Creating Science – Gravity and Gravity Falls

What goes up must come down! Unless it reaches escape velocity?! So what IS gravity?

#CreatingScienceGravityFalls

Suggested Outcomes

(NOTE: This is by no means an exhaustive list of possible outcomes, neither is it intended that ONLY these outcomes can or should be met. Science is a deeply interrelated activity, and you may find cross curriculum links you can and should use.)

Science understanding

- Physical science 7: Earth's gravity pulls objects towards the centre of the Earth.
- Earth and space 5: The Earth is part of a system of planets orbiting around a star (the sun).
- Physical science 4: Forces can be exerted by one object on another through direct contact or from a distance.

Science inquiry skills

- Planning and conducting 4: With guidance, plan and conduct scientific investigations to find answers to questions, considering the safe use of appropriate materials and equipment (ACSIS065)
- Communicating 5: Communicate ideas, explanations and processes using scientific representations in a variety of ways, including multi-modal texts (ACSIS093)

Science as a human endeavour

- Nature and development of science 5&6: Important contributions to the advancement of science have been made by people from a range of cultures.
- Nature and development of science 7&8**:** Scientific knowledge changes as new evidence becomes available, and some scientific discoveries have significantly changed people's understanding of the world.

Science vocabulary words

Tier 3 (specialised vocabulary):

- Gravity - the force that holds us and the ground together. We used to say it's the force that holds us down, but all forces have two parts. So it's a lot more accurate to say that gravity is the force that holds us and the earth together – the Earth is just so much bigger that it 'wins'.
- Force - something that can create a change in the direction or speed of an object. Forces include pushes, pulls and twists.

Warning

- Homemade Gravity Falls can be very frustrating, being fiddly projects that can sometimes only work intermittently. Use caution.
- While cardboard and tape usually aren't very dangerous, scissors and knives can be.

Preparation

- A large collection of cardboard tubes and boxes
- Something to hold it together, such as sticky tape
- Something to cut it with, such as scissors or a knife.
- Marbles of various sizes, or soft balls. Practice golf balls are great if they fit in the tubes.

Notes

Remember: It's only an **experiment** if students are testing *explanations*.

- If they're just trying to see what's happening, it's a **test**.
- If they're doing something with an expected result, it's an **activity**.
- If you're doing something for the class with an expected result, it's a **demonstration.**
- Only if they are trying to test the accuracy of an explanation is it an **experiment.**

Remember:

- Every piece of matter in the universe has gravity, but it's such a weak force that it takes loads and loads and loads of matter before we can *feel* gravity. Just look how big the world is, and yet its gravity is so weak a toddler resists it every time they stand up.
- Gravity holds two things together. It doesn't just 'hold us on the ground' – it holds the ground and us together. The Earth is so much bigger that it wins, and it looks like the Earth pulls us down, but it's much more accurate to say that gravity pulls us and the earth together (and the world 'wins').

Building Gravity Falls. Gravity Falls aren't hard – they take time and a little skill. And they're a great chance to recycle! Here are some pictures for inspiration:



Learning Intent (student friendly)

'We are learning to' (WALT) begin to appreciate and understand gravity by making and playing with our very own Gravity Falls.

Success criteria

'What I'm looking for' (WILF) a successful Gravity Fall.

Student learning goals

Help students make a self-monitored learning goal for this lesson, such as trying to see how high they can make a successful Gravity Falls.

Evidence of learning

How will you know when the learning goal is achieved? What EVIDENCE do you have that your students have met or exceeded the learning expectations?

Suggestions for other year levels

As always, more material is presented here than can be used by the average class during the average lesson time. However, since the students' questions can and should guide student learning, more material is presented for your convenience. Remember, it is not uncommon for students to only remember those points which answered their personal questions.

Younger:

The activity should be simplified for this age group, avoiding complex information. Perhaps a simplified gravity fall that makes only one outcome is appropriate.

Middle:

This activity is well suited to this group. Certain students will find it compelling and engaging, and should be given extra time to work on their projects.

