Rubbish Science

HOW TO:

TEACH YOUR KIDS TO BE BRILLIANT RUBBISH SCIENTISTS

BY NEIL ATKIN

“Somewhere, something incredible is waiting to be known.”
— Carl Sagan

The Full Training Manual

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You might think that the inhabitants of a planet threatened by a viral pandemic and a potential climate catastrophe would come together and say, ‘What does the evidence suggest we should do? “

Too many people do not understand that science is not about facts, but about a consensus, based on evidence. There is a lack of trust in some groups towards science and an idea that their belief based on a hunch has the same validity as peer-reviewed data. In Teaching your Kids to be Brilliant Rubbish Scientists you are equipping them not to blindly accept anything, but to ask where is the evidence before making a decision. Our planet's future will depend on thinkers like this.

This training manual is aimed at those wanting to do or deliver Rubbish Science Workshops. This is the full version with all of the pedagogy and thinking behind it. A simpler version is also available How to become a Brilliant Rubbish Scientist or you can simply miss out on some of the elements. What is essential though is that you follow the design thinking process. There is also an online course and live streaming available so follow our social media for what's happening.

A Brilliant Rubbish Scientist? Surely this is a contradiction!

In this manual, we will train you to think like a brilliant scientist and to pass these skills and knowledge onto others, **Using only rubbish** how might you solve real problems. How can you make a **fishing line from a plastic bag?** How might you turn **dirty water into clean** only **using a plastic bottle and a tin can**? How might you create a **vertical garden** to grow food if you have no land? You will learn to answer all of these questions, but that isn’t the point of the course. We will **train you to think** in a way so that you make **better decisions**, are less influenced by fake news and always **look for the evidence.**

Read the manual, do the course and/or sign up for the live streams. Have fun, learn and contribute.

We also try and connect communities around the globe to foster understanding and equality. If you want to collaborate please get in touch

Neil Atkin
Pembrokeshire
Wales

Neil Atkin is a published author, international speaker and qualified Advanced Skills Teacher with over 30 years of experience in teaching science. He has taught the richest and the most deprived students in the world at the best and the toughest schools. We are all the same! His passion is creating evidence-based scientific thinkers equipped to deal with a challenging world of misinformation and fake news. Rubbish Science aims to change peoples perceptions of rubbish to see it as a resource and use it to solve real problems. The real value is in changing the way people think in order to make better decisions.

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Our Website: We are the educational arm of Operation Orphan

https://www.operation-orphan.org/rubbish-science

Find us on Facebook
www.facebook.com/rubbishscience

Twitter
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Email
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PROLOGUE

Rubbish Science as an idea has been 35 years in the making. As a teacher, I was never happy with the constrained and uninspiring nature of classroom science. Much of the curriculum was dry and not relevant. Practical science usually involved following basic recipes with simple questions that we and usually they already knew the answers to. Or else it was students playing with the equipment, entertaining themselves, but not learning. Over time this didn't get better, for many students science became death by PowerPoint and simulations replacing hands-on experiments. Teaching to the test was something you could not blame teachers for as it was how they were judged. Imagine if the criteria were changed to how many students continued to study that subject at a higher level, what would change? Science lessons would be more like Rubbish Science, relevant, engaging and truly journeys of exploration.

I'm doubtful that the science teachers who inspired me, Mr Woodward and Mr Palmer, would survive in the present system that seems to only rate that which can be measured. This book is dedicated to them!

TESTIMONIALS

Having collaborated with Neil Atkin several times already, I can wholeheartedly state that Neil is an outstanding educator and science facilitator. His ability to both entertain and engage his audiences with puzzling inquiry-based tasks while at the same time creating an exceptional educational environment is unparalleled. Neil's approach to education is highly innovative, evidence-based, and inclusive on every level. Indeed, Neil ensures that all participants of his workshops leave the room happy, inspired and with a smile on their faces.

Jeff Wiener CERN Teachers Programme manager

Neil Atkin is our Primary Science trainer and for each cohort, we ask him to talk to our Trainee Teachers about Rubbish Science. It is clear that Neil's vision for Rubbish Science is to have a huge and sustained impact on children around the world and he has the passion to increase the scope of Rubbish Science, which is already having an impact both globally with Operation Orphan, and in the hearts and minds of teachers and children who have benefitted from his training.
Our trainees gain a huge amount of knowledge and understanding from Neil's sessions with us and our end-of-training surveys speak very highly of the impact his talks have had. His sessions are highly engaging and our trainees gain a real sense of how to use waste products to teach problem-solving in science and to give their pupils scientific literacy in their teaching of scientific concepts.

Tracey Smith | Senior Lecturer – Education | Academic Staff |The University of Buckingham

Neil Atkin's passion for science teaching is a joy to behold. His innovative approaches and extensive pedagogical knowledge will make you keen to get back to your classroom to try things out.

Helen Reynolds - Author and probably the best physics teacher on the planet!

During my time as a teacher at Aiglon Switzerland, I set up and led service projects in Thailand and Cambodia. Engaging with Rubbish Science made a very noticeable, positive difference to the success of our service project. Specifically, the activities designed and delivered by Neil:

- Encouraged our students to quickly form a strong, unified team with a powerful shared goal
- Reminded our students quite how privileged and lucky they are
- Taught them that you need nothing other than everyday "rubbish" as tools to investigate the world
- Even small actions can make a massive difference to the world.

When we arrived in our project location in rural Siem Reap province, our students interacted daily with the local children, Using Rubbish Science activities helped to build a strong connection between our students and the local children; they could all work together on shared tasks, exploring, learning, and laughing together, while making things that could improve the lives of the local community.

John Turner - Wonderful teacher and human being!

1: STARTING YOUR RUBBISH SCIENCE JOURNEY, TRAINER FUNDAMENTALS

Rubbish Science workshops have been delivered to some of the poorest communities in the World, but also to some of the most expensively educated in Swiss boarding schools. What is striking are not the differences in the students, but the similarities. Kids are kids, we should never underestimate the ability of those with less privilege even if dressed in rags, nor dismiss indigenous knowledge.

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This course manual is written for those delivering Rubbish Science workshops. It is written so that even if you, the teacher and your children/students have little scientific knowledge, you can still present the course or simply carry out the activities yourself.

If you are a science teacher then these activities are ideal for science clubs and extending thinking. You can also base entire projects around them.

If you are a home educator then you can fully explore the ethos and use this to prepare students for exams from an in-depth understanding rather than rote learning. Look out for our opportunities to connect to others.

Simple, complicated or complex activities?

Simple things are easy to do and easy to replicate

Complicated things are hard to do the first time, but can be done again with the expectation of a similar result.

Complex things may be hard to do but are difficult or impossible to replicate as there are lots of variables that cant be controlled.

Most experiments done in science classrooms are **simple**. This is not always a bad thing as novice scientists need practice. It only becomes an issue if that is all they ever do. Like practising kicking a football against a wall, but never playing a game. We might never know what our students are capable of if we never set them free.

Putting an astronaut on the moon is very difficult but once done the same procedure can be followed so that activity would be **complicated.** None of the Rubbish Science activities are complicated. Many of our students have little or no scientific experience and we want to have activities that are accessible to all.

Most Rubbish Science activities are easy to do but difficult to do well. There may be many variables that cannot be controlled. For a fly trap for example there are lots of reasons the trap might not work. The flies might not be around, due to birds or other predators, or smelly food that is more attractive than your bait etc. So these tasks are **complex**, they are messy, but a good preparation for real-life which is also messy!

The complex Rubbish Science activities give those doing them the opportunity to discover something that maybe no one else knows.

“Somewhere, something incredible is waiting to be known.”
— Carl Sagan

In this book, we will cover the fundamentals of what science is and what scientists do. Each activity we do reinforces the process of **Question - Ideas /Predict - Design a fair test - Do it - Decide how confident you are - Make a claim - Tell someone.**

This method is often what is followed by people learning new skills. A skateboarder learning a new trick or a footballer attempting a different free-kick will loop around this process. It is a very natural learning cycle. Try to make this as explicit as possible so it becomes a habit for your students.

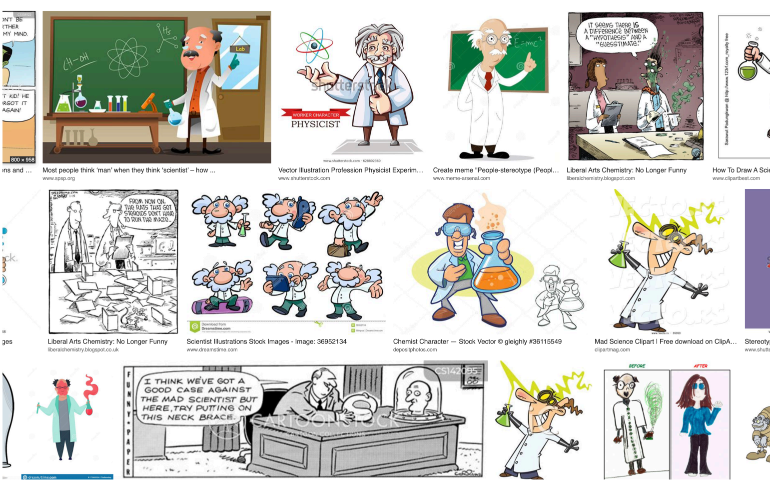
We aim to connect as many students as possible globally to foster understanding and collaboration. The nature of Rubbish Science is that it is a leveller. We all have access to similar equipment irrespective of how poor or rich.

Can I be a **Rubbish Scientist?**

Can you ask questions?
If the answer is yes then you can be a Rubbish Scientist

"The scientist is not a person who gives the right answers, he's one who asks the right questions."
― Claude Levi-Strauss

Do you look like one of the cartoon scientists below?
If the answer is no that is fine, most scientists don't look like them either!



Real scientists do not usually look like these stereotypes!!!

Everyone can be a Rubbish Scientist, but to be a brilliant one you will need to develop these skills.

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- **Curiosity -** have an interest in the World and **question everything!!** We learn by asking questions.
- **Resilience** treat failure as a learning experience.
- R**espectfulness** Listen and try to understand what other people are thinking and to consider that they might be right. Don't think anyone is superior or inferior to you.
- **Humility** is being prepared to **change your mind,** there may be others who know more than you. Always consider that you may be wrong.
- **Courage to** get involved. Being brave isn't not feeling any fear, it is feeling the fear and doing it anyway!
- **Tenacity** never give up!
- **Take responsibility** do not blame others if things go wrong, you may have had something to do with it!
- `**Positivity!** No one likes a moaner! Stay positive

You might be better at some of these things than others. Score yourself from 1-10 on each then try and develop the ones you are weakest at. Most of all have fun through learning.

"Remember to look up at the stars and not down at your feet. Try to make sense of what you see and wonder about what makes the universe exist. Be curious. And however difficult life may seem, there is always something you can do and succeed at. It matters that you don't just give up."

— Stephen Hawking

Don't scientists have to be clever?

Cartoons always depict scientists as being super clever boffins. What does clever mean? You don't have to be good at passing tests to be a Rubbish Scientist. Following the Rubbish, the Science design thinking process will make you smarter and better able to make good decisions. Our brains are not fixed at one state of cleverness. The more we exercise our muscles the stronger we become. **The more we think, the better our thinking becomes** as we exercise our brains. You will learn how to use something called **evidence-based thinking** as a Rubbish Scientist and that will help you make better-informed decisions.

"It is, in fact, nothing short of a miracle that the modern methods of instruction have not yet entirely strangled the holy curiosity of inquiry."

- Albert Einstein

How do Rubbish Scientists work?

We follow a process. We always start with a **question that can be tested.** Usually, answering this question will improve some aspects of life. Improving water, food or health security. The answers are not obvious and may be very complex. Ideas on how they might answer this question are generated and the 'best one' chosen. Then a **fair test** is planned. A **prediction** is made (or hypothesis) of what we think is going to happen. When we feel we have sufficient results to answer the question we make a **claim** and explain the **evidence** we are using to make that decision. Then we say how **confident** we are about their claim. The better the **evidence**, the higher the confidence should be. After carrying out an investigation we decide whether to **investigate further** and may make **another claim** with **updated evidence** and a

new confidence level. This new confidence level may be higher if our findings support their claim and lower if our evidence does not support the claim. Science is never finished in that there are always more explorations to be done.

What all these means will become clear as you work through the course and hopefully turn into a brilliant Rubbish Scientist.

How is Rubbish Science different to normal school science?

Research shows many students find school science boring. This is often not the teacher's fault as they often have to teach huge amounts of knowledge in a short time to prepare students for a test. What gets tested gets taught. This leaves little time for creativity nor exploration. Many potentially brilliant scientists do not continue with science as the subject has not stimulated them. Rubbish Science is about using scientific thinking for creative problem-solving.

Riding an exercise bike is an efficient way of getting fit, but the experience can be boring compared to the excitement of a bike ride up and down a mountain. However, trying to ride up a mountain when you are not fit is not enjoyable (believe me!) We need to be properly prepared to get the most out of an activity.
Similarly, just learning knowledge in science without ever applying it can be boring compared to exploring and practical problem-solving. But, trying to solve a problem without really understanding is pointless and little real learning will take place. Rubbish Science tries to get the balance to ensure thoughtful curiosity is used to solve real problems.

We use the principle of **low threshold high ceiling tasks**. Everyone can do the task, but there are no limits to how well they can be done. We can give the same task to a primary school student or a researcher, both will be challenged by the task up to the limits of their ability. Take for example making a plastic bottle fly trap. Everyone can make one in minutes so it is a low threshold. The more you learn about it and flies the better your flytrap will be so there is no ceiling to learning. Everyone could discover something no one else knows

You can make a fly trap in seconds, but spend a lifetime making it better

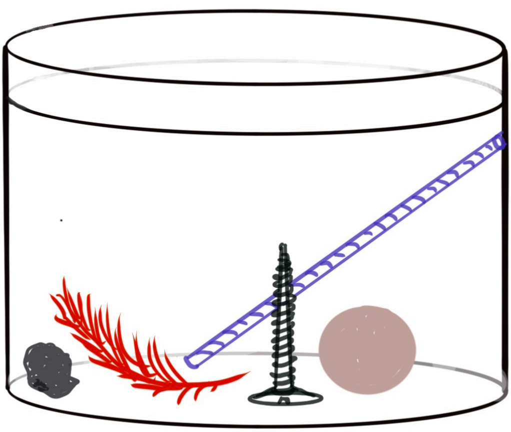
Mystery Box Activity

A Mystery box or boxes are a way of modelling how scientists try to make sense of the unknown. There are many ways of making these but essentially an object or objects are sealed in a box and students have to try and work out what it or they are.

