Creating Science – The Returning Roller

Develop your skills at theory generation and testing with the Returning Roller – what make it return?
#CreatingScienceReturningRoller

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 inquiry skills

- Questioning and predicting 7: Identify questions and problems that can be investigated scientifically and make predictions based on scientific knowledge (ACSIS124)

- Questioning and predicting 1: Pose and respond to questions, and make predictions about familiar objects and events (ACSIS024)

Science as a human endeavour

- Nature and development of science 5: Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena.

Science understanding

- Physical Sciences 7: Change to an object's motion is caused by unbalanced forces acting on the object.

Cross curricular outcomes

Design and Technologies Processes and Production Skills 7:

- Critique needs or opportunities for designing, and investigate materials, components, tools, equipment and processes to achieve intended designed solutions (ACTDEP024)
- Generate, develop and communicate design ideas and processes for audiences using appropriate technical terms and graphical representation techniques (ACTDEP025)

Science vocabulary words

Tier 3 (Specialised vocabulary)

- Observation - Something your senses detect, such as bright light, loud sounds, etc.
- Inference - Making sense of what your senses detect, deciding what your observations mean.
- Theory - an explanation of what is going on. Inferences are all theories of one kind or another.

Warning

- Teachers should build a working model of the Roller before presenting it to the class, *and* know how to make it work with some reliability. DO NOT underestimate the importance of that last sentence. There can be quite a trick to getting your Roller to work reliably, and as all science teachers know, they must get their demonstrations to work for them *before* fronting a class with them. There are few things more defeating to a science lesson than a demonstration that doesn't work…
- Sharp knives and scissors abound, please manage carefully.
- This product is technologically challenging. Be prepared to scaffold students in their development and creation of their model.

Preparation

To make the Returning Roller (see appendix), you will need:

- A cylinder at least 10cm wide and 10 centimetres long… or thereabouts. Large postal rolls will often do just fine.
- A small, very heavy weight: a large metal nut, a solid rock, etc. Several coins will also do a great job when stuck carefully together.
- Some strong elastic bands, but not too thick: 2mm thick will usually do.
- Two paperclips or paddle pop sticks.
- Construction materials: sharp knife, tape, etc.
- Perhaps some decoration materials: paper, paints etc.

Also,

- A flat surface, such as a table or floor, to roll the Roller on.

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:

This activity is deeply interesting to this age group, but they will not be able to make their own returning Roller without significant help.

Also, they have an astonishing tendency to grab the Roller after its first roll, and before it has a chance to return. Demonstrating and requiring patience to 'see the game through' will be necessary.

Middle:

This activity is well suited to this group, but still quite challenging. Scaffold the students in making their own rigorous scientific conclusion as to how the Roller *really* rolls.

Teen:

Increase the challenge by requiring students of this age group to teach younger children about the magic trick, and help them to build more Returning Rollers. This makes it quite a challenge, but teaching an idea to others can more deeply solidify learning objectives for the older children.

You may like to encourage them to engage in a thorough investigation, such as finding out which rubber bands are more effective, or to measure the actual coefficient of friction of various surfaces as it relates to Roller performance.

Learning Intent

'We are learning to' (WALT) – use science to 'see through the magic', to base our ideas on evidence and generate our own conclusions.

Success criteria

'What I'm looking for' (WILF) – students who can explain the magic of the Roller clearly and concisely. Also, making a working Returning Roller.

Student learning goals

Help students make a self-monitored learning goal for this lesson, such as 'make a returning roller' or 'understand how science works' – though this should happen after the Engage section below.

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?

When describing how their Roller works, students will be able to explain:

- The invisible internal workings: what the weight and rubber bands are doing when they cannot be seen.
- Use of scientific languages, such as pushing force, motion, energy, tension, stretch, pulling force, rotate (or turn), and return.
- That if students still believe the inaccurate reasons why the Roller returned (slope of the table, presence of well-trained mice, magnets, etc.), that they can present an experiment to test their theory.

Engage

Explain to the students that you have 'magic powers' and can prove it – and that you'd welcome it if students can prove you wrong!

Perform the returning Roller trick. You can try using a 'magic click' telling them that the Roller can 'hear' you and magically returns. Have them think of ways to test your theory. (Roll it without clicking, have someone else click their fingers etc.).

Point out that the students are doing science by thinking of ideas and testing them. This is what practicing scientists do in the community. Scientists may not have all the answers, but are looking for new things to learn just like your students in class today.

Explore

- 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!

Have your students practice observing by watching; listen to the Roller as it is shaken, or feeling it in their hands. You might like to invite one student to closely examine it (without opening it) and share with the class what they are experiencing. If you have previously introduced the idea, this can be an opportunity to remind students how observing is different from *explaining* observations (which is called inference).