Teen:

Using the equation for gravity, calculate the strength of the force between a marble and the planet Earth.

Engage

- ⇨ Note the Learning Intention of this lesson for students.
- ⇨ Make sure all students write down any questions they may have generated during this phase regarding the topic for today.

Activity: Hold something up and ask students what will happen if you let it go. (Predict) Then let it go.

Observe: It falls.

Ask: Why did it fall? (Students may answer: due to gravity)

Ask: What is gravity? (The stuff that holds us down / we don't really know.)

Announce: That's OK; scientists don't really know what gravity is either!

Explore

Make your own Gravity Falls. Gather the materials from the Preparation section and help students to make some of their own Gravity Falls. Some advice to help includes:

- Grab out some cardboard tubes (toilet rolls and clingwrap will work), thick cardboard, thick plastic tubes (if you have any) and other items you can use for making Gravity Falls.
- You can stack boxes on top of each other, tape them together, and put a hole in the bottom to let the marbles out. You can also use boxes, cut in half to form marble trails, or cut diagonally to form pointed gutters.
- You'll need a place to put the Gravity Falls. Sticking them to a door works and provides a ridged surface to work on, but leaves a lot of tape on the walls
- You'll need something to stick the runs together with, such as sticky or masking tape. Blue tack will rarely be enough.

Invite students to build a device that allows the marble to run down into a little cup, but that has at least three different parts to it. Adventurous students might even add windmills.

Ask students to consider what makes the marble run down. Would their invention work on the moon?

- ⇨ Encourage and validate student explanations of this phenomenon. You may like to ask students to write or draw their explanation personally to avoid embarrassment to students unfamiliar with this material. Remember, 'I don't know' is a valid explanation in science – it is the beginning of learning new things!

Explain

History of the concept of gravity:

Story: in 1665 a young English man called Isaac Newton was walking around his grandmother's apple farm, wondering why apples fell to the ground but the moon didn't. Putting together all the science he already knew he came up with rules about gravity and how things move, ideas that still work today at explaining why apples fall but the moon doesn't. But when they asked him what gravity *actually was* he famously replied; 'I make no hypothesis,' or in other words, 'I don't know'!

An answer didn't come about until 1916 when German-born scientist Albert Einstein published his general theory of relativity, which is a very complex theory about space-time and equivalence and matter. And while Einstein's theory was very good at explaining how gravity worked among stars, it didn't work for how gravity worked at very small levels, such as among atoms.

That took a theory by Werner Heisenberg from Germany in 1927. Unfortunately, Einstein's and Heisenberg's theories don't work together, at least not yet, so for now the question of gravity, or 'why do things fall down' is 'we don't really know!' Perhaps **you** may yet grow into one of the scientists that answers those questions one day!

Galileo's research – what falls faster, heavy or light objects?

- ⇨ Ask – which falls fastest, a heavy object, or a light one?

We usually assume the heaviest falls faster, after all, feathers and a sheet of paper fall very slowly!

But Galileo, a scientist in Italy over 400 years ago, had another sneaking suspicion: all objects fall at the same speed – once you get rid of air resistance.

To test his idea we think he dropped hundreds of large and small cannon balls (same material but different weights) from a tall tower – possibly even the leaning tower of Pisa. He might have used a flat board in an attempt to make sure they fell at exactly the same time. He had people watching carefully down below to see which hit first, and did the experiment potentially hundreds of times. He concluded that any object will continue to speed up under gravity until something acted to slow it down.

What do you think? Was Galileo right?

Was his experiment rigorous and accurate enough to make that claim, Could he have done any better with the technology of his time? They did not have stopwatches or slow motion cameras.

Was Galileo the first person to create this idea?

Elaborate

⇨ Ask students if they can design new ways to test this explanation, is it really sufficient? Can they think of further or better explanations, and the experiments needed to test them?

Fun facts about gravity

Gravity can do a whole lot of fascinating things!

