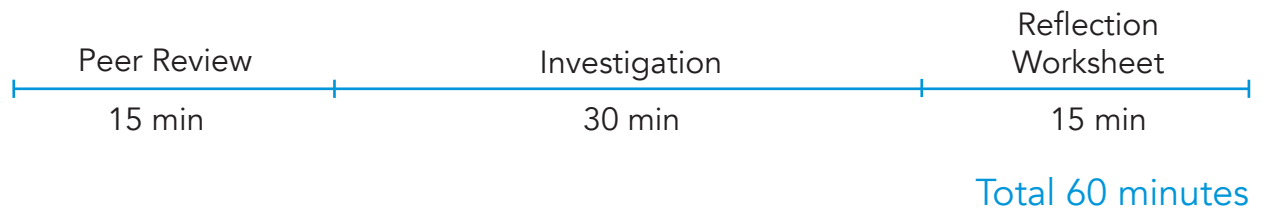
Day
2

Create an investigation plan to measure mass of planets using the Level Editor.



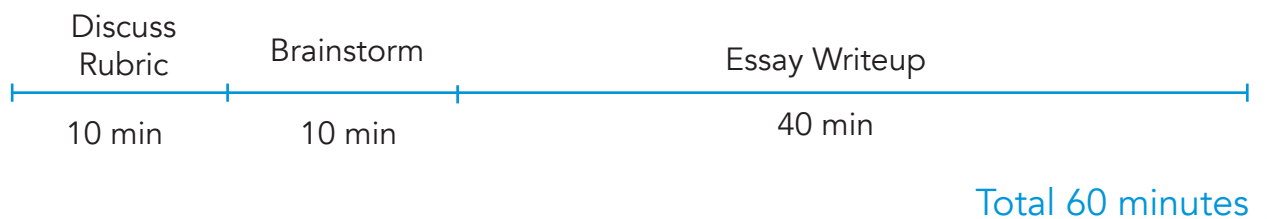
Day
3

Get peer-feedback on their investigation plan, and carry out their investigation.



Day
4

Finish their investigation and present their results in a written essay/report.



Experience the Game and Think About the Role of Mass



Lesson Plan

Play and make observations about the role of planet properties in the game.

Standards

NGSS:

MS-ESS1-3: Analyze and interpret data to determine scale properties of objects in the solar system.

CCS:

RST.9-10.7: "Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically into words."

Learning Target

Students will be able to describe the different properties of planets in the solar system. Students will understand how some of those properties (size, mass) affect planets' response to gravitational forces in the context of the game.

Assessment

Students will complete a short exit ticket that records their observations about the role of mass in the Gravity Ether game.



Warm Up 10 minutes



Have students brainstorm all of the different properties that planets can have. What makes planets similar or different? Ask students to come up with as many as they can in pairs, and ask each group to be ready to share one property. Try to get each group to give a different property. Ask students if any of these properties are related (e.g. if a planet is gaseous or solid, it will have different amounts of mass).

Describe the game that students are about to play. Points to emphasize:

- The Gravity Ether is a game that simulates conditions in outer space.
- In the game, you can move the planets by creating blackholes, which make gravitational fields and pull planets towards them. Blackholes exist and function similarly in space.
- Pay attention to how many different kinds of planets there are, and how those planets are different from each other. Just like the planets in space, each is unique and has different properties. Pay attention to how different types of planets act differently in the simulation.
- What strategies do you use to play the game better?

Gameplay 35 minutes



Free Game Play - Students play through the levels in the Gravity Ether at their own pace, either individually or in pairs (depending on technology availability).

Short Reflection (10 min) - After 15 minutes or so of free play, prompt students to stop playing the game. In pairs, ask students to describe 2-3 of the strategies they used to play the game better. Then ask students to share their strategies with the class, while you write them on the board. Example strategies can be items such as:

- Get rid of a blackhole when a planet is really close to it, to make the planet move fast.
- It's easier to break blocks with big planets.

After you have a list on the board, ask students if any of the strategies depend on taking into account the properties of planets. Are any strategies only effective for big planets, or high density planets? Highlight those strategies. Then prompt students to continue playing the game, but to think about and try out some of the strategies from their peers as they keep playing.