Next students may be encouraged to generate explanations for their observations of the 'returning Roller'. Examples might be that the desk is on a slant, or that it has something to do with magnets and paperclips (or well-trained mice). Teachers should complement student suggestions, and then ask them to generate ways to test their ideas just as practicing scientists do (without opening the Roller up yet). Point out that this is the way that scientists use to generate their understanding of how the world works.

Eventually, opening up the Roller will be the best way to test students' ideas. Remind them that this is a good way to do science (opening things up to see what they are made of); but that you need to make sure we do so safely and responsibly. Open it up to reveal the weight and rubber bands (curiously, I've noticed that many students ignore the rubber bands as important evidence).

Have them now try and explain how and why it works. You may like to let them pass it round and examine it. Listen to their ideas and theories of how it works. Reward scientific thinking and terminology, after all, science is all about thinking of ideas and then thinking of ways to test them. You might like to give them a day or two, or give upper primary students the chance to try and build their own Rollers before giving them the 'formal explanation' of how it might work.

Explain

How it works

I often use this as an opportunity to show the need for imagination in science. You need to imagine what is happening inside the Roller while it is operating[1].

What happens to the weight as the container is rolling around? Is it turning as the container does (It is moving along with the container, but is it turning around as well?) When it is closed, can you imagine it not turning as the container does?

So as the container turns, the weight moves but does not turn. What would this do to the rubber band? It causes the elastic band to become twisted up. This twisting slows the container down and pulls on the weight. Eventually the rubber band begins to untwist and, since the weight is so heavy, it pushes the container in the opposite direction instead. And presto! The Roller returns.

Why it works

High school science

Newton's laws of motion can help here! As the container turns, the rubber bands exert a small turning force (law 2) on the weight. But the weight is being pulled down by gravity, so instead of turning, it just stays facing the same way (which is possible due to the momentum of the weight, and assisted in that most weights are offset, making them heavier on one end and inclined to point that heavy end downwards). The rubber bands get tighter and tighter, exerting more and more of a force on the weight. But forces are always in pairs (law 3), so the rubber bands are exerting a force of the container as well, helping it slow down. Eventually the rubber bands are at their tightest, pulling on both the container and the weight. Generally the container is lightest, so it is the first thing to get moving (and the weight still has gravity's help to stay facing the same way.) If there was nothing to stop the container, it would roll. Forever (law 1).

You can also try describing the Returning Roller in terms of the scientific concept of "Energy". The kinetic energy of the original motion is transformed into elastic potential energy in the rubber bands. The tension in the rubber bands produces a force which begins to turn the container in the opposite direction, as the elastic potential energy is transformed back into kinetic energy, and the container rolls back again.

[1] Unless you happen to have built a transparent Roller!

Confirmation bias

- Ask: Why do some scientists say science cannot prove things right, only wrong?

Karl Popper argued that science can only prove things wrong, not right.

Karl Popper was a scientist and philosopher in the 1950s. He pointed out that theories often talk about things that cannot be directly observed (or maybe only exist as concepts), such as atoms, gravity, and energy. Thus, Karl Popper said, **we do not experiment on theories**, we experiment on **the predictions the theories make**. Thus, the theories are only ever *supported* or *not supported* by the evidence. We do not say if theories are 'right' and 'wrong'.

However, while there is no end to the number of experiments we can do to prove a theory right, it only take ONE observation to prove our theory wrong.

Say you thought that 'all swans are white' – you'd have to test all swans in the world to say that for sure. That's a lot of swans, and swans tend to keep making more swans. At current technology, that's impossible.

But if you see ONE black swan, your theory is busted.

For this reason, and others, in science we often find we're not trying to prove our theory right, we're trying to prove our theory wrong.[2]

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[2] Seems an odd way to create knowledge, doesn't it? But it reminds me of an old riddle:

Why is what you are looking for always in the *last place* you look for it?

Answer: because that's where you find it, and therefore, that's where you stop looking.

It is an old human mistake to stop looking once we think we've found what we are looking for.

Say, for instance, that the power has just gone out on our light nearby. We're beginning to wonder why. But it just so happens we also have to burp at just the moment the light comes back on. What can we conclude? That burping fixes broken lights?

Thing is, just because two events are related, does not mean that one of them causes the other. It's the old mistake of correlation versus causation. Even if the per capita consumption of cheese correlates with the number of people who died by becoming tangled in their bedsheets (http://www.tylervigen.com/spurious-correlations), this sentence is unfinished. Of course, this does not mean one causes the other. To take a

Elaborate

What is the science of creating scientific knowledge?