Safety Note: Ensure boxes are clean and have no sharp edges.

Students might shake the box, weigh it, shine a light through it, use a magnet to see if the objects are magnetic and anything they want apart from opening the box itself. They are looking for **evidence** as to what might be in the box. How **confident** are they that they know what is in the box?

You might make some boxes slightly translucent, others opaque or have all the boxes identical. Have someone else make the boxes for you so you do not know what is in the boxes. Do not open them! This may annoy your students, but the whole point of the activity is that this is what science is. We can use more and more sophisticated techniques like scanning etc and build on previous thinking, but we never



really know what is in the box.

It is the mystery that makes science endlessly fascinating. When we think we know something we tend to lose interest in it. Science provides us with boundless mysteries as there is always more to know.

“The most beautiful experience we can have is the mysterious. It is the fundamental emotion that stands at the cradle of true art and true science.”
— Albert Einstein

However

“If you try and take a cat apart to see how it works, the first thing you have on your hands is a non-working cat.”
— Douglas Adams

What is **science**?

Surprisingly few people can give a good answer to this question.

It is not about knowing stuff or facts, nor is it about trying to prove things, rather it is a way of thinking, Police detectives try to piece together evidence to find out what happened when a crime has been committed., Similarly scientists try to make sense of the **evidence** that they have observed and measured to understand what is happening and how the world works. The more **reliable evidence** there is, the more **confidence** there can be in our findings. Everything should be questioned!

We all have natural curiosity. Science is a process of investigating, it's posing questions and coming up with a method.' Sally Ride (1951–2012), first US woman in space

'Science is a history of corrected mistakes.' Karl Popper (1902–94), philosopher of science

'Science is a process by which you observe the universe and come to a view. There aren't any truths in science, just our best views of the way the universe works given the data set available at the time. Science is a process of replacing models with better models.' Brian Cox (born 1968) Physicist

What do we mean by **evidence**?

Evidence is information that has been collected that can be used to either support or refute a claim. Whenever a Rubbish Scientist hears a claim they need to shout "WHERE IS THE EVIDENCE?' When a Rubbish Scientist makes a claim they need to support it with evidence.

What makes **good evidence**?

Ideally, we have observed the evidence ourselves but most of the time we have to get information from a different source. We need to decide how reliable that evidence is. Could there be any bias? Has it been peer-reviewed or checked by others?

What does **reliability** mean?

Imagine that you buy a car. The person you bought it from says that it is reliable, meaning it always starts and never breaks down. Does this mean it is?

No! It might be, but the person selling it has a motive not to tell you the truth.

You turn the key and the engine starts immediately. Does this mean that the car is reliable?

No! This is a single data point. We can never rely on one measurement. We would only know if it was reliable if it started every time over and over again. The more times we try it the better we can decide how reliable it is.

Even better would be a survey of all the owners of the same type of car to see what results a bigger sample size tells us. We might have bought the least or most reliable car of that type but we won't know until we have compared it to a lot of others,

Who should we believe if the manufacturer says their car is very reliable, but a breakdown company that helps thousands of motorists a year says that it is not? Probably the breakdown company as long as it is independent and does not have links to a competing manufacturer.

What would be more reliable than the breakdown of companies data? A report that gathers all the breakdown companies data and compares that car to others. Using this type of information is better than just listening to the person trying to sell the car.

What order of reliability would you put these into. Put what you think is the most reliable at the top and the least reliable at the bottom.

- ✻ A pharmaceutical company Drugs R Us says their vaccine is the most effective against Covid and doesn't say anyone died after taking it, but it also does not say how it was tested.
- ✻ Your friend who is a medical doctor says he wouldn't use the Drugs R Us vaccine as one of his patients died having had the vaccine
- ✻ Billy says he read something that said Drugs R Us is working with the government to control us with microchips and should not be trusted
- ✻ Sue saw on Facebook that it wasn't safe and lots of people had died after having the Drugs R Us vaccine
- ✻ A clinical trial of 100 patients treated found that the Drugs R Us vaccine caused no deaths
- ✻ A clinical trial of 1000 patients found that one patient died, but they already had serious health problems
- ✻ A meta-study (a study that looks at the results of many other studies) of 10 clinical trials found that there were no significant problems with the Drugs R Us vaccine and that it was safe and effective

A possible order and reasons

1. A meta-study (a study that looks at the results of many other studies) of 10 clinical trials found that there were no significant problems with the Drugs R Us vaccine and that it was safe and effective. *The more data we have from the more different sources, the more reliable the information tends to be.*
2. A clinical trial of 1000 patients found that one died, but they already had serious health problems. *Clinical trials are usually carried out under strict conditions and 1000 patients is a reasonably high sample size.*

3. A clinical trial of 100 patients treated found that the Drugs R Us vaccine caused no deaths. *The sample size is too small to be reliable and is less than the 1000 sample size*
4. The pharmaceutical company Drugs R Us says their vaccine is the most effective against Covid and doesn't say anyone died after taking it, but does not say how many patients were tested. *We need to see the data or have this confirmed by trustworthy, independent sources. The company are unlikely to not have any bias.*
5. Your friend who is a medical doctor says he wouldn't use the Drugs R Us vaccine as one of his patients died having had the vaccine. *A medical doctor should probably be listened to above someone unqualified but the sample size may be very small and everyone has biases, even doctors.*
6. Sue saw on Facebook that it wasn't safe and lots of people had died after having the Drugs R Us vaccine. *If we cannot check the information is correct we should not take any notice of it!*
7. Billy says he read something that said Drugs R Us is working with the government to control us with microchips and should not be trusted. *It would be fair to say that Billy is not a reliable source of information. Ask Billy what the source of information was and where he read it.*

Science and religion

Rubbish Science is based entirely on **evidence** and looks only at what information or data we have. Religious **beliefs** are different in that they do not require scientific evidence for something to be considered true. That does not mean that religions and beliefs are wrong. Rubbish Scientists are not so arrogant that they think they know everything the opposite is true., When we act as Rubbish Scientists though we only look at the evidence and try not to be **biased.**

Science investigates; religion interprets. Science gives man knowledge, which is power; religion gives man wisdom, which is control. The two are not rivals."
— Martin Luther King, Jr

Scientific thinking

There are not any 100% facts in science, We are never 100% certain about anything. Suppose an event has happened in the same way a million times. We can be pretty sure that it will happen again the same way for the millionth and first, but we cannot be certain. We cannot ever prove anything, so we don't try. What we do is try to disprove them.

Something happening a million times does not tell us that it will certainly happen again, what it tells us is that it probably will. If we are as certain as we can be then we can develop a **theory**, something that there is no evidence against. However, our theory is disproven and we have to start again if there is a single exception to it.

For example. You watch cars on a busy road at a set of traffic lights. You might make think of a question that can be tested experimentally

My question is: Do all cars stop at red traffic lights?

The first car we see stops at the red light, Does this answer our question? We have a problem in that only have one observation, we call this a **single data point** the **evidence is very weak**. We cannot be confident there are any patterns at all. This might be the only car that stops, we do not know! We need more observations, more evidence to build confidence and to test the **reliability** before we can make our claim.

We watch a thousand cars and still everyone stops. We now can claim with some confidence that cars stop at red traffic lights. Can we say **all** cars stop? No! We can only say that all the cars we watched stopped.

A million cars later and still they have all stopped. Can we now say as a fact all cars stop? Still no! The evidence is now building towards a theory, no cars have ever not stopped at the red traffic light so our theory is that cars stop at red traffic lights.

Then one car does not stop. Our theory has gone instantly. We can now have to modify our claim to say **most** cars stop at red traffic lights.

It can take millions of observations to build a theory, but that theory can be destroyed by one single result that does not fit.

S**cience consists of observing the world by watching, listening, observing, and recording. Science is curiosity in thoughtful action about the world and how it behaves.**

NASA

The problem with thinking

Thinking is not something most humans do willingly. According to Daniel Kahneman in his book 'Thinking Fast and Slow' we have effectively two systems for answering questions

1. **System One Thinking** is our rapid and automatic response system. It is the one that does not consider alternatives and says what we already know, or what we think we know. Most of us use this the majority of the time.
2. **System Two Thinking** is our slower, deeper way of thinking. We use this type of thinking to try and solve issues we have not considered before.

System One reveals our beliefs. System Two challenges them. Rubbish Scientists need to be able to override System One thinking and rely more on System Two. We are trying to challenge our own as well as others beliefs. Unfortunately, there is a problem. Deep thinking is very heavy on our resources. When we are thinking deeper these things happen:

- Our pupils dilate
- Our heart rate increases
- Our blood pressure rises
- The glucose consumption of the brain increases massively. If you want to lose weight, think more deeply!

For the majority of our ancestors, food was not something always available and certainly not with the high fat and sugar content that many of us have access to today and often consume in excess. We tend to conserve our resources and deep thinking is something that uses them, hence we often have an aversion to it. Careful consideration of ideas or evidence we tend to avoid, preferring to stick to our beliefs and biases. This is one reason why people rarely change their minds. How often do we see an argument on the Internet concluded with one of the parties saying that they now realise that they were wrong?

What do you know?

Stop and think, not just what do you know, but why do you think you know it?

Most of what we know, or think we know comes from personal experience or trusted sources. Unfortunately, we are all prone to biases and are much more likely to believe what we would like to believe, rather than what the evidence suggests we should believe. How do we know our sources are trustworthy? Every time we see a **claim** we need to think **"Where is the evidence?" and** to try and not jump to conclusions before we have thought it through

We have a series of knowns

- **Known knowns** - Things you know you know or at least think you do.
- **Known unknowns** - Things you know you don't know, or at least think you don't.
- **Unknown knowns** - Things you know but you don't realise you know them.
- **Unknown unknowns** - Things you don't know and you also don't know you don't know them.

Learning involves challenging our known knowns and exploring carefully our unknowns.

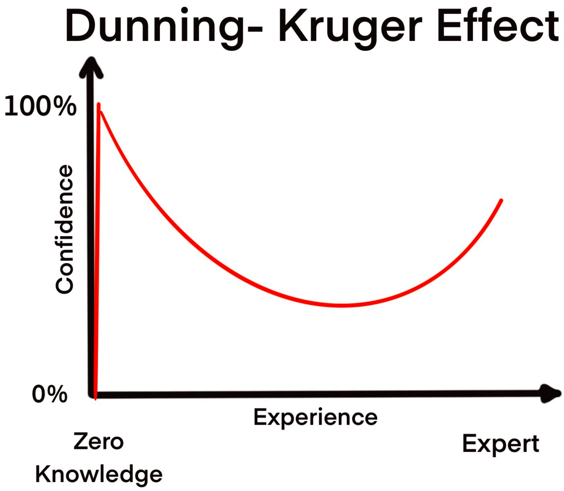
"The first principle is that you must not fool yourself and you are the easiest person to fool."
— Richard P. Feynman

The Dunning Kruger Effect

It may seem obvious that the more competent people get at something, the more confident they become. However, this is not the case. Often as we learn more we realise how much more there is to learn and also how difficult it is to understand concepts we have never really thought about before. As Rubbish Scientists, we need to be humble.

We generally tend to be overconfident in our ability, research suggests males more so than females.

We need to challenge ourselves to consider we might be wrong. Creating an argument that is the opposite of what we believe is a good way of doing this and may lead to new insights. Try to explain this graph to someone else who may be overconfident!



“Ignorance more frequently begets confidence than does knowledge: it is those who know little, not those who know much, who so positively assert that this or that problem will never be solved by science.”

— Charles Darwin

2: GETTING STUDENTS FROM UNDERREPRESENTED GROUPS INTO SCIENCE: THE RUBBISH SCIENCE WAY

Teacher expectations play a large role in students performance and enjoyment.

Once a racial or gender imbalance is in place, it is an uphill struggle to overcome it. We all have unconscious biases that play a role in our interactions. We are more inclined to believe that the person who looks like our idea of a physicist is a better physicist than one who doesn't. It is hard for people in underrepresented groups to break into established structures as there are often few role models in place to follow. Underrepresented groups also suffer from Stereotype Threat - By believing they are less competent their performance is diminished and so the stereotype is reinforced.

Cartoons usually portray scientists as unhinged old white men in white coats doing crazy and often evil stuff in laboratories. Not surprisingly few kids can relate to these stereotypes. Kids shows often perpetuate the crazy scientist trope and this may be entertaining but is not helpful.

Before we address underrepresentation we need to answer the question Why do some people not go into science?

- Lack of access to equipment
- There are many answers some of which are
- Lack of interest, the science is not relevant to my life

- Lack of challenge
- Lack of inspiring teachers
- It's not for people like me

Rubbish Science aims to be as inclusive as possible and accessible and relevant to all. We aim to address the lack of people getting involved in science in the following ways:

As far as possible no specialist equipment is used, the majority of the resources used can be found in rubbish or trash

We aim to make the challenges as relevant as possible to the students' lives. Growing plants hydroponically in plastic bottles to improve health, creating water filters for water security or insulated flasks from waste materials.

The challenge is not just in completing the task, the challenge is in doing the task as well as possible and learning to do it better. There are no limits!

Although all the tasks can be seen as competitive. I have seen some students killing flies to put in their fly trap to boost the numbers! The winner is always the person who has learned the most and we should always focus on the learning.

Inspiring science teachers cannot be replaced with any book or online course. However, when there are no science teachers to hand, Rubbish Science steps in with either live, recorded sessions or written ones like this book. Have a look at some of our other offerings.

The lack of role models in science is a Catch 22 situation. The fewer people from underrepresented groups who become scientists, the fewer role models there are to encourage others from that group to take up science. **Many people believe that people like them do not do science.** A study in the UK found that the majority of girls by the age of six thought science was a boys subject and that boys are better at it than girls. There is considerable research into why in the UK girls tend not to study physics if given the choice.

What might we do?

Creating a **“ladder”** of **role models**

You might think that putting an incredible role model from the same underrepresented group in front of young students would inspire them to want to do the same, but often it does not. The reason why is that these amazing people seem so far removed from what the young students think they are capable of that they have little effect.