Reflection and Assessment 15 minutes



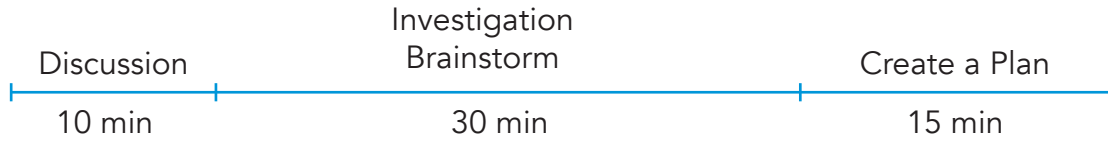
After more gameplay, ask the students, did you find any additional game strategies that worked well? Did any of the strategies on the board not work well? Come back to the initial list generated at the beginning of class. Of the properties of real planets, which ones were a part of the planets in the game? Density, mass, size are all valid answers. Did any of those properties of planets play a part in game strategies?

Exit Ticket

1. Write down a game strategy you found most effective in the game.

2. Write down a property of planets that affected the game strategy you wrote above. How did that property affect your game strategy?

Investigation plan to measure mass of planets - Level Editor



Total 55 minutes

Lesson Plan

Create an investigation plan that will help you analyze the relative mass of planets.

Standards

NGSS:

MS-ESS1-3: Analyze and interpret data to determine scale properties of objects in the solar system.

Practice 3: Planning and carrying out Investigations

Practice 4: Analyzing and interpreting data

CCS:

RST.9-10.7: "Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically into words."

Learning Target

Students will create an Investigation that will help them to analyze the relative mass of planets.

Note: students will have to sort every planet in the game by mass.

Assessment

Student groups will hand in an investigation plan about how they will use the Gravity Ether to determine the relative mass of all the planets in the game.



Discussion 10 minutes

Use a class discussion technique that you are comfortable with.

Recap the strategies from the previous class.

Review Mass:

- Do bigger or smaller planets have more mass?
- Do denser or lighter planets have more mass?
- What if we have a big, light planet, and a small, dense planet, which has more mass?

Investigation Brainstorm 30 minutes

Option 1 Introduce the game's level editor as an exploration and investigation tool. Then, task students with creating an investigation plan that can sort the planets by mass. You can scaffold this activity in many ways, depending on the student's comfort level with inquiry activities. It is important to give students time to create their own mini investigation plans on the level editor, let them explore and learn to manipulate the platform, as well as test out ideas as they go.

If your students are comfortable and familiar with inquiry activities, you can leave them to explore in groups and facilitate as needed, with some general prompts, like:

- Did any of the game strategies from Day 1 relate to mass? Can you use them here?
- How can you measure the mass of a planet?
- How can you figure out if one kind of planet is more massive than another?

If your students are less comfortable or experienced with such open-ended structure, you can make this section a little more guided. You can work through one example of how to measure mass with the class together for the first 10 minutes, and then leave the next 20 minutes for your students to generate a similar method.

Option 2 *Ethers Level Editor Demo* - Together, create a mini investigation in the editor.

- Possible mini-investigation: add some blocks in the middle of the screen, and add a planet on the left side of the screen and a sun on the right. Start the simulation see how many blocks the planet breaks.
- Now go back to editing mode and replace the planet with a new one. Run the simulation again and count a different number of blocks that break.

Note: these examples are intentionally built to not work well. Then, if students want to use the idea they will have to redesign and refine it. You can prompt students to explore further by asking:

- What was not very good about this investigation?
- How could you design a better investigation?

Create a Plan 15 minutes



Create a Draft of an Investigation Plan

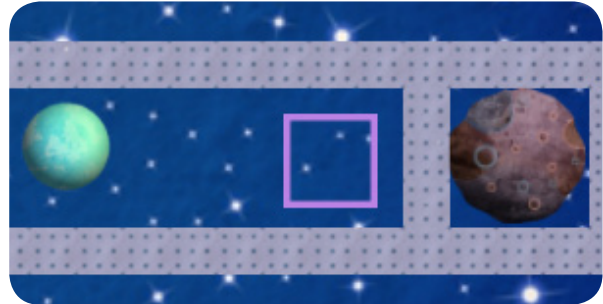
See "Investigation Plan" worksheet below

Challenge groups to create an investigation plan that seeks to determine the relative mass of all the planets in the game (i.e. they need to sort every planet in the game by mass). This investigation plan will push students to formalize the ideas they have been generating up to this point.