Explore with students what steps they took to decide how the Roller worked. Did they:

- Carefully observe? Watching, but also listening, or shaking the Roller? Perhaps they even measured the table to make sure it was not on a slope?
- Come up with an idea of how it worked (called a theory) and then test that idea (called an experiment)?
- How did they feel? Did they feel dumb for not getting it right first time? Did they give up, and leave all the thinking to someone else? In science, it **doesn't matter** if we're wrong, what matters is that we learn: and hopefully *everyone* was able to learn something today.
- Even if we tested the Roller, can we be sure that's how it works? Can we be sure invisible pixies don't appear when we're not watching? At some point, science is based on people deciding for themselves, based on the **logic** of what they already know and the **experiences** they have generated through experiments. Science invites us to consider new and challenging ways (that are supported by evidence) to think about the world!

What is the science of the Returning Roller?

What other examples of forces are there in your classroom? Can you think of evidence to support the idea that 'moving things keep moving unless acted on by a force', when so many things in our daily lives slow down without constant pushing (cars, bikes, or toys, for instance)? An idea called 'friction' will help here.

Students can build their own Rollers using materials they bring to class (a good example of the technology syllabus). Can they make one larger than your demonstration? How about a transparent Roller? Have them sketch out careful plans before beginning.

Finally, I have a conundrum for you: if the earth is turning completely around in only 24 hours, and it really is as big a ball as scientists say it is, then the people at the equator would be moving at around 1700 kilometres per hour! Surely they would be squashed flat, and the wind rushing past would rip everything to pieces! Yet they can walk around the tropics as happy as can be without noticing a difference. Can you give me an explanation for this? ("Earth is turning! Bah, Humbug! It certainly doesn't *feel* like it is turning to me! Is it…?")

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satirical example, while Batman and Bruce Wayne have never been seen in the room at the same time, this does not **prove** they are the same man.

Thing is, when we set about to prove something is right (verify) in science, we can too often fall into errors. This problem was flagged by Karl Popper in the 1950s, who pointed out that no one can win with the theory 'you are repressing your anger' - since if the comment makes you angry, the theory is right. And yet if you don't get angry, the theory is still right since you were 'repressing'.

But by relying on knowledge created by attempting to prove it wrong (??falsify??) we are always open minded towards new and better knowledge. In short – we never stop looking in science.

Evaluate

- Review with students what they feel they learnt from this unit. 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?

Assessment

Prior Learning:

Ask:

- (Early childhood) What shape do things need to be to roll?
- How do scientists conclude which theory is right?
- Can energy be stored? What does it become once it's released?

Be sure to watch out for the following common alternative conceptions:

- Scientists know what is true if their experiments work. [Actually, scientists are trying to prove their theories wrong. Many believe they will never know if their theories are fully right, but they DO know if their theories are wrong!]

Formative:

As students are learning, help them self-monitor their own learning and achievements. For example, students can prepare learning journals of how they learnt about how the Roller works, and how their ideas have changed as they explored and thought about it.

Summative:

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

You may like to assess students on the effectiveness of their returning Rollers (i.e. do they return), but this may be more appropriate as a hurdle requirement or technology requirement. Understanding the science does not require a working Roller, but it's very satisfying.

Have students make posters or oral presentations that explain **how** and **why** the Roller works, using current scientific terminology. Be sure to reward them for any effort they put into understanding their explanations (not just repeating yours!)

So what?

Sometimes people might try and trick us, but we can use science to see through the magic!

Gaining the skills to build, and explain, a Returning Roller are not only challenging, they're fun!

Creating science

Science Inquiry Skills

In attempting to explain the Returning Roller, we had the chance to;

- Questioning and predicting 1: Pose and respond to questions, and make predictions about familiar objects and events (ACSIS024)
- Questioning and predicting 7: Identify questions and problems that can be investigated scientifically and make predictions based on scientific knowledge (ACSIS124)

Science as a human endeavour

As we experienced uncertainty, quested to answer conundrums, and tested out our own explanations of how the Returning Roller returned, we saw that;

- Nature and development of science 5: Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena – as students make their own conclusions as to how the Roller returns.

Science understanding

As we learnt about how the Roller returns, we had the chance to learn that;

- Physical Sciences 7: Change to an object's motion is caused by unbalanced forces acting on the object.

Cross curricular outcomes

In taking on the challenge of building and presenting our own working model of the Returning Roller, we;

- Critique needs or opportunities for designing, and investigate materials, components, tools, equipment and processes to achieve intended designed solutions (ACTDEP024)
- Generate, develop and communicate design ideas and processes for audiences using appropriate technical terms and graphical representation techniques (ACTDEP025)

Appendix: Building the Returning Roller

Caution

When allowing students to construct their own Rollers, safety concerns need to be taken into prior consideration. Be wary of sharp knives and snappy rubber bands. Also, students need to be persistent; the Rollers can be fickle toys (relying on just the right density weight, thickness of rubber bands, etc.!)