How might we deal with this issue?

The answer is to deliver inspiring Rubbish Science sessions to the youngest students by a group of slightly older students from the same underrepresented groups. These older students are taught how to deliver these by another group of even older students and these are taught by … and the ladder goes on as high as possible. The ones at the top of this chain are trained by Rubbish Science trainers in our **Train the Trainer Programme.**

This is called **Rubbish Science Ambassador Training** and is not to be confused by other groups Ambassador Training!

Gender and Rubbish Science Workshops

Gender differences are an emotive topic. There are bigger differences between those of the same gender than those of different genders. We should never expect anyone to behave in certain ways because of their gender or ethnicity and try to put any biases aside. However, research in the UK suggests that boys may dominate science conversations and often you will find mixed groups of students doing a practical with the girls recording and the boys doing the hands on stuff. I have been fortunate to work in many parts of the World and have found a consensus of agreement that we **tend** to bring our boys up to be brave and to take risks. Girls are usually brought up to be good, ideally perfect!

For practical science sessions, you might end up with some boys doing all sorts of things they are not supposed to be doing without thinking and girls paralysed with a fear of failure.

If they don't know what to do, boys will tend to do something, girls nothing. If you have been brought up to take risks Rubbish Science activities with the freedom to make decisions is wonderful. If however, you are always trying to make sure you are doing the right thing, freedom can cause anxiety. If it is important to you for people to think you are clever or perfect then your performance always needs to be brilliant. The uncertainty of Rubbish Science is like a tripwire to these students. High academic achieving students often do not like Rubbish Science activities as it takes them out of their comfort zone. These students will often ask a lot of questions as to whether they are doing it 'right.' Be supportive of them and they will eventually learn to flourish when faced with uncertainty.

Should you keep boys and girls separate? I would prefer not to but you need to keep a close eye on the group dynamics if you do not. Some boys may tend to dominate but do not consider that all boys will.

An example workshop of how we might get girls to think science is done by people like them,

A group of seventeen-year-old girls were shown a range of experiments from our **Curiosity Inducing Ideas** chapter and taught **How to be a Scientist.** From these activities, they were asked to create a session for ten-year-olds to make them engaged and curious in science. However they were not to deliver the session themselves, they had to train a group of six, fourteen-year-old girls to deliver it and work with them to plan the delivery.

The seventeen-year-olds were nervous at the start of the day, but their nerves seemed to go when they did their training. The group of fourteen-year-olds were now the nervous ones. The oldest students supported their trainees and watched proudly as they delivered their sessions in pairs to groups of ten of the youngest students. Again the nerves seemed to disappear and the girls grew into their roles, often the quietest students impressed the most. These days have always been a resounding success and the best feedback of all is from the students who say ' **I didn't think I could do that!'** Removing self-imposed limits is one of the aims of Rubbish Science.

This cascade approach is incredibly efficient and hugely scalable. I might train twenty students who then can train one hundred and twenty students to deliver sessions to six hundred students and at each stage is a role model doing cool stuff in science encouraging younger ones to engage.

If you are interested in this program please get in contact.

I learned very early the difference between knowing the name of something and knowing something."

— Richard P. Feynman

3: CURIOSITY - AN ESSENTIAL INGREDIENT OF LEARNING

CURIOSITY

It is said that curiosity killed the cat and it has probably killed a fair few scientists. Curiosity is the driver of discoveries and is essential for Rubbish Science students if they are to challenge themselves. If all of the questions you ask or are asked in your classroom can be answered by Google or an AI device then you are probably limiting your students or being limited.

The important thing is not to stop questioning. Curiosity has its reason for existing."

Albert Einstein

What is **curiosity?**

Simply the desire to find out more. We stimulate curiosity by creating a knowledge gap that learners want to fill. Research suggests that provoking curiosity seems to prime the brain for learning, So if we make our students curious before we teach them the boring stuff, they will remember the boring stuff better than they would have done if we hadn't provoked it.

How can we provoke curiosity?

Clickbait works by giving enough information to make us curious, but not enough to satisfy it. We click on the link It promises much and rarely delivers. We can use some of these techniques in a purely positive way.

How can we use this psychology ?

Curiosity can be triggered by using the curiosity inducing experiments outlined later.

Other ways of creating curiosity in science lessons

- Starting lessons with - **What might happen if ....?** These can produce some amazing answers. It is also very useful to think about extremes what might happen if something was very light or very heavy for example
- Getting students to make a prediction, then listening to and challenging other peoples predictions. This can make them invest in the answer. Delaying telling the answer provokes interest and annoyance. This technique uses the **Zeigarnik effect**. We have more interest in incomplete tasks. It is the reason why TV series leaves us with a cliff-hanger at the end of each episode to ensure we carry on watching So leaving your students in suspense is a very effective learning tool. We should attempt to annoy our students to provoke thinking. We must be careful though.

The younger the student is the shorter the time we should leave them pondering. If we leave it too long they have probably forgotten it. Too short and they haven't had enough time to think it through. The sweet spot is for the skilled teacher to find.

There is no single definition of curiosity. Astrophysicist Mario Livio in his book Why? outlines three different types of curiosity

1. **Perceptual Curiosity** - That feeling when something unexpected happens a surprise that may or may not be positive. We try to find information to remove the discomfort that this type of curiosity can cause. Like scratching an itch it is something we are driven to do rather than for the pleasure in its own sake. Horror films rely on perceptual curiosity with some people loving them and others hating the feelings evoked. Some people love surprise parties and others do not.
2. **Epistemic Curiosity** - This is an entirely positive curiosity. That feeling of anticipation whilst expecting a reward. This is the type of curiosity that is entirely intrinsic, learning in itself is the reward. Epistemic curiosity can bring a lifetime of pleasure in discovery, whether it be through the arts or sciences.
3. **Specific Curiosity** - This curiosity drives us to find information such as the name of a band or the capital of Sierra Leone. The internet is perfect for satisfying this type of curiosity. Rubbish Science activities are such that the internet is unlikely to have the answers to the challenges and the only way of sating your specific curiosity is by finding out yourself.

One of the barriers to delivering Rubbish Science activities are that many of our students find **perceptual curiosity** unpleasant and they can shy away from it. These students are often very successful traditional learners and do well in exams. They like to know exactly what to do and would far prefer to carry out an investigation that is mapped out for them, recipe style rather than an open-ended exploration where no one knows what the outcome will be. Rubbish Science is challenging for these students as it takes them out of their comfort zone. High achieving girls may seem particularly prone to anxiety when faced with a task that there is no clearly defined correct way to do things. These students need support and scaffolding to develop the skills needed to deal with uncertainty. Other students may enjoy the perceptual curiosity created when surprising results make them have to rethink their ideas. Science in mainstream science classes may never trigger perceptual curiosity if everything is taught in a way that nothing is unpredictable. Possibly one of the reasons why some students find science lessons boring is that their perceptual curiosity is never triggered.

Epistemic curiosity is partly genetic in origin. We seem to have natural drivers for the pleasure of learning, but it can be developed given the right curriculum. Sadly time constraints can mean that we cannot explore our student's interests. We need to be careful not to stifle epistemic curiosity. Starting lessons with "**What might happen if....?"** gives a chance for students to unleash their creativity and ideas triggered by their curiosity. Research suggests that as students get older they maintain an interest in science, but lose interest in science lessons. Rubbish Science aims to allow epistemic curiosity to run free. Investigations may answer but always generate another question too. Our investigations are never finished.

Specific curiosity can be sated instantly by asking Siri or Alexa or Google and many students are not used to having to put the effort in to find out things. Nor do many see the need to remember information that can be easily looked up. Specific curiosity can be triggered by challenging students to predict what might happen when the answer is not obvious or even better counterintuitive. An example is the juice cartons in the image below. One is full, one-half full and the other is empty. They are all pushed at the same time. What order will they fall over in? We can crank up the curiosity value even further by getting students to make a prediction and then find people who disagree with them and trying to decide who has the right idea.

How might we do that?

What order will the cartons fall in as they are pushed over?

An Example: Some maths questions for you to do

1. What does 2 + 2 =
2. What does 21 + 47 =
3. What does 21 x 47 =

So what are the answers?

How many did you do?

I delivered a five-minute session to a large audience who did not know each other and asked them those questions.

Everyone answered 2+2 and shouted out 4 (System 1 thinking)

Most shouted out 68 as the answer to 21 + 47 - The ones that didn't admit they thought others would answer it first. We need no hiding places in our classrooms that allow students to not participate.

The vast majority sat and smiled at me rather than answering 21 x 47   I explained to them that they were choosing not to use System 2 thinking and why we don't think deeply unless we have to or curiosity is provoked.

I then showed them the juice cartons in the image on the previous page. One is full, one-half full and the other is empty. They are all pushed at the same time. What order will they fall over in?

What answer would you give?

Giving them no time to think deeply I asked which would be the most stable, the last carton standing and to

- Put up their left hand if they thought it was the full one
- Put up their right hand if they thought it was the empty one
- Put up both hands if they thought it was the half-full one

Keeping their hands up they then had to find someone who had a different answer and to try to work out what the correct answer probably was.

Having stopped them I asked how many of them had changed their mind. Out of 450 in the audience. Only a handful had. Once we have a belief we are reluctant to change our minds, even more so if we have publicly stated it.

I then told them that my time was up and I had to go. There was complete silence! People were outraged that I wasn't going to tell them the answer.   I pointed out that if I told them the answer they would stop thinking about it and I was going to leave them with the knowledge gap.

Some people think for science to be engaging they need big flashes and bangs, but you can do it with three cartons. Nearly all of them agreed I was the most annoying speaker they had heard for some time!

So what order will they fall in?

If I were to tell you the answer you would stop thinking about it!

4:0 DEALING WITH FAILURE

How does failure feel to you?

How about public failure?

Some people seem to be immune to failure, they simply smile, shrug their shoulders and move on. To others, failure in public is potentially devastating. Surveys regularly show that people fear public speaking more than death. The thought of appearing foolish to others is something that can prevent us and others from sharing brilliant ideas. We should not follow the adage' It is better to keep your mouth shut and be thought a fool than to open it and prove you are one!'

It is not only concern about ourselves that can cause reluctance to contribute or to get involved. Many brilliant girls and women have told me they are reluctant to put their ideas across in case people think that females are not good at physics. If you feel you are representing a group then the pressure will be even greater, You can try and combat this by asking people who admit to being terrified of failure to stand before others and to fail. The curiosity inducing ideas are ideal for this. When they fail the rest of the group applaud and congratulate them. Bravery is not the absence of fear. It is feeling the fear and doing it anyway. A life spent in fear is a limited life.

What can be done?

If we are to teach others to not be afraid of failure, we have to analyse ourselves first. When do we feel that we can cope with pressure and when does it all seem too much? A footballer stepping up to take a penalty in front of millions of viewers seems immune to the idea of failure. That same footballer may be terrified of saying a few words in an interview afterwards. On the football pitch, they are confident, they have practised penalties over and over and are experts. They have not practised interviews and so feel vulnerable.

It may be helpful to look at extreme positions. An achievement motivated mindset versus a failure avoidance one outlined in the table. Can you recognise yourself?

Achievement Motivated	Failure Avoiders
Thrive on challenges and continue trying to solve them	Embarrassed by failure and seek to avoid or give up easily
Take individual responsibility for the success or failure	Quick to blame others or circumstances, procrastinate or can self - handicap (I didnt work for it ..) behaviour
Motivated by challenge and see it as an opportunity	Sees challenge as a threat
See working hard as dedication	Feel stressed
Feels can improve skills and tries different strategies	See skills as fixed and can be helpless
Sees initial failure as a learning experience and is not put off - optimistic	Sees initial failure as a shape of things to come - pessimistic

No one is a failure avoider or an achievement motivated person all the time. What is important is to recognise when we might fall into failure avoidance and to drag ourselves out of it. If you can get your students to share times when they felt achievement motivated and when they suffered failure avoidance it may help them in the future.

As Rubbish Scientists, they can only ever fail if they fail to learn. What does **FAIL** mean?

First
Attempt
In
Learning

You might want to celebrate failures and have a failure of the day award.

Note: Students who have been brought up being told they are clever can be the biggest failure avoiders as they feel pressure to be seen to be clever at all times.

4:1 RESILIENCE - THINKING ABOUT EVIDENCE RATHER THAN BELIEFS

How can we apply the ideas of evidence-based thinking to ourselves and our interactions with others?

Resilience is the ability to deal effectively with adversity. Some people appear to be better than others at this. `Whether you are fragile or as hard as nails, resilience can be improved by taking a scientific evidence-based approach to your problems
We have to be very careful delivering this session as strong emotions can be provoked. We are just concerning ourselves with thinking flaws and how we might get better at dealing with things that cause us stress. To try to think rationally rather than emotionally to solve problems.

Emotional Reasoning is the opposite of evidence-based thinking. Emotional reasoning is about beliefs that may be unfounded. The problem is when the pressure is on we tend to move away from logical thinking and lapse into emotional led behaviours that are seldom a match to reality. If we can identify our thinking flaws and carefully analyse our behaviour we may be able to stay out of emotional reasoning or at least correct ourselves to think more rationally.

Eight thinking flaws: for each of these give yourself a score of 1-10 with 1 being nothing like you and 10 being exactly like you.

1. **Conclusion Jumping:** We are all prone to deciding what we think has happened without having real evidence to support our view. This belief then steers our thinking and interactions with others, sometimes disastrously. We need to consider what do we know and how do we know it. What other reasons might there be? It is wise to never put down to malice what could be explained by stupidity!
2. **Tunnel Vision:** We fail to see the bigger picture and focus only on one area. Usually, this is a negative aspect of our life and we can make fairly small problems the whole focus, ignoring all of the positives. A small detail can ruin what should be a lovely experience. Alternatively, we can be blinded by a single positive and rush headlong towards a crash by failing to see negative issues.
3. **Maximising and Minimising:** This is the tendency to be a doom and gloom merchant or an unrealistic optimist. Neither of these is healthy, but people who radiate negativity tend to be those others do not want to be around. We are all prone to mood swings and we need to be able to accurately analyse ourselves which is difficult.
4. **Personalising:** Personalisers focus everything on themselves There are no external events that have caused failures just the way I dealt with them. Sometimes we have violated the rights of others which is what causes the deserved feeling of guilt. For personalisers, though most situations trigger guilty feelings and with it a lack of confidence and self-worth.
5. **Externalising:** The opposite of personalising. We all have blamed others or external events for failings we really should have admitted were our own. Some people blame everything on external events and never take any responsibility themselves. These people rarely feel sadness or guilt, but instead are prone to anger. Relationships between personalises and externalises can

be unhealthy and toxic with the externaliser angrily blaming the personaliser for everything and the personaliser living a life of unhappy guilt.