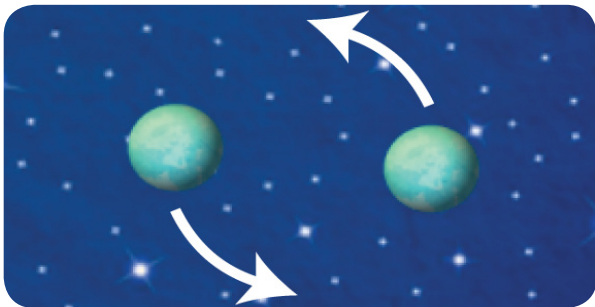
Investigation plans will probably fall into one of these four main categories. It's less important that a student ends up with a certain type of investigation, and more important that they understand the strengths and weaknesses of the investigation that they have chosen.



Block breaking: how many blocks can a planet break after reaching a certain speed?



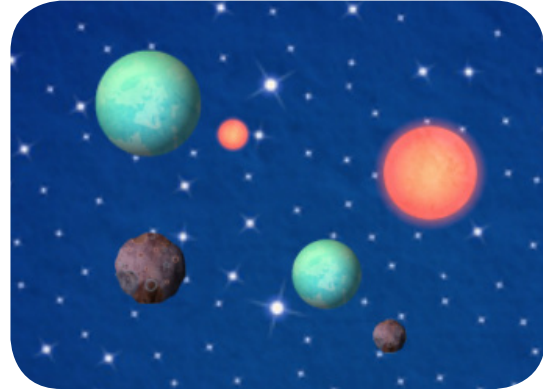
Time to accelerate: Students can mimic the "Mass" challenge level, and time how long it takes different planets to accelerate forward. Having stopwatches handy can be good for this.



Orbit test: Shoot two planets past each other so that they form a binary orbit. Record which planet has the bigger orbit.

Breakage test: Break two planets into each other, and see which one (if any) breaks. This is probably the most reliable measurement of mass, but the data will be the most difficult to interpret.

Group Members:



1) How will you measure the mass of different planets? Describe the steps you will take on the level editor to collect your data:

Step 1: _____

Step 2: _____

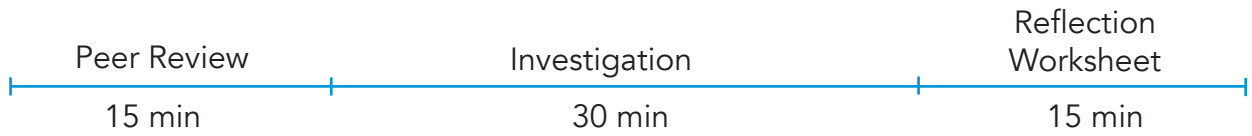
Step 3: _____

Step 4: _____

2) How do you know that your system for measuring the mass of each planet is correct?

3) What problems do you foresee with your planet categorization system?

Peer Feedback on Investigation Plan + Carry Out Investigation



Total 60 minutes

Lesson Plan

Carry out an investigation on the level editor and reflect on results.

Standards

NGSS:

MS-ESS1-3. Analyze and interpret data to determine scale properties of objects in the solar system

Practice 4: Analyzing and Interpreting Data

Practice 8: Obtaining, Evaluating, and Communicating Information

Common Core:

RST.9-10.7: Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

Learning Target

Students will work in groups to test the investigation they created to categorize planets by mass and independently write and reflect on their investigation by completing the "Investigation Worksheet Part Two" on their own.

Assessment

Investigation Worksheet Part 2

Students will reflect on how they investigated planet mass with the level editor.