Materials

- A cylinder at least 10cm wide and 10cm long… or thereabouts. I find large postal rolls do just fine!
- A small, very heavy weight: a nut from an aeroplane, a solid rock, etc. Many coins will also do a great job when stuck carefully together.
- Some strong elastic bands, but not too thick: 2mm will usually do.
- Two paperclips or paddle pop sticks.
- Construction materials: sharp knife, tape, etc.
- Perhaps some decoration materials: paper, paints etc.

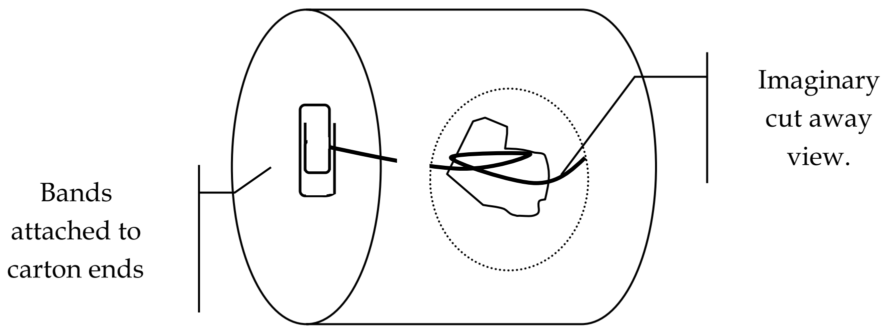
Building the Roller

1. Attach the elastic bands to the weight (being sure to leave enough slack to attach the bands to the cylinder walls in the next step). Some creativity is required here. You can wrap the elastic bands around the weight and secure the whole lot with a third elastic band. The bands need to be just a *little* tight for the best results

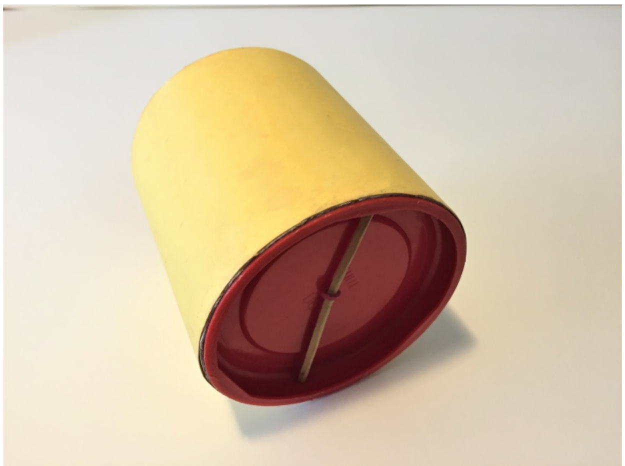
2. Cut some small slits in the centre of either end of the cylinder. Thread the elastic bands through, and keep them there with the paper clips (or paddle pop sticks) on the outside. Your Roller should now have a weight suspended by rubber bands inside a cylinder. It is important that the weight does not touch the sides of the container. It is important that the paperclips are fixed to the container or the rubber bands will not transfer their spin properly. (I use paper clips because the rubber bands sometimes need replacing, but you might find something that works better.)

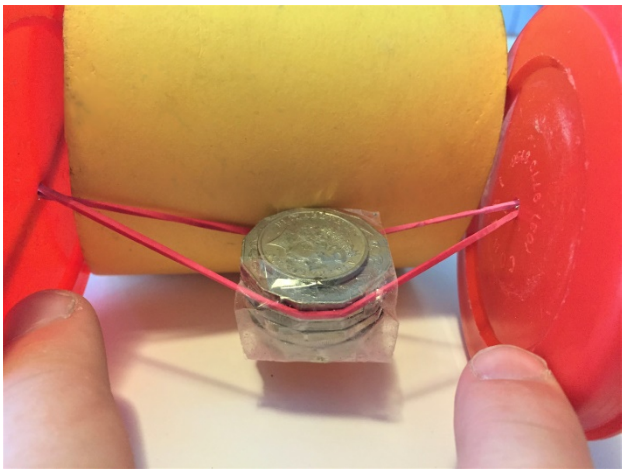
3. Decorate to your heart's content. Well, nearly. The Roller works better with smooth, round walls: cupcake holders are not conducive to this effect.

Help to make it work



The Roller may require some winding up in the same direction that you intend to roll it. This can be a delicate art: you need to feel the Roller just gently trying to roll back. Too much, and the elastic bands unwind by themselves as the weight is spun around wildly inside. Too little and the Roller rolls away and is too 'tired' to return. Each Roller will be an individual with their own personal requirements to get motivated.





Now pop online and share your pics and experiences to #CreatingScienceReturingRoller or admin@drjoe.id.au