6. **Overgeneralising:** This can be where our biases, sometimes unconscious ones kick in. We can make blanket generalisations often about groups. These may be positive but are more often negative. The truth is nearly always more complex than we believe it to be. The tendency to overgeneralise is often partnered with personalising.

7. **Mind Reading:** Most of us think we are pretty good at this. We can work out what people are thinking based on our intuition. Research suggests that we are terrible at it. When we combine mind-reading with conclusion jumping we are on a slippery downward slope to misunderstanding.

Thinking Flaw	**Score**	**Possible ways to combat the flaw**
Conclusion jumping		Slow down and consider the alternatives. Where is the evidence for your conclusion?
Tunnel Vision		Try and see the big picture. What positives (or negatives) might you be missing?
Maximising and Minimising		Are they really such big problems? Are you missing something? Are there any threats? What is the worst that could happen?
Personalising		Am I really responsible. What other factors are affecting this situation?
Externalising		Ask yourself. Could any of this issue have been caused by my behaviour? If the answer is always no you may want to reassess yourself!
Overgeneralising		Is the situation as black and white as you are thinking? What shades of grey are there.
Mind Reading		Just don’t trust your intuition without finding out more information. Where is the evidence for your conclusion?

You may want to run this or a simplified version with your students. Be careful though as some may have every reason to be unhappy.

5: SAFETY AND RISK ASSESSMENTS

You will need to carry out your risk assessments.

For the activities, safety points are highlighted but the responsibility for safety is yours. Rubbish Science can accept no liability for any damage or injuries.

Whatever the age of the students it is important to carry out risk assessments and to get your students to learn the art. At Rubbish Science we split it into four parts

1. What is the hazard?
2. Who might be affected and how?
3. How likely is it to happen?
4. What can be done to reduce the hazard?

We have to balance risk against the reward for doing the task. Remove all the hazards and we also tend to remove all the excitement. Going too far the other way and we risk damaging the health of our students with a dangerous activity.

We need to do a **cost/benefit analysis**. What are there likely costs and the chance of hazards impacting our students versus what is the learning reward for carrying out the investigation? Practicals for the sake of doing something practical should always be avoided. Always focus on the learning.

When doing risk assessments need to take into account the biggest effect the hazard could have and multiply it by the likelihood of that happening to get a true risk. The higher the risk factor the more important it is to try and control that hazard. Sometimes though we cannot, take the example below of driving the students in a minibus to an activity. The worst-case scenario is death, the chances of this happening are very small and we can reduce those chances by checking the condition, the weather and enforcing the wearing of seatbelts. What we cannot control is the actions of others. These events outside our control make assessing the risk harder

Hazard	**Who might be affected and how?**	**How likely is it to happen?**	**How can we reduce this risk**
Driving minibus	Crash might injure or kill staff, others and students	Very unlikely	Check condition of minibus. Check weather Ensure all passengers wear seatbelts. Have a plan in case of accidents
Growing plants in compost (Bottle tower)	Microbes in compost could cause illness	Medium	Use sterile compost if possible. Wear gloves if possible. Wash hands carefully afterwards

The second example of using compost has the hazard of microbes being ingested or entering cuts. This has a smaller impact than death but is more likely to happen. Risk assessing this for students using sterile compost in a laboratory is likely to be different to carrying out the same activity on a dump with homemade compost and no hand-washing facilities.

I deliver the science of surfing sessions. To some people surfing is highly dangerous, indeed the worst-case scenario is students drowning. But, if I am careful about the tides, rip currents and am in an area where powered craft do not operate and have trained lifeguards then the vast majority of the risks can be controlled. Surfing with an instructor is an activity that has a high **perceived risk**, but in reality, is fairly **low risk** making it an exciting, but not risky activity. Going in a minibus probably has a higher real risk, but as it is familiar it has a lower perceived risk and is not exciting. If the conditions are not safe then we will not do the activity. Always be very cautious about risks you cannot control.

If you are delivering these sessions outside of a secure classroom environment can you ensure the safety of your students? One of the biggest risks that are hard to control is the action of humans

THE DIFFICULTY IS GETTING THE BALANCE BETWEEN BALANCING RISK AND REWARD. EXCITING LIVES ALWAYS ARE RISKIER THAN BORING ONES, BUT SOMETIMES ARE SHORTER!

6: CURIOSITY INDUCING IDEAS

We covered the reason why curiosity is so important earlier. Provoking curiosity has been shown to improve subsequent learning no matter how boring it is. These activities are part of the toolkit for inducing curiosity. They can be used at any point during Rubbish Science sessions, but are often best at the start and the end of sessions. The reason for this is the primacy and recency effect. We remember things at the start and the end of activities more than we do in the middle, so it is usually best to load the session at the start and end with the most engaging activities. Here are 10 to get you started

1. Matchbox and coin /knitting needle and apple to show inertia
2. Push matchbox to stand up
3. Tablecloth pull
4. Stability of falling cartons
5. Cup and feather
6. Flying tea bag
7. Paralysed finger
8. Glass of water as a lens
9. Helium straws
10. Straw oboes

Matchbox and coin

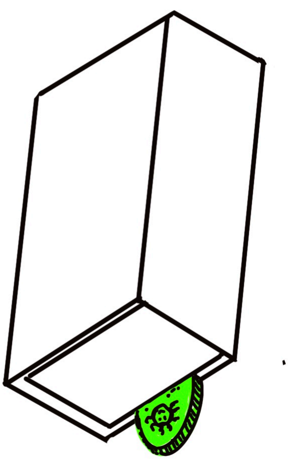
Activity: Matchbox and coin - Can you make a coin travel up a matchbox without touching the coin or turning the box over?

Topic: Forces Inertia

Equipment:

- Empty matchbox - any size
- Coin -slim large coins work best

What you might do:



Coin challenge -What might you do?

Push the coin into the bottom of the matchbox so it is between the base of the drawer and the cover. Hold the matchbox so the coin is at the bottom.

Challenge the students to make the coin come out of the top of the matchbox, but they cannot touch the coin, nor turn the box over. They will fail!!

Simply tap the top of the box and the coin will appear to magically rise and pop out of the top.

Safety: ***Note: You need to carry out your risk assessment.***

- Ensure there are no matches in the box
- Coins may be dirty - wash hands afterwards

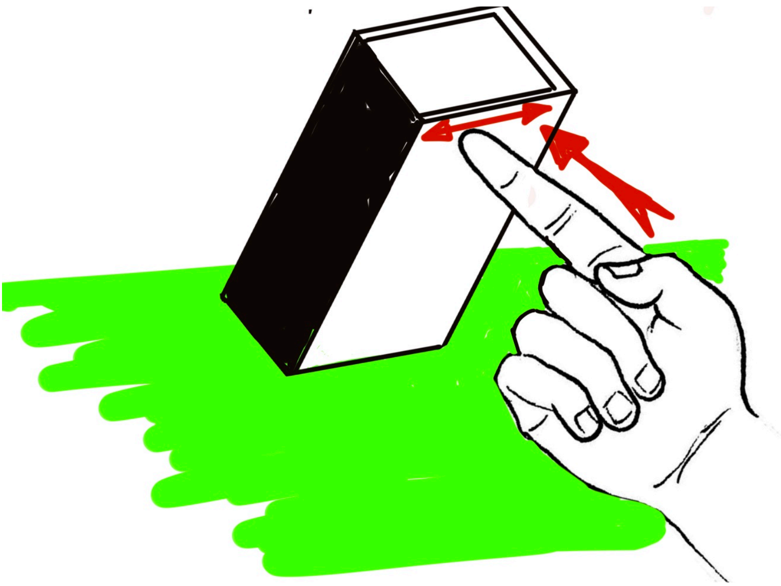
What is the science behind it?

There is a force exerted downwards by the tap so the coin can't do what it appears to be doing and have it’s motion change and move in the opposite direction to the force. What is happening is that the coin has greater inertia than the matchbox and so when the box is tapped it moves downwards as well as the box but it moves less than the box does. Friction between the box and coin changes from a state of grip to slip, then back to grip. Each time we tap we lift the box again so there is an apparent motion upwards by the coin whereas in reality the box is just moving downwards more than the coin is.

Matchbox push

Activity: Make a matchbox stand upright. Ensure you succeed and your opponent fails

Topic: Forces Stability, the centre of mass



Push a Matchbox to make it stand on end

Equipment:

- Empty matchbox - any size

What you might do:

Simply push a matchbox up from about 45 degrees to upright. Pass the matchbox to your opponent and challenge them to do the same. This is so simple, yet brilliantly effective as they will fail. Matchboxes are heavier on the side that has the bottom of the drawer against it. When you push up the matchbox you have the heavier side pointing towards you. When you pass it to your opponent who is sitting directly opposite you you do not turn the matchbox round. They have the lighter side pointing towards them and so the matchbox topples over. Make it better by waggling your finger and making sucking noises that have no effect whatsoever, but distract your opponent from the true reason.

Safety: ***Note: You need to carry out your risk assessment.***

- *Ensure there are no matches in the box*

What is the science behind it?

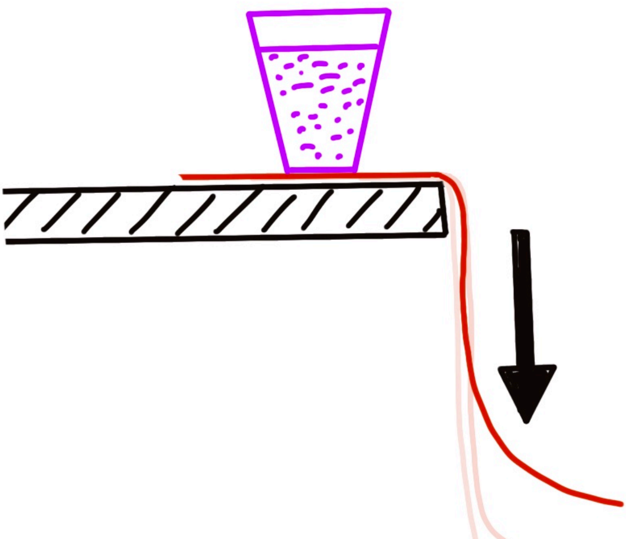
The centre of mass of the matchbox is not central to the box. When you push it most of the mass is on your side so it is biased towards you. When your opponent pushed it from the other side the centre of mass is biased away from them and so the box has sufficient inertia when moving that it falls over

Tablecloth Pu; ll

Activity: Tablecloth pull: Challenge Can you leave the cup of water standing? This works well with an analysis of the "Popes Tablecloth Pull " on Youtube - Is it real?

Equipment:

- Cloth without a seam or paper
- Plastic cup
- Water



Pull Downwards!!

What you might do:

Put the cap on the cloth and pull slowly. The cup will move along with the cloth.

Tug the cloth sharply downwards (not outwards) and the cup will stay in place

Adding water to the cup makes it easier as the greater mass has more inertia. Although it is much more stressful for the student and much more fun for everyone else.

Safety: ***Note: You need to carry out your risk assessment.***

- *Do not use anything breakable or sharp (have had a metal fork impale my eyebrow leading to spurts of blood and screams from the audience)*
- *Be careful of water on the floor - slipping hazard or close to electrical items or sockets.*

What is the science behind it?

Many people suppose that it is friction that is affecting it, but friction is a property of the surfaces and the weight exerted on the surface. The longer a force acts on an object the greater the change in motion of that object (Impulse: $Ft = mv - mu$) by making the force act for as short a time as possible the change in motion will be as small as possible.

Extension: Can you leave a marker pen standing?

Can you pull a note out between two plastic bottles - Is it easier if you fill them with water? Why?

Can you pull out a note from below an empty plastic bottle? You can cheat here by rolling the paper up and slowly pushing the bottle towards the edge of the paper (you can do this with cloth but it is harder

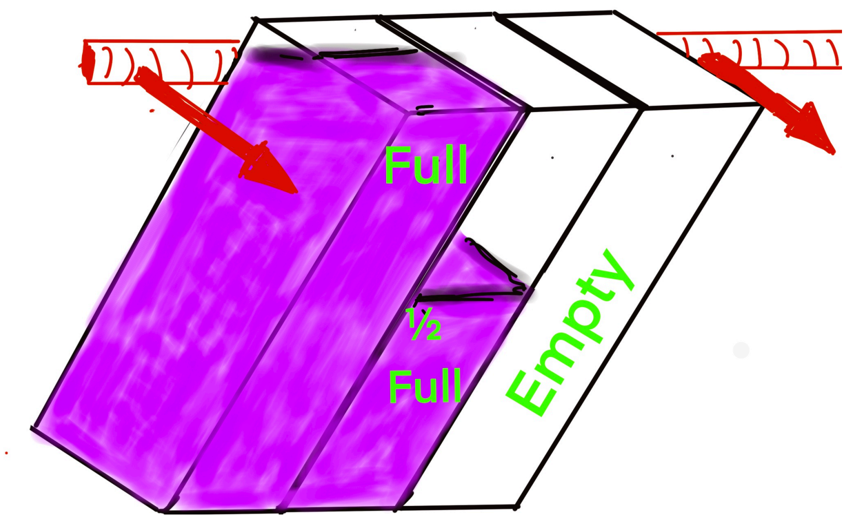
Stability of falling Cartons

Activity: Stability of full, half full and empty juice cartons

Topic - Forces - Stability centre of mass

Equipment:

* full, half full and empty juice carton



What order will they fall in?

What you might do:

Have a full, half full and empty juice carton together in a line. Using a ruler or straight object push them all at the same time. Get your students to predict what order they will fall in and why.

Safety: ***Note: You need to carry out your risk assessment.***

- *Be careful of water on the floor - slipping hazard or on electrical items*

What is the science behind it?