- Gravity never switches off – even when a bird or plane is flying, they need to be pushing something down so that they can stay up!
- Air is always in motion. We need gravity to hold the air down.
- Gravity is inexplicably weak, compared with other fundamental forces of the universe. It takes the gravity of an entire planet to hold you down, but the ground holds you up with the electromagnetic force of only a few (billion, billion) atoms.
- Yet gravity operates over amazingly long distances. Most other forces, like electricity, are difficult to detect after a while. But gravity just keeps going on and on, maybe right to the edge of the universe!
- Is there gravity in space? Sure is! But you have to be very big to feel it, say, as big as a planet.[1]

So what IS gravity?!?

Newton wasn't going to speculate about what gravity was, and like a true scientist said "I don't know". It took hundreds of years to come up with an answer, but we're STILL NOT SURE!

Einstein"

"It is the curvature of spacetime". Matter bends space and time, but we don't notice it because we're IN space and time. But this theory explains the movement of Mercury around the sun, explains the gravitational lensing of light as is passed to us around nearby galaxies, and predicts that where gravity is strong, time slows down – and in Black Holes it might stop completely. We have measured all these effects.

However…

Quantum mechanics"

Einstein's theory does not work well in the teeny, tiny arena of sub atomics. It can explain planets, but not atoms. To this, quantum mechanics steps up and tells us that "Gravity is a tiny particle called the graviton that pops into existence in one piece of matter, flies to another piece of matter pulling it closer, and then pops out of existence." Sounds strange, but all tests so far confirm these strange ideas at that very teeny, tiny level.

So what is gravity??

In a very real sense, ***we still don't know***. We've got two theories that work, but they *don't work together*!! Maybe one day you will be the scientist that finally works out what gravity is!

In a very real sense – we still don't know why things fall down. We call it gravity, but what is it!?!

[1] We can get more complicated than that. See next section.

How do things stay in orbit?

For instance, if the space station stopped moving it would experience about 70% normal gravity. Things in orbit, however, are moving incredibly quickly around the earth. So fast, in fact that while gravity DOES pull them down towards the earth, they move so far *sideways* in the same amount of time that they 'miss'. This keeps going on, keeping the objects in orbit.

But just as you need to hold on to a ball when you swing it around in order to stop it flying away, so too gravity holds on to things in orbit to prevent them flying away.

Newton's definition of gravity

Gravity is a force that acts between two objects. Isaac newton explained that "a particle attracts every other particle in the universe using a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them."

In other words:

$$F = \frac{G(m1xm2)}{r2}$$

Where:

- F is the force between the masses
- G is the gravitational constant (6.674×10−11 N ·(m/kg)2)
- m1 is the first mass
- m2 is the second mass
- r is the distance between the **centres** of the masses, not their outside edges

Elaborate (advanced)

Explain: Law 3

Forces are always in pairs. They always affect two things, and always in equal and opposite directions.[2]

Thus, gravity holds two things together.

Re-emphasise that gravity isn't only 'what holds us on the ground' – that's just a side effect. Gravity HOLDS US AND THE GROUND TOGETHER.

So why doesn't the earth move towards you, when you move towards the earth?

It does, but because the earth is so much HEAVIER, it 'wins', and you're the only one that appears to move. See Law 2.

[2] This is known as Newton's Third Law – 'To every action there is an equal and opposite reaction'.

Explain: Law 2

Gravity pulls two things together. So does a marble have gravity? Yes, but not very much.

Because a force is equal to how much an object weighs, multiplied by how much it changes speed and direction. Thus the more massive, or 'heavier', object has least acceleration, so it looks like the smaller object does all the moving. But the force is equal between the two objects.[3]

As the world and the marble pull each other together you can get the marble to do all kinds of work, rolling down a predesigned path. And it can be heaps of fun!