Peer Review 15 minutes



Have Students Talk about their Investigations Via the "Speed Dating" Strategy

Give students two minutes to describe their investigations to peers. Teacher may consider guiding questions for students to discuss, including:

- How will you use the editor to investigate planet mass?
- What steps will you take to investigate planet mass?

Other options for sharing their investigations could include: presenting to small groups or assigning this task as homework to "share" with their parents. Alternatively, all of the students' plans can be written on a board, and whole class can compare and contrast different investigation plans, deciding which one is best.

Investigation 30 minutes

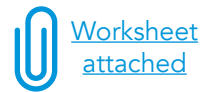


Have the groups carry out their investigation plans, each student can follow the plan and run the investigation on their own level editor.

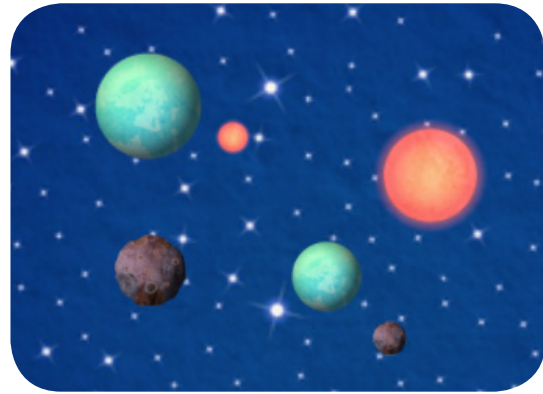
Reflection Worksheet 15 minutes



Students reflect on how they investigated planet mass via the level editor. If possible, students can also take screenshots of the way they tested their planets in the editor and submit those pictures as part of their final short essay.



Group Members:



1) How did you measure the mass of different planets?

2) Draw out the investigation your group created on the simulator here:

3) What did you learn about planet mass from your investigation on the level simulator?

4) Draw out the planets from least to most mass here, include labels:

Finish Investigation + Present Results in a Written Essay



Total 60 minutes

Lesson Plan

Reflect on results of level simulator investigation by completing reflection essay/lab report.

Standards

NGSS:

MS-ESS1-3: Analyze and interpret data to determine scale properties of objects in the solar system

Practice 4: Analyzing and Interpreting Data

Practice 8: Obtaining, Evaluating, and Communicating Information

Common Core:

RST.9-10.7: Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

Learning Target

Students will independently write a short reflection essay/report that interprets and justifies the results of their planet mass investigations.

Assessment

Reflection essay including information about sorting the planets from the greatest mass to lowest mass including:

- A description of the method by which they achieved these results.
- A synthesis of how data was collected and analyzed.
- A justification of the validity of their results (how do they know it's correct).
- Complete categorization of each planet in the game by mass.
- An analysis of how these results can be applied to determining mass in the solar system.



Discuss 10 minutes



Discuss Planet Categorization Short Essay Rubric

Go over each requirement on the rubric and answer questions.

Brainstorm 10 minutes



Groups Work together to Brainstorm Ideas

Allow students to talk with their investigation groups about their results, data collection methods, and justification of results.

Essay Writeup 40 minutes



- A description of the method by which they achieved these results.
- A synthesis of how data was collected and analyzed.
- Results of investigation (all planets are categorized from least to most massive).
- A justification of the validity of their results (how do they know it's correct).
- An analysis of how these results can be applied to determining mass in the solar system.

Suggested Follow Up

Students will independently write a short essay, using the learning they did in their groups to talk about the investigation they planned to sort the planets from the greatest mass to lowest mass including:

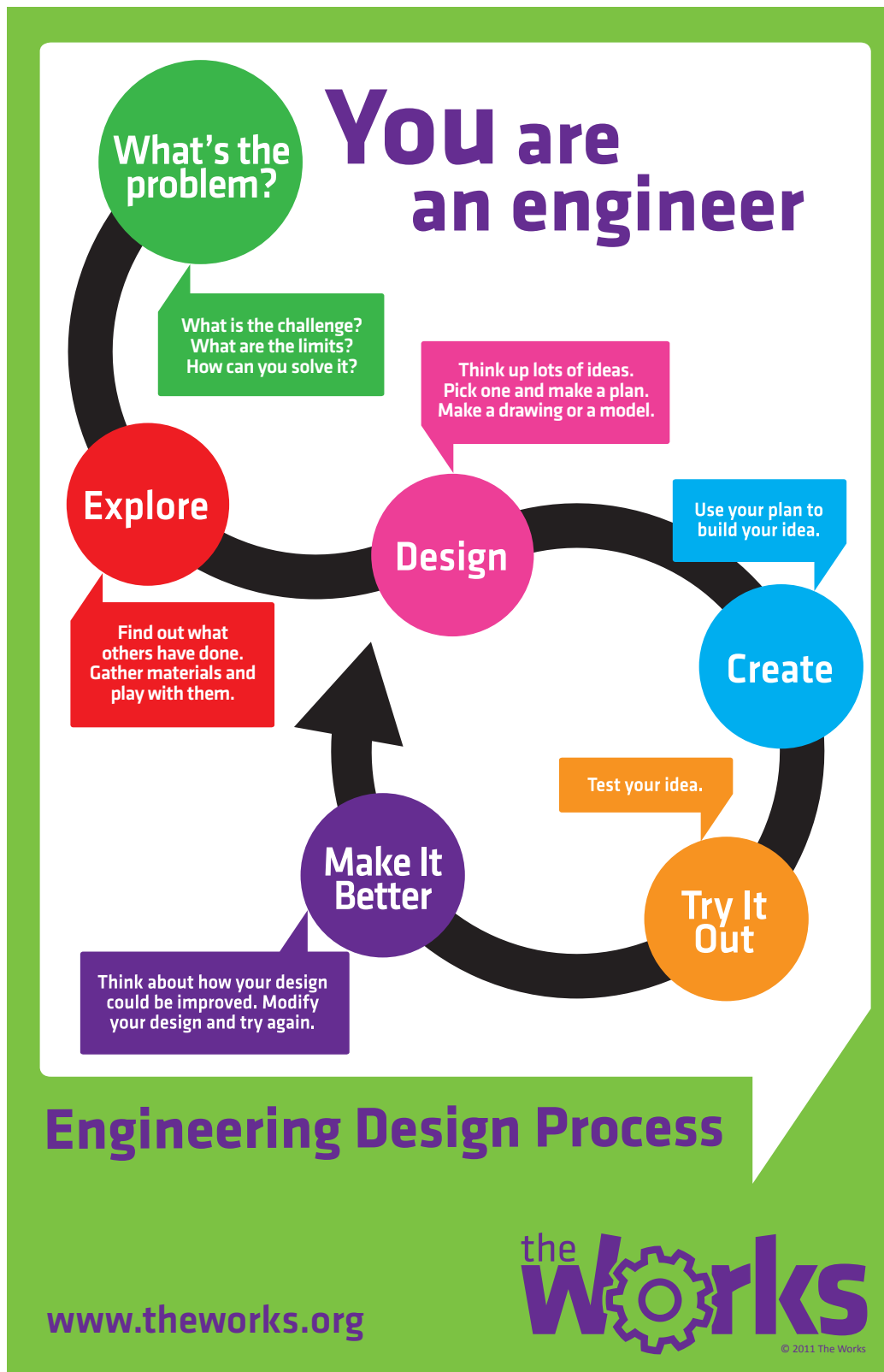
- Allow students to provide feedback to each other's essays
- Have students create a puzzle level in the game, which has a solution that depends on using planets of different mass
- Discuss with students how will they redesign their Gravity Ether investigation plan knowing what they have learned through the essay and provide them time to redesign
- Discuss with the students how they can use the investigation from Day 3 to design a challenging level on the Gravity Ether.