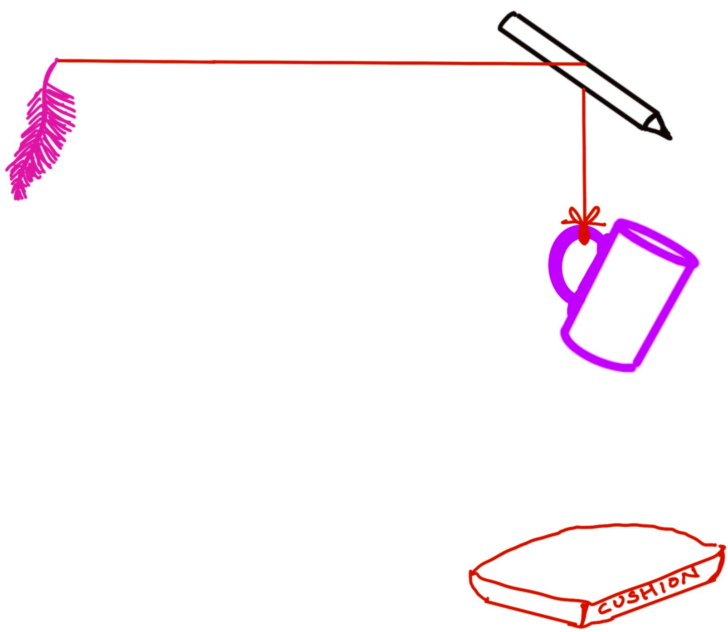
Objects fall over when a line drawn vertically from their centre of mass passes over the edge of their base. The full and empty cartons have a centre of mass halfway down them in the same place and will fall over together. 9This is not intuitive) The half-full one has a lower centre of mass and so is more stable and falls over last

Cup and Feather

Activity: Cup and feather on a string. What happens when you let go of the feather?

Equipment:

- Cup or mug (not one of your favourites as they might get broken)
- String about 1 metre long
- A feather, paperclip or key
- A pencil
- A cushion or soft bag



Dont forger the cushion!

What you might do:

Tie the string to the cup and the other end to a feather (or key or paperclip) Hold the feather and have the cup suspended by the string over the pencil that you are holding in your other hand. (see the diagram)

Have a cushion under the path of the cup in case it goes wrong

Ask your audience what will happen when you let go of the feather. It seems obvious that the cup will crash to the ground.

Let go and see what happens!

Safety: ***Note: You need to carry out your risk assessment.***

- *The cup might fall on your foot*
- *The cup could break causing cuts*

What is the science behind it?

As the cup falls it accelerates towards the ground. This also accelerates the feather that it is tied to. The feather has momentum and will spin around the pencil and this will lock the string, preventing the cup from falling to the floor.

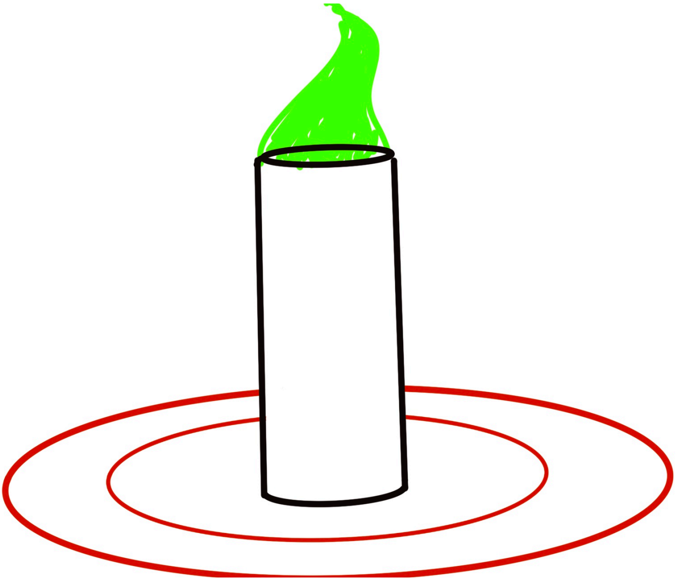
Note: If you let your pencil droop you will fail as the string will drop off! Keep it horizontal!

Flying Teabag

Activity: How can you make a teabag fly?

Equipment:

- Teabag - stapled type
- Matches
- Plate



Ensure that there are no draughts!

What you might do:

Ask your students how many ways they might make a tea bag fly. Tell them you can do it without touching the teabag or exerting a force on it.

Take the tea out of the teabag so you have a long cylinder. Put the cylinder onto the plate. Ensure there are no draughts.

Set fire to the top of the teabag. Watch as it burns down before reaching the point where it flies.

Safety: ***Note: You need to carry out your risk assessment.***

- *Put it on a heat-proof saucer*
- *The teabag could fall over so ensure it cannot set fire to anything.*
- *There will be a flaming teabag briefly in the air*

What is the science behind it?

As the teabag burns its mass and therefore its weight (the force downwards due to gravity) gets smaller. At the same time, the heating effect creates a convection current that exerts an upwards force on the teabag. When it reaches the point where the upwards force is greater than the downwards force the teabag flies.

Paralysed Finger

Activity: How can you paralyse your ring finger?

Equipment:

- coin

What you might do:

Have students bend their middle fingers and push down on the table or desk. Put a coin under their 3rd finger (ring finger) and tell them if they can lift their finger off the coin they can keep it.

Safety: ***Note: You need to carry out your risk assessment.***

- *Coins may be dirty - wash hands afterwards*

What is the science behind it?

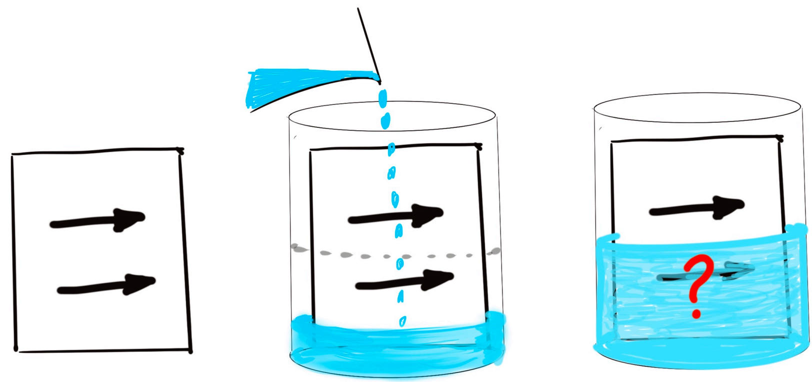
The way our fingers work there is no way that this finger can be lifted when the middle finger is bent. The reason for this is that the ring finger and middle finger share a tendon by bending the middle finger that tendon becomes stretched and cannot move paralysing the ring finger,

Glass of water as a lens

Activity: What **happens to the direction of the arrows when a glass of water is filled?**

Equipment:

- Paper with two horizontal arrows one above the other pointing the same way
- Cylindrical glass
- Water



Draw 2 arrows On paper

Put a glass in front and half fill it with water

What happens to the bottom arrow? Why?

What you might do:

Put the paper up behind the glass so that the arrows can be seen through it. As you fill the glass the arrows will point in the opposite direction to before

Safety: ***Note: You need to carry out your risk assessment.***

- *The glass might break and cause cuts*
- *Water may spill on the floor and create a tripping hazard.*

What is the science behind it?

As the water fills the glass it acts like a lens and so the rays are refracted. This creates an image that appears reversed.

Helium Straws

Activity: Helium Straws - Can a group lower the straws to the ground whilst keeping all fingers in contact?

Equipment:

✻ Straws or something that can make a long but very light stick, Reeds can work well

Note: This activity works brilliantly if it is done properly and the students do not cheat

What you might do:

Have students in groups of 8 or more line up facing each other and supporting the straw on their index fingers. They place their thumbs over the top of the straw to hold it in place. When they are all ready they lift their thumbs and try to lower the straw to the ground **keeping their fingers in contact at all times.** The straw will go up and they will get annoyed and confused. When they realise it is impossible. get them to see how many ways they can solve it by bending the rules and thinking differently.

Safety: ***Note: You need to carry out your risk assessment.***

- *Ensure there is enough space to carry out the activity*

What is the science behind it?

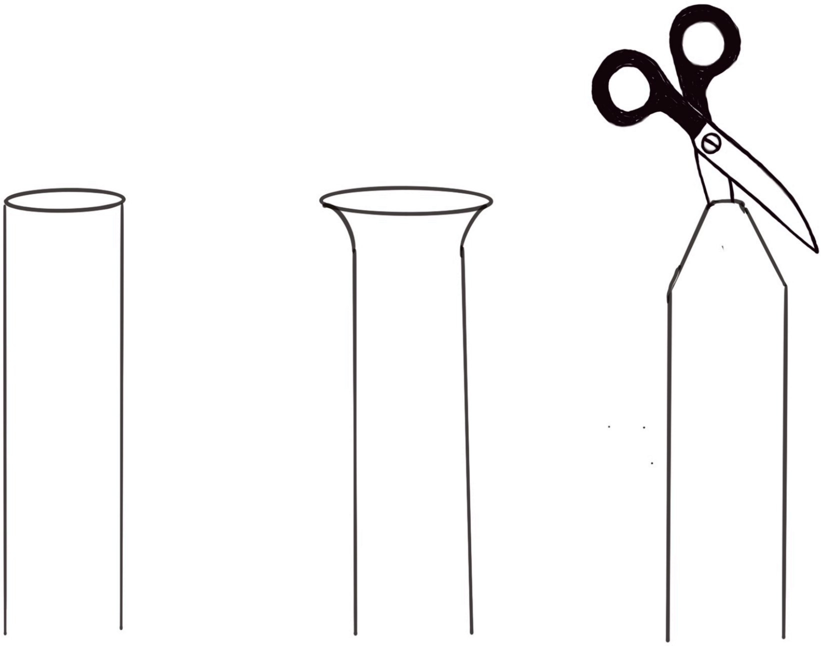
The straw is very light so there is a very small force acting downwards, it's weight. As the students lose contact with the straw as they try and lower it and then make contact again the upward force is greater than the weight and the straws move upwards.

Straw oboes

Activity: Straw Oboes - Can you play a tune with straws?

Equipment:

- Straws
- Scissors



What you might do:

- *Flatten the end of a straw*
- *Cut a V shape at the end of the straw*
- *Put the V-shaped part in your mouth and blow until you have a sound.*
- *Cut the straw as you are playing and the note will change*

Safety: ***Note: You need to carry out your risk assessment.***

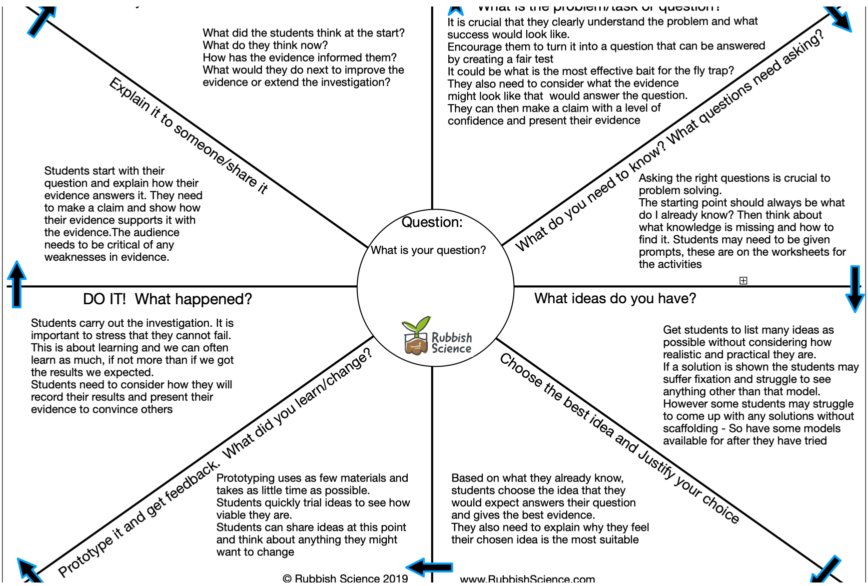
- *Take care with the scissors*
- *Hygiene with. Straws Ensure they are clean and not shared*

What is the science behind it?

The oboes produce a sound from the vibrations in the air column along with the straw as you cut the straw the columns become shorter, the wavelength becomes shorter and the frequency is higher.

7: USING THE DESIGN THINKING TEMPLATE

You may wish to use the design thinking templates with your students. These are available to download on the links below as a blank pdf or one with teacher prompts



The Design Thinking Template

What is the **Task or Question?**
We have to be very explicit about this and spend a long time ensuring that we understand what we are investigating and why.

Always start with the idea that scientists generate a question, create a fair test that can answer that question. They then carry out an investigation and analyse the results for evidence to see if their question has been answered. Finally they assess the quality of this evidence to state a degree of confidence in whether the claim was correct or not.

It is worth reiterating that we want to be able to show someone else what we found out so are looking for good evidence. So we need to ensure if we are doing a test that it is a fair test.

How could I show evidence to answer a question/support a claim that ...

- Am I a faster runner than you?/ I am a faster runner than you
- Which is the best washing liquid? / This washing up liquid is better than that one
- Am I smarter than you? / I am smarter than you!
- Do birds prefer a bigger bird feeder to a smaller one? / Birds prefer a bigger bird feeder to a smaller one

Note: that questions are usually less annoying than claims!

Remind students that the more evidence we have the more reliable the results will be. You can use the way reliable is used in everyday language. What does reliable mean?

Reliable: *consistently good in quality or performance; able to be trusted.*

What does consistent mean? - It does the same thing over and over again. Reliable friends never let you down over some time. You cannot tell if something/someone is reliable from a single trial!

Get your students to explain the task to each other to see whether they think they have the same understanding - This does not always mean they have the right idea!

Task examples

(1) Newspaper Tower

Build the tallest free-standing newspaper tower out of two sheets of newspaper.

You can fold, tear or cut the newspaper. but you cannot use tape or staples or any other kind of support.

- What can you do and what can't you do?
- What would success look like?
- How long does it have to stand up for?
- What question might I generate?

Question for you the teacher: What could go wrong? What might they not understand?

(2) Plastic Bottle Bird Feeder

Make the best bird feeder from only plastic bottles, string and a pencil, piece of wood.

Note: This is an investigation involving multiple variables and is challenging to do well

- What can you do and what can't you do?
- What food is provided?

- How can we feed the birds without the food falling out of the feeder?
- What would success look like?
- What might change the results?
- What question might I generate?

What do I need to know?