Escape velocity

Escape velocity is a very artificial number. All objects have gravity. Escape velocity is the *initial* speed at which something needs to be travelling in order to pull away from another object's gravity. On earth, that speed is 11 kilometres *per second*. So if you can go at 11 kilometres every second you will eventually get away from Earth's gravity, even though you won't be going very fast by that point. But this velocity also ignores things like air resistance, which when you're a rocket leaving earth is a very important thing. Black holes don't technically have an infinite escape velocity, but they do have an escape velocity higher than the speed of light, which means light going up will bend back down into the black hole, hence, they are 'black'. But if you could ignore gravity you could, theoretically, walk out of a black hole…

Evaluate

- ⇨ Review with students what they felt they learnt from this lesson. Did they have any questions at the start that they feel were answered?

Success criteria

- ⇨ Review the Learning Intentions of this lesson with students. Was it met?

At the end of each class, review the learning objective and see how we did. Ask:

- Did you achieve your learning goal?
- What did you learn?
- What worked to help you achieve it?
- What might you do better next time?
- (If needed) where can you go for extra help or information?

[3] This is law 2 - 'Force = mass multiplied by acceleration'.

Assessment

Prior learning:

Take time to focus on planned content material during the engage phase, for example:

- Why do things fall?
- What is gravity? Who 'discovered' gravity?
- How powerful is gravity?

Focus on the outcomes – how can we create the BEST scientific knowledge?

Formative:

As students are learning, help them self-monitor their own learning and achievements. Be sure to watch out for the following common alternative conceptions:

- Gravity switches off [A still ball on a table is still experiencing gravity. If the table stopped pushing up, the ball would plough right on through].
- Gravity pulls us down [This is a side effect. Gravity pulls two things together].
- Gravity is strong [Gravity is by far the weakest of the 4 fundamental forces of the universe that we know about currently].
- There is no gravity in space [There is plenty. Gravity is what keeps the solar system in shape, and what keeps the galaxy in form. Gravity is what makes the arms of the Milky Way].
    - We don't feel gravity in orbit because we're falling as fast as gravity is pulling us down – we just move so fast sideways at the same time that we 'miss' the earth and don't crash. But if most orbiting spacecraft stopped in relation to the earth, they'd feel somewhere between 70%-90% normal gravity… until they started plummeting towards the ground.
    - We don't feel gravity far out in space because gravity, like all forces, decreases with distance. I like to say we don't feel the gravity in space unless you're very big. As big as, say, a planet.

Summative:

Help students consider ways they can communicate their new understanding to others, just as scientists need to do.

Build a Gravity Falls and explain how they work. Assess students' *ability to assess* their own marble run in terms of what they learnt; explaining their choice of materials, what mistakes they made and how they corrected them, and what recommendations they have for others who are about to embark on the project: award only a few extra points if it actually works.

Older children can explain the history of the theory of gravity with Newton, Einstein, and Heisenberg. Students might also like to calculate the exact force of gravity on their bodies using the equations given today.

High school groups might enjoy a more complex engineering challenge – can they build a Gravity Fall that sorts out different sizes of marbles or coins?

So what?

Science isn't finished – we don't know why things fall down, though we call it gravity and we know enough about it to get people to the moon and predict the position of planets and comets.

Creating science

Science understanding

As we learnt about gravity and built our gravity falls, we saw that;

- Physical science 7: Earth's gravity pulls objects towards the centre of the Earth.
- Earth and space 5: The Earth is part of a system of planets orbiting around a star (the sun).
- Physical science 4: Forces can be exerted by one object on another through direct contact or from a distance.

Science inquiry skills

As we overcame technical challenges of the gravity falls, and shared our learning, we;

- Planning and conducting 4: With guidance, plan and conduct scientific investigations to find answers to questions, considering the safe use of appropriate materials and equipment (ACSIS065)
- Communicating 5: Communicate ideas, explanations and processes using scientific representations in a variety of ways, including multi-modal texts (ACSIS093)

Science as a human endeavour

As we discovered that 'we still don't know why things fall down, we saw that;

- Nature and development of science 5&6: Important contributions to the advancement of science have been made by people from a range of cultures.
- Nature and development of science 7&8**:** Scientific knowledge changes as new evidence becomes available, and some scientific discoveries have significantly changed people's understanding of the world.

Appendix: Gravity Falls – fun toys from recycled things!