Planet Categorization Short Essay Rubric

POINTS	0	2	4	6
Description of Investigation	No description of investigation group carried out on simulator	Description of investigation carried out on simulator unclear	Description of investigation carried out on simulator well thought out	Detailed description of investigation carried out on simulator
Description of Data Collection	No description of how data was collected from simulator	Mention of data collection, little effort to describe system	Mention of data collection, system unclear	Detailed description of how data was collected from simulator
Categorization of Planets	No planets are categorized from least to most massive	Some planets are categorized from least to most massive	Most planets are categorized from least to most massive	All planets are categorized from least to most massive
Justification of Results	No justification of your results	Incomplete justification of results	Some justification of results	Complete justification of results
Analysis of How Results Relate to Mass	No analysis of how these results can be applied to determining mass in the solar system	Very little analysis of how these results can be applied to determining mass in the solar system	Some analysis of how these results can be applied to determining mass in the solar system	Complete analysis of how these results can be applied to determining mass in the solar system

APPENDIX 1

The Engineering Design Process



This flow chart was created by The Works as a simple, kid friendly representation of the Engineering Design Process described in NGSS.

APPENDIX 2

Core Concepts and Middle School Standards Addressed

Force and Distance	From the Middle School NGSS: 1. MS-ESS1-2. Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system. 2. MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. 3. MS-PS2-4. Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects. 4. MS-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. 5. MS-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system 6. MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
Orbits	From the Middle School NGSS: 1. MS-ESS1-1. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons. 2. MS-ESS1-2. Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system. 3. MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. 4. MS-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. 5. MS-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system
Mass and Inertia	From the Middle School NGSS: 1. MS-ESS1-3. Analyze and interpret data to determine scale properties of objects in the solar system. 2. MS-PS2-1. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects. 3. MS-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. 4. MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. 5. MS-PS2-4. Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

APPENDIX 2 (Cont.)

Level Editors and Games as Simulations	From CCSS Literacy in Science Anchor Standards Reading Anchor #7: Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words. 1. RST.6-8.7: "Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table)." 2. RST.9-10.7: "Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words." 3. RST.11-12.7: "...evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem." Reading Anchor #8: Delineate and evaluate the argument and specific claims in a text, including the validity of the reasoning as well as the relevance and sufficiency of the evidence. 1. RST.11-12.8: "Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information." Reading Anchor #9: Analyze how two or more texts address similar themes or topics in order to build knowledge or to compare the approaches the authors take. 1. RST.6-8.9: "Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic." 2. RST.9-10.9: "Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts." 3. RST.11-12.9: "Synthesize information from a range of sources (e.g., 34 d texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible." Writing Anchor #7: Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation. 1. RST.6-8.7: "...answer a question (including a self-generated question)...generating additional related, focused questions that allow for multiple avenues of exploration." Speaking and Listening Anchor #5: Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations. 1. SL.8.5: "Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence..." 2. SL.9-12.5: "Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence..."
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APPENDIX 2 (Cont.)

Level Editors and Games as Simulations (Cont.)

From **CC Math Standards***:

1. **MP.2** Reason abstractly and quantitatively
2. **MP.4** Model with mathematics
3. **MP.5** Use appropriate tools strategically

From the **Middle School NGSS**:

1. **MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
2. **MS-ETS1-2.** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
3. **MS-ETS1-3.** Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
4. **MS-ETS1-4.** Develop a model to generate data for iterative testing an modification of a proposed object, tool, or process such that an optimal design can be achieved.

From the **NGSS Science and Engineering Practices** (across grades)**

- Practice 1:** Asking Questions and Defining Problems
- Practice 2:** Developing and Using Models
- Practice 3:** Planning and Carrying out Investigations
- Practice 4:** Analyzing and Interpreting Data
- Practice 5:** Using Mathematics and Computational Thinking
- Practice 6:** Constructing Explanations and Designing Solutions
- Practice 7:** Engaging in Argument from Evidence
- Practice 8:** Obtaining, Evaluating, and Communicating Information

* Note that the CC Math Standards are based on 3 concepts that NGSS claims to align with across its standards. It should be noted that in many activities which involve using the level-editor as a simulation tool also involve interacting with mathematical relationships in a visual way. In fact, that is basically what a good simulation is- an animated, visual representation of mathematical relationships. In other words, playing the game forces students to conceptualize relationships, whereas using the level-editor allows students to model and represent those relationships.

** The Science and Engineering Practices are embedded in each specific age-level standard. Creating levels for other users to play is a design process that builds upon these practices (even if the level designed does not illustrate a specific middle school standard, and is just intended to be fun to play).