A quick brainstorming through the principles that are being investigated. What do I need to understand before I start this investigation?

Create a bullet point list of the task and the key questions.

So for example with the Newspaper Tower activity

- Why do things fall over? - It is crucial that this is understood before the investigation and how the centre of mass affects stability.
- The wider the base. the more stable the tower, but the wider the base the shorter it will be so where is the optimum position?
- What is the best way of creating a long, but strong piece of paper?
- How might I bind the paper together without tape or staples?

This is the area that most support should be given. They are more likely to create a successful investigation if they have a deeper understanding of the concepts. Though you may wish to see what they learn experientially.

Where can we find information?

Scarily many students never even consider asking the teacher
This is an opportunity to revisit the reliability of the information.

- Who will you ask?
- Can you trust them to know the answer?
- Can you trust the information on the internet?
- Should you ask others and see if they give you the same information?
- How might you carry out cross-referencing
- Does all the information agree?
- What conflicts are there?
- How confident are you that this information is correct?

Generating ideas

Some students are much better at this than others, but like most things, they will get more creative the more they practice.

The idea-generating phase does not involve any consideration of the value of the ideas. Just keep coming up with ideas for a few minutes and record them all. Sometimes this can work best to set it as an individual task and then switch it to a group task with students sharing their ideas and others in the group adding to them.

A simple but very effective prompt is to say **"Yes and ….'** where students listen to the ideas agree and then add something. This can add greatly to the idea generation.

Consideration should be given as to whether you show them some solutions or not. Showing solutions can aid them and support those fearful or having no idea how to solve the problem. However, it can lead to fixation. Fixation is where a single idea is all you can think of and it is the one shown to you. Fixation occurs when trying to do crossword puzzles or trying to name a band when ya solution that is not correct gets stuck in your head and you can't think of anything else.

Prototyping

A fundamental part of any effective practice is to carry out quick trial tests to see whether your ideas are likely to work.

Prototyping requires

- **Using as few materials as possible**
- **Using as short a time as possible**

Studies have shown that young children naturally prototype. It is often an integral part of play, trying out little things before building something bigger. It is not a skill that is generally taught or practised in schools so it may take time to develop.

You may choose to have students show their prototype ideas and results before going onto the next stage. It may lead to students incorporating several new ideas into their investigation, or possibly just lead to them all copying what might be considered the best option.

Select your idea

You may do this before or after the Prototyping depending on the students and what you may be trying to achieve.

We now need to apply critical thinking to the ideas

Critical thinking is using reason to make judgements about what idea may be the best.

Questions to ask

- What is the task? Review what you are trying to achieve
- Does it answer the question?
- Do I have the time or materials to carry out all the tasks? Remove those ideas that cannot be resourced.
- What could go wrong? Are any of the ideas dangerous?
- How will the results be recorded?
- What could go wrong?
- How might the results be presented to others?
- Is it a fair test?
- Can I control the variables well enough to get good results?

NOTE: As the teacher, you are responsible for the health and safety of your students. You MUST risk assess and record your assessment. Rubbish Science takes no responsibility

Do It!!

Before you do it you need to think about how you are going to record the evidence or results - Students are often not very good at this and may need support. There appears to be a bit of a gender divide here, with boys getting on with it without considering that they will need to show others what they found out. Some students may be reluctant to start if they are not sure what to do.

SAFETY: You have the responsibility to ensure that any hazards are either eliminated or controlled. There is an inherent danger in allowing students to carry out their ideas in investigations. Always ensure that you know what your students are doing, particularly if you have set an investigation online

Tell Someone

Ideally report to someone outside of your classroom, even better outside of the school.

Depending on the sophistication of your students reporting what happened can be anything from a verbal report up to something like a scientific journal. It may be worth considering the Young Scientists Journal

We need to consider that some of our students are extremely disadvantaged and this aspect is one where they may struggle to communicate their ideas as effectively as their more privileged peers. Suitable support should be given.

What happened?

Investigations that do not give the results you might not expect are not necessarily failures. We should always look at things as learning experiences. Many scientific breakthroughs have been made by accident. Sometimes results can be counterintuitive. The Mpemba effect, named after the Tanzanian high school student who discovered it is a good example. He found that hot water froze faster than cold water. Vv

How might the results be displayed?

Can someone else understand what happened from the way that results are recorded?

How can you convince others that your results are reliable?

What did you learn?

A lot of the activities we might do in the classroom could be seen as competitive. Students compete in the newspaper tower activity to build the tallest tower they can. The winner however is not always the person that has built the tallest tower. It is the person who has learned the most.

Metacognition (thinking about their thinking) is important here. Thinking about their thinking and what progress has been made in understanding. Or what confusion has arisen from the investigation.

- What does the evidence suggest?
- What other explanations could there be for the results?
- How reliable are the results?
- Were any mistakes made?
- How confident am I with what I think I found out?
- How could I increase my confidence?
- What did I use to think before the investigation?
- What do I think now?
- What has changed my belief? (if anything)
- How might I try to convince others who might not believe what I found out?
- How might I use this new knowledge in other areas?

What might you do to find out more?

Many students think that science is about facts and that we already know most things. This could not be further from the truth. Science is a journey of exploration that never ends.

- Where might this journey carry on to?
- Are there other aspects related to it that could be investigated?

✻ Could the experiment be scaled up?
✻ Is there anything useful that can be done with what has been learned or made?
✻ Is there any commercial potential?
✻ How could it be shared with others?
✻ If I had unlimited materials and time what could be done?

EXAMPLE OF DESIGN THINKING - NEWSPAPER TOWER

The **Newspaper Tower** activity is not a usual Rubbish Science activity in that it has no real purpose other than to quickly run through the whole design thinking process in under an hour. It is also fun and very challenging. Using 2 sheets of the tabloid-size newspaper the record for height is 1 metre 20 cm!!. There will be no photos of this as that will lead to copying! As this is the first activity prompt students to think of a question. Whether rolling or folding is the best option for tower building is a good one, but they may come up with their own

The Task: Create the tallest FREE STANDING tower made of only 2 sheets of newspaper. You can fold, roll tear and twist the paper but cannot use anything else like tape or staples. The tower must be free-standing and not be supported by anything else. It must be standing at the exact time the Do it! The section ends for at least one minute.

The Question: Some possibilities: How can we build a strong, tall tower**?** Is rolling or folding the paper the best strategy? What shape should our tower be?

Equipment Provided: 3 Sheets of newspaper - 1 sheet is is for prototyping and 2 are for building and must not be touched until the **Do It!** section. Ideally only give out the prototyping paper and then take it away after prototyping and give them the building sheets.

Health and Safety: You must carry out your risk assessment. Apart from hygiene, this is a very low-risk activity. Check newspapers do not have staples in the pages

Things you might need to know/ Questions you might ask:

- Why do things fall over? - This is essential. knowledge You need to know the concept of stability and centre of mass - Think of the Eiffel tower - How is it made tall and strong? How can I balance the 2 conflicting concepts - Stable things have wide bases, but the wider we make our base the less likely the tower is to fall over, but the shorter it will be.
- How might the paper be made strong? - Is it best to fold it or roll it? Find out in the prototyping!
- How might the 2 (or more if it has been torn) pieces of paper be connected?
- Where is the best place to build it -- The least wobbly surfaces or windy areas.

Prototyping: 5 minutes to trial ideas with the single sheet of newspaper given for prototyping. Do not touch the 2 pieces of newspaper that are for the building!

Note to teacher: You may want to allow prototypes to be shared and the thinking behind them outlined.

Modifications: What did you learn from the prototyping. What might you do better? Do you have enough evidence to answer your question yet? What more evidence might you need?

How might you modify your designs based on what your preliminary results look like? What have others done and what can you learn from them? Is there any evidence from others that might help you answer your question?

Prediction: What do you think will happen and why?

Do it: You have 5 minutes to build your tower

What happened?: Was your tower effective? Did you answer the question? Remember that failure is a learning experience and you might learn more when things have gone wrong than if they didn't.

Tell Someone: Explain what you did and why you felt your tower was effective or why it was not. Listen to others do they have any good ideas?

What did you learn? What do you know now that you didn't know before you started this investigation?

Tell Someone: Explain what you did and why you felt your tower was effective. Listen to others do they have any good ideas?

Extension/Modify/Do it again: How could you extend this to build a better tower? How might the ideas gained be used somewhere else? How well do the towers stand up to wind or earthquakes?

Possible Models – How can you optimise the design?

How does this relate to the Real-world? When could this be of use? : Understanding stability can improve the ability to build structures, but also sporting performance.

Essential Knowledge.

Mass is the amount of matter in an object measured in **kilograms**. **Weight** is often used in everyday language when mass should be used. Weight is the force exerted downwards due to gravity measured in **Newtons.** If you went to the moon your mass would stay the same, but your weight would be less **-** The number of bits in you would not change on the moon, but you would weigh less as the force of gravity is less on the moon.

The centre of mass or centre of gravity is the point where all of the **mass appears to act.** It can be thought of as the balance point in three dimensions. Or the point at which an object will rotate around if it is spinning.

An object will fall over when the centre of mass is no longer over the base of the object.

The wider the base and the lower the centre of mass the more stable an object is.

Humans have a centre of mass round about their belly button in the middle of our body We fall over when our belly button goes past where our feet are. We can make ourselves more stable by widening our base - Putting our feet further apart and lowering our centre of mass. Students can try putting their bodies in different positions and you can **carefully** push them to see how easy it is to push them over. What are the least stable and most stable positions? Why is this useful to know? Walking involves letting your centre of mass move past your base, effectively falling over and then stepping to recover. This is one of the reasons why babies take so long to learn to walk. Quadrupeds like horses and cows don't have this problem

Look at how people stand or move in different sports.

Making Centre of mass toys that balance on one part. If available balance two forks and a match on the side of a glass,

High jumpers doing the Fosbury Flop do not get their centre of mass over the bar

A skateboarder or BMX rider get the front wheels off the ground by lever action for a skateboarder and by pulling the handlebars. The back wheels come off the ground by making the board or bike rotate about its centre of mass

Having explained the centre of mass return to the question. What order will they fall in?

It is not intuitive that the full and empty cartons have a centre of mass in their centre. So as the centre of mass is in the same place land the bases are the same width they will fall over at the same time. The half-full one has a lower centre of mass and hence is more stable and will be the last to fall.

EXAMPLE OF PROTOTYPING - BIRD FEEDER

This activity is outlined later in the book, but it is included here as an example as to how new questions appear that may be more interesting than the original one.

Four prototypes were created just to test what might happen. Remember prototyping is to use as few materials and as little time as possible. Different colours and size bottles were used. See the image below:

I predicted the white Kefir bottle would be the least effective, as it was small and the food was hidden, but it was very popular and was the only one the robin took food from. Why was this?
The blue bottle was the least popular, but was this because of the colour or the shape? How might we find out?
Cutting the flaps off one of the bottles enabled birds other than the tits to access the food, but that seemed to put the tits off. How might we find out if this is true?

Birds seemed to wait and follow others rather than use a free feeder. This makes sense in terms of survival. Let something else try it first and see if something kills it! Does this really happen? How might we find more?

What is the best way of measuring popularity? Surveys, measuring the weight or volume of seed taken?

8: DELIVERING A RUBBISH SCIENCE WORKSHOP SESSION: A POSSIBLE PROGRAM

How might you deliver a Rubbish Science Workshop?

The workshops can be done in a variety of ways. I set out how I do it below;

Day 1: This is quite a tough day for many students as it asks them to do things that may be well out of their comfort zone. We need to have a constant repetition of the idea of evidence as this is crucial to their understanding of science. Research suggests that people know much more about scientific 'facts' like what is a molecule than they do about scientific processes and how theories are formed.

1. Introduction - who I am and what my interest is in science.
2. Who are you, the students and what do you love/hate about science? I need to get a feel for my students before I start teaching them. Make sure I know who they are and let them know they are valued.
3. What is science and who does it? Not just old white men in lab coats.The idea of Claim - Evidence - Confidence
4. What do you know? A discussion about how we know what we think we know and why we should question how did I get here? Leading to the idea of evidence and how little we know

5. **FAIL** as the first attempt in learning. I do counter-rotating fingers, rotating right foot clockwise then drawing a large 6 in the air and keeping your foot rotating in the same direction (for most people it will change)
6. Helium straws - Giving me evidence of what type of people they are. Can they handle failure? Can they listen to each other? Can they think divergently? What can they learn from this?
7. The Popes Tablecloth Pull - See Youtube!. Is it real? What evidence suggests it's real?. What evidence suggests it is fake? What can we do to find more evidence?
8. Table cloth pull challenges. What is the smallest, lightest object? What can we learn? How does this relate to other things?
9. Newspaper tower challenge using the design thinking process. You may want to simplify it but keep it very structured. What have we learned so far that can help us? What is your claim, what evidence can you produce? How confident are you? What can you learn from others? What would you do differently next time? What have you learned about stability? What have you learned about solving a problem scientifically?
10. Flytrap. Or Solar Stills (both of these tasks need as long as possible to see effective results - do solar stills if the weather is hot and sunny) How might you make a fly trap from a plastic bottle? Use the design thinking process but scaffold them. Take them through it step by step

- What is the task?
- What question might I ask?
- What is my prediction? This should be revisited
- What are the risks? - Carry out a risk assessment
- What do I know already that can help me?
- How. do I know this - What evidence is there?
- What do I need to know?
- How might I find out?
- What ideas do I have?
- Which one looks the most promising and why?

✻ How am I going to prototype it?
✻ What are others doing?
✻ What have I learned from them?
✻ How can I carry out a fair test?
✻ How will I record my results?
✻ How long will I run the experiment
✻ What happened?
✻ How can I show someone else the evidence of what happened?
✻ How confident am I about this evidence?
✻ What have I learned?
✻ What would I do differently next time?
✻ How might I use what I have learned in everyday life?

11. Wrap up: What do you know now that you didn't know at the start of the day? Tell someone what you have learned and show them something

Day 2

This is the day where things start to come together as for every activity we do we follow the same design thinking process.

Possible Program

1. Greet and chat - What did they like about yesterday? What did they tell or show other people? What did they learn?
2. Matchbox tricks curiosity inducing ideas.
3. Solar Stills activity or fly traps depending on what was done yesterday)
4. Check their fly traps or solar stills. Review all of the other people which ones are working well or not working. What can you do to improve yours?
5. A fishing line from plastic bags - Who can find the best method to make them as strong and long as possible?

6. Hydroponic plants - seeds for germination
7. Thermos flasks to keep liquids hot or cold depending on whether you have access to ice or hot water. If thermometers are not available then try and use ice as the time it takes for the ice to melt as an indicator of the effectiveness of the insulation.
8. Check the solar still and flytrap. Make any modifications
9. Review of the day - Where are you now compared to where you were at the start of day 1. What have you learned that is useful. Are there any local problems we might be able to solve using this
10. What might you want to do tomorrow?

Day 3

Review from the previous 2 days

This is the day where you want them to be as independent as possible. Often I will just give them a menu of options and they can carry them out.

I

9: THE MAIN ACTIVITIES

Use the design thinking process to work through these

9.1: PLASTIC BAG FOOTBALL

Plastic Bag Football

Most Rubbish Science activities provide benefits for health, nutrition and water. Plastic bag footballs might not appear to fit in these categories but can provide for the mental health of the students. The full range of problem-solving ideas developed in other activities can be developed with this challenge:

Make the best Rubbish Football

What factors should we rate the footballs on and how might we test them?

Some ideas are:

- How spherical it is – This can be measured by seeing how far it travels in a straight line when rolled
- How high it bounces when dropped from a given height – say 1 metre

- How heavy it is for a given size – How might the density be measured?
- How long it lasts– How might this be measured?
- How easy it is to make or replicate? The simpler the better

Equipment Needed

- Newspaper/ paper bags for the core
- Plastic bags of different types
- String
- Rubber bands or cycle inner tubes if available

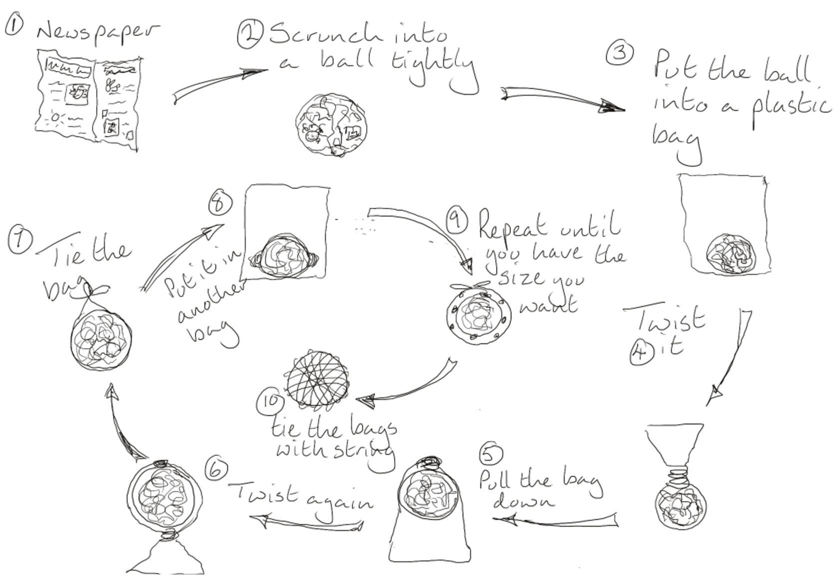
Safety: You must risk assess this activity yourself. Using scissors to cut the string or bags could lead to cuts. Ensure the bags and newspaper are clean.

Testing their plastic bag footballs for bounce

How to make a Rubbish Football There are many possibilities which is what makes this activity particularly valuable as a learning event. One possibility is shown in the diagram below it relies on a spherical newspaper core with a series of bags twisted and tied together: Finally wrapped in string or rubber bands / cycle inner tubes if available.

Using this model creates the following questions:

- How big should the core be?
- How heavy might it be – Would using wet newspaper improve the performance of the ball?
- How tight should the plastic bags be tied? Is tighter better?
- What type of plastic is best?
- How big should the bags be?
- How much string should be used?
- What type of string?
- What else?



HOw to make a plastic bag football

9.2: FISHING LINE FROM A PLASTIC BAG

Fishing Line from a plastic bag

Plastic bags can be turned into fishing lines if they are cut into strips and pulled very slowly and twisted. The strips must be cut as straight as possible – Small 'nicks' in the edges of the strip will cause it to break when it is pulled. The lines produced can be used for a variety of things and even turned into nets.

Pulling the strips quickly causes them to break. They have to be pulled as slowly as possible and twisted as you pull. Once you have got the technique it is very satisfying!

Equipment Provided: Plastic bags and scissors

Health and Safety: You must carry out your risk assessment (Rubbish Science accept no liability) Note: Be careful when cutting.

- **Things you might need to know / Questions you might ask:**
  - What type of plastic bag works best?
  - How thick should the strips be?
  - How long a strip can be cut from one plastic bag?
  - What is the fastest that the plastic can be pulled?
  - Does twisting help create a stronger line?
  - How are the lines going to be tested? **Note:** If weights are used care must be taken to ensure they do not fall on people's feet. Plastic bottles filled with water make good weights. A litre bottle has a mass of around 1 kilogram and a weight of 10 Newtons.

Prototyping: Try to answer the questions above using small scale experiments

Modifications: How might you modify your technique based on what your preliminary results look like?

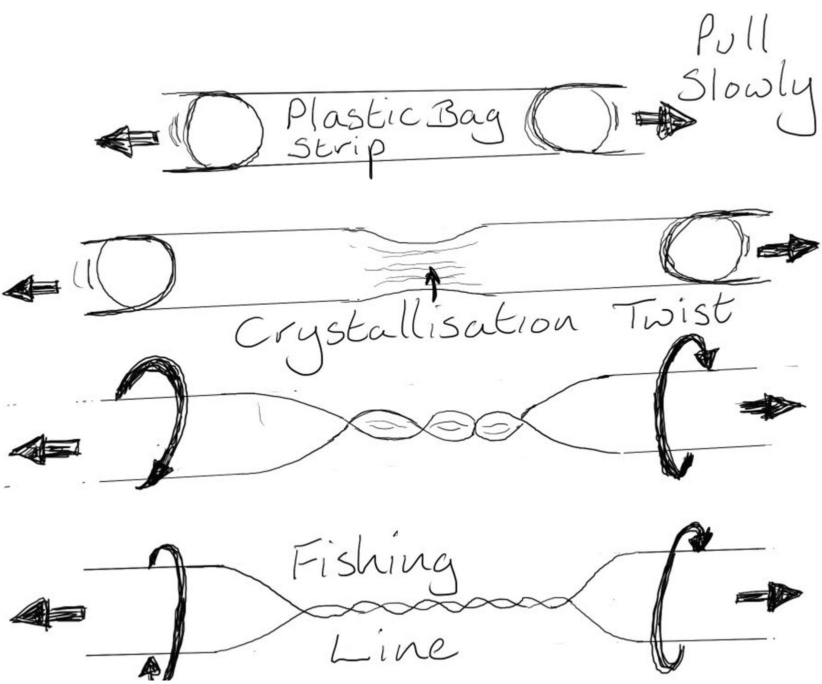
What have others done and what can you learn from them?

Prediction: What do you think will happen and why?

Do it: How are you going to see if your fishing line is successful?

What happened?: Was your line effective?

Tell Someone: Explain what you did and why you felt your line was effective. Listen to others, do they have any good ideas?



How to make a fishing line from a Plastic Bag

What did you learn? What do you know now that you didn't know before you started this investigation?

Extension/Modify/Do it again: What else could you use the lines for?

How could you extend this to produce a commercial fishing line business?

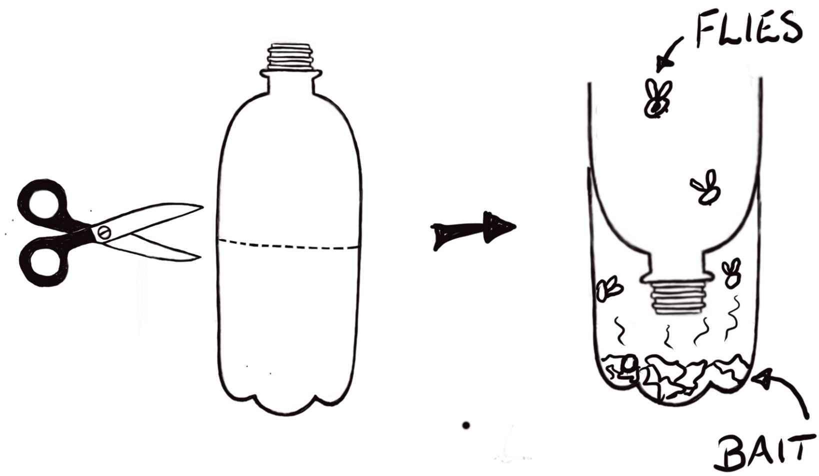
What is the science behind this?

Plastic bags are made of a series of long-chain molecules that have bonds between the chains. When in the cut strip they are randomly aligned. Think of a plate of spaghetti. By twisting and pulling slowly you are aligning the long chains and forming a rope. The bonds between the molecules are now much closer, there are more of them and they are now strong. This is how Dyneema fishing lines are made

9.3: PLASTIC BOTTLE FLY / MOSQUITO TRAP

Flytrap **from a plastic bottle**

Overview: Flies can cause the spread of diseases. Mosquitos carry Malaria and Dengue Fever. You can create simple fly traps in seconds, but then spend a lifetime optimising the design



A simple funnel fly trap

Task: You are to create a fly or mosquito trap out of a plastic bottle or other rubbish. You then need to take steps to optimise the design to make it as effective as possible. A mosquito trap can use the same design, but fermenting material can be used as bait as they are attracted to carbon dioxide.

Equipment Provided: Plastic Bottles, plastic bags, scissors

Health and Safety: You must carry out your risk assessment (Rubbish Science accept no liability)

- Take care using cutting instruments.
- Always wash your hands after dealing with flies and waste. Consider how infections might spread

Things you might need to know / Questions you might ask:

- What are flies attracted to / what do they eat?
- What damage/diseases do they cause?
- Are different species more or less dangerous? (which ones should you target?
- What is their lifecycle? Can you attract them to lay eggs?
- What colour are they attracted to? (if any)
- How might you produce a trap that is easy for flies to get into, but hard to get out of?
- Where might be the best place to site the trap? Note: You don't want to attract them to places where there is food or they can spread disease.
- Are there any environmental implications to removing flies?

Idea Generation: How many ideas can you think of?

Prototyping: What designs might work? Create some quickly and test their effectiveness. Note: If possible record what happens as the flies approach your trap/s. Can they get in/out easily?

Modifications: How might you modify your designs based on what your preliminary results look like? What have others done and what can you learn from them?

Prediction: What do you think will happen and why?

Do it: Create a table of results or some way of recording how many flies you caught.

What happened?: Was your trap effective?

Tell Someone: Explain what you did and why you felt your trap was effective. Listen to others do they have any good ideas?

What did you learn? What do you know now that you didn't know before you started this investigation?

Extension/Modify/Do it again: How could you extend this to catch more flies?

Flytraps in action

9.4: GERMINATION GREENHOUSE

Germination Greenhouse

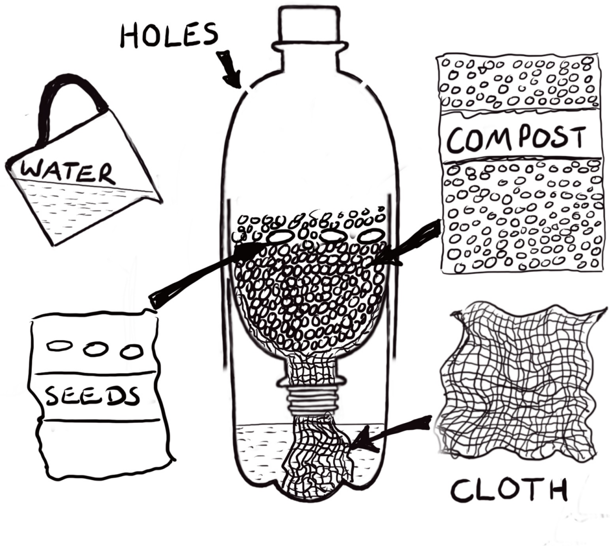
Germinating seeds in the soil can be disappointing as it is hard to keep them at the right moisture levels. Most seeds can be pre-germinated by keeping them in a container on moist paper out of direct sunlight. Most seeds will germinate in the temperature range of 18-30C They should be checked regularly as some seeds can germinate in one day. As soon as they show signs of roots they need to be transferred to pots or the germination greenhouse. **Note:** The Germination Greenhouse is just a bottle garden with another bottle on top to keep the moisture retained Once they are planted they should be kept moist for at least a week until they are well established.

Some seeds need to be in the dark before they will germinate and the damp paper towel method is the quickest way to check this.

There are lots of experiments that can be done to create the optimum conditions for germination

Questions that could be asked:

- What is the best temperature?
- Is soil or paper better?
- How moist should the soil or paper be?
- Should they be in the dark or light?



A Possible Germination Greenhouse

9.5: COMPOSTING TECHNIQUES

Composting:

Compost is made from the breaking down of organic (natural) material. It is not the same as rotting. Leaves, uncooked food waste and cardboard can be broken down by bacteria and worms to produce nutrient-rich soil for plants to grow. Air is needed as the bacteria and worms need oxygen.

Rotting which doesn't need oxygen doesn't provide the same nutrients or soil structure.
Task: You are to produce compost as quickly as possible

Equipment Provided: Plastic containers, cardboard, soil, uncooked food or garden waste.

Health and Safety: You must carry out your risk assessment (Rubbish Science accept no liability) Note: Wash hands carefully after handling waste and compost. Be aware that compost bins can attract mice and rats.

Things you might need to know / Questions you might ask:

- What is the difference between composting and rotting?
- What are the best conditions for composting to occur?
- What are the best materials to use to make compost?
- Is animal dung useful?
- What order should these materials be stacked in?
- What size compost bin works best?
- How big should the air holes be?
- Should the materials be disturbed eg some compost bins can be turned upside down regularly?

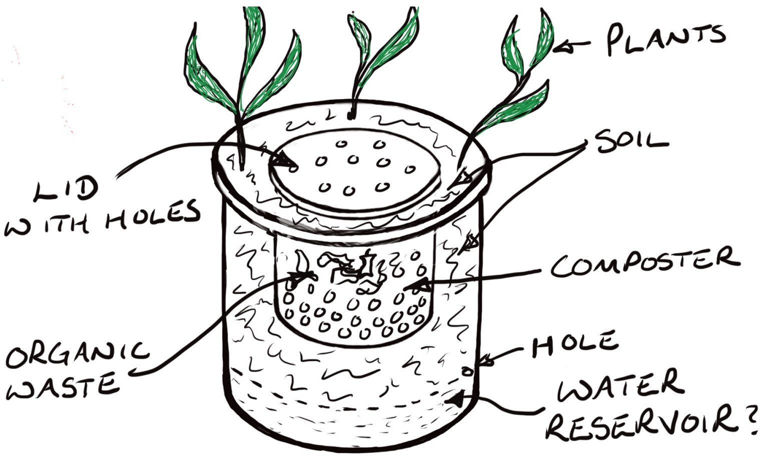
Prototyping: Try to answer the questions above using small scale experiments

Modifications: How might you modify your designs based on what your preliminary results look like? What have others done and what can you learn from them?

Prediction: What do you think will happen and why?

Do it: How are you going to find what method works best? How will you record your results?

What happened?: Was your composter effective?



Self contained composter / grower

Tell Someone: Explain what you did and why you felt your composting was effective. Listen to others do they have any good ideas?

What did you learn? What do you know now that you didn't know before you started this investigation?

Extension/Modify/Do it again: How could you extend this to produce more compost, more quickly?

How can you optimise the design?

How might this be scaled up? See the keyhole garden

9.6: SELF-WATERING MINI GARDENS

Self Watering Mini Gardens:

Plants in traditional pots lose a great deal of water through the bottom of the pot as well as through evaporation from the top of the soil. Some designs allow a water reservoir at the bottom of the container that the roots can access either by using a wick that transfers water from the reservoir to the roots or by having a separate section for the water

Task: You are to produce the most water-efficient method for growing plants possible using plastic bottles, bags or containers.

Equipment Provided: Plastic Bottles, plastic bags, plastic containers, compost/soil measuring cylinder/bottle with gradations. seeds/plants. Paper/cloth/socks etc to act as a wick

Health and Safety: You must carry out your risk assessment (Rubbish Science accept no liability) Note: Take care when cutting and wash hands after handling rubbish and compost

Things you might need to know / Questions you might ask:

- How much water do plants need?
- Where is water lost when growing plants in a conventional pot?
- What happens to a plant if the roots get completely waterlogged?
- How can you get paper or cloth to act as a wick?
- How might you reduce water loss by evaporation?
- How might you create a fair test to find

Prototyping: Try to answer the questions above using small scale experiments

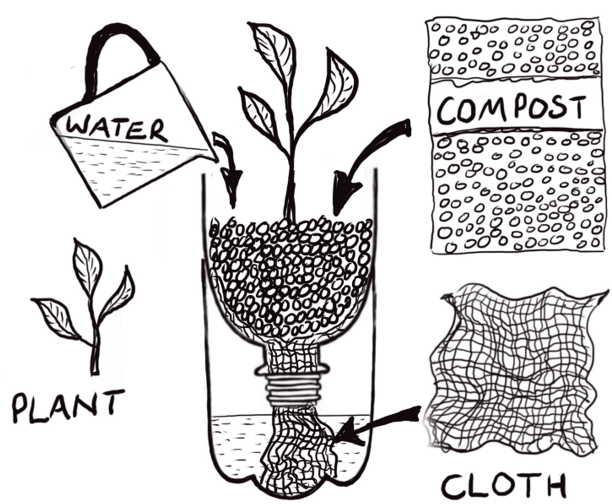
Modifications: How might you modify your designs based on what your preliminary results look like? What have others done and what can you learn from them?

Prediction: What do you think will happen and why?

Do it: Create a table of results or some way of comparing the amount of water used

What happened?: Was your garden effective?

Tell Someone: Explain what you did and why you felt your



Self Watering Mini Garden

plant growing was effective. Listen to others do they have any good ideas?

What did you learn? What do you know now that you didn't know before you started this investigation?

Extension/Modify/Do it again: How could you extend this to produce a commercial plant growing business

9.7: VERTICAL BOTTLE GARDENS

Vertical Bottle Gardens

Stacking bottles on top of each other and filling them with the soil creates a very water and space-efficient place for plants to grow. The question is what are the optimum conditions for plants to grow?
These are very water and space-efficient, but if you make them too high, then the bottom plants will not get enough water.

The water from the collection bottle at the bottom can be used again, but not more than twice as the salts and mineral concentrations can get too high

Task: You are to create a vertical bottle garden to grow the highest crop of spinach (or other) plants in as tall a stack as possible

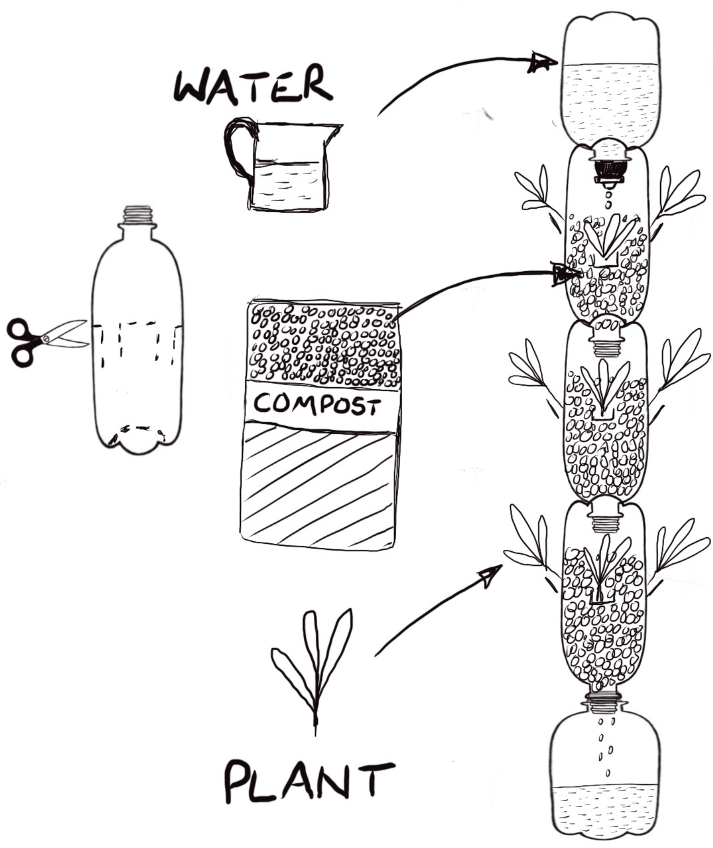
Equipment Provided: Plastic Bottles, scissors, compost/soil, seeds/plants, string,

Health and Safety: You must carry out your risk assessment (Rubbish Science accept no liability) Note: Be careful when cutting, wash hands after handling soil/compost

Things you might need to know / Questions you might ask:

- What size bottles would be best?
- How high can the stack be?
- How will you ensure that the water is evenly spread through the bottles?
- How many holes should you cut in the bottles to grow plants?

* How could you include a self-watering system/drip bottle?
* Could you collect the water that seeps through to the bottom of the bottle garden?



Vertical Bottle Garden

Prototyping: Try to answer the questions above using small scale experiments

Modifications: How might you modify your designs based on what your preliminary results look like? What have others done and what can you learn from them?

Prediction: What do you think will happen and why?

Do it: How are you going to see if your garden is successful?

What happened?: Was your bottle garden effective?

Tell Someone: Explain what you did and why you felt your plant growing was effective. Listen to others do they have any good ideas?

What did you learn? What do you know now that you didn't know before you started this investigation?

Extension/Modify/Do it again: How could you extend this to produce a commercial plant growing business

Possible Model – How can you optimise the design?

9.8: PLANT WATERING SYSTEMS 1

Plant watering systems:

Making a hole or holes in a bottle top can create a sprinkler system. However,r it isn't easy to control the speed of the flow of the water as the pressure inside the bottle varies depending on how full the bottle is. What can you do to create a system that only needs refilling at appropriate time gaps?

Task: You are to create a watering system from a plastic bottle that releases water at a controlled rate. so it only needs filling up at certain time intervals that you choose: Every 24 hours every week etc

Equipment Provided: Plastic bottles (some with sports drinking caps if available) Knife/scissors. Optional Mounted needle and matches (for melting small holes)

Health and Safety: You must carry out your risk assessment (Rubbish Science accept no liability) Note: Take care when cutting. Take great care if burning holes – Chance of burning yourself and be aware that burning plastic gives off fumes so do in a well-ventilated place

Things you might need to know / Questions you might ask:

- Why doesn't water come out of a bottle with a hole in the lid when turned upside down?
- How can I make water come out?
- What happens if I make a bigger hole in the lid?
- Do 2 holes drip twice as fast as 1?
- How might I control the flow of water?

Prototyping: Try to answer the questions above using small scale experiments

Modifications: How might you modify your designs based on what your preliminary results look like? What have others done and what can you learn from them?

Prediction: What do you think will happen and why?

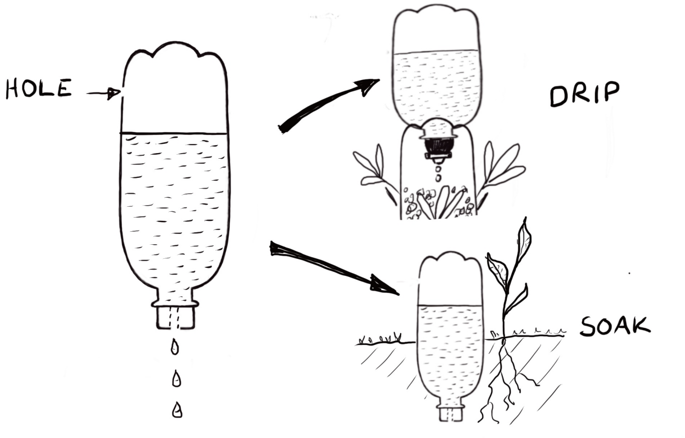
Do it: How are you going to see if your garden is successful?

What happened?: Was your bottle garden effective?

Tell Someone: Explain what you did and why you felt your plant growing was effective. Listen to others do they have any good ideas?

What did you learn? What do you know now that you didn't know before you started this investigation?

Extension/Modify/Do it again: How could you extend this to produce a commercial plant growing business



Drip Bottle Watering System

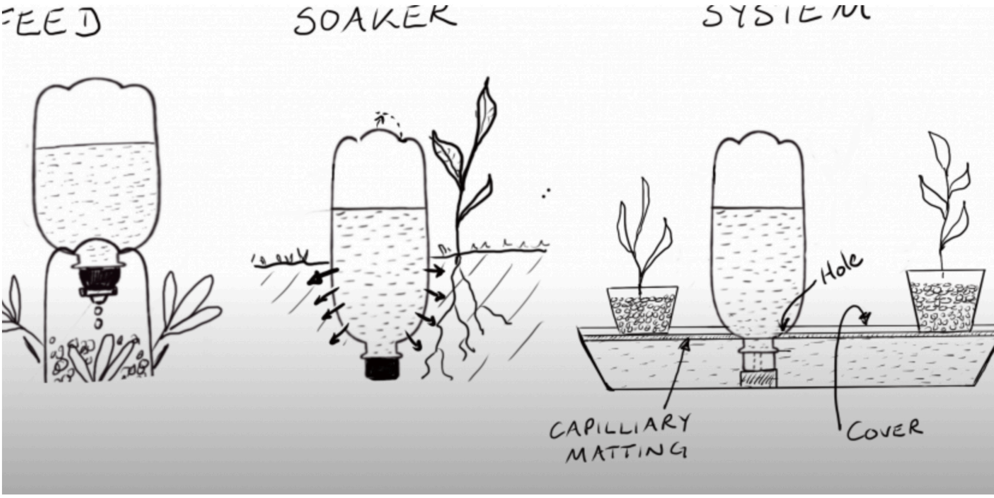
9.9: PLANT WATERING SYSTEMS 2

Plant watering systems:

Watering plants in terracotta pots are huge water inefficient as well as time-consuming. Water is lost due to evaporation from the soil and through the terracotta as well as running out through the bottom of the pot. There are better systems available and we will consider three types: You could just set up all three systems and use trial and error to optimise them. They are, however, likely to be successful if we use the Scientific Design Thinking approach. Here we will look at the science behind them and how we can use this knowledge to make predictions and learn new concepts.

Pressure in a Fluid – What might happen to the water if we had holes in a bottle? A bottle has three holes above one another in its side. How will the water flow out of the bottle when the lid is opened? A, B or C? You may want to watch this video (or read below) to help you decide **Answer** (C) A higher pressure would lead to the water squirting out further. You can see this by squirting water in your mouth out through a straw. The higher the pressure you exert, the further the water goes. The deeper you go in a fluid the higher the pressure gets due to the weight of all of the molecules above. Deep-sea fish have adaptations to survive these massive pressures. Similarly, we live at the bottom of an ocean of air. Above you is about 100km of air molecules and the combined weight of all of these is about the same as having a small car on your head. If you didn't also have air inside your body balancing these forces you would be crushed.

Possible experiment: How does the rate of water flow change as the bottle empties?



Other plant watering systems

What might happen if the hole size was different but the pressure was the same? Would you see (A) (B) or ©? Make a prediction and justify it Answer:

Possible experiment: How does the diameter of the hole affect the rate of water flow from the bottle? So far we have two factors that affect the rate at which plants would get water. The height of the water column and the size of the hole or holes.

(1) Make a Drip Bottle Watering System So here is a bottle with a hole in the lid hanging upside down. What will happen? What happens if you take the lid off? Why?

Possible experiment: What is the maximum size of the hole in the lid so that water does not flow out of the bottle when turned upside down? Watch the video

Challenge: Make your bottle take an hour to empty How can you regulate the flow? What might happen if …..

- The hole in the lid is made bigger or smaller?
- A hole is made at the top of the bottle? How might the size of this hole affect the flow rate?
- Sand/cotton string is used to restrict the flow through the bottle?
- A sports bottle top is used?

Alternative method. How does this work?

(2) Make a Soak Bottle Watering System The same principles apply to the drip bottle but multiple holes are now made in the bottle. This makes things more complicated. What did we learn before that may help us here? Volume marks can be added to the bottle to allow measurements that might happen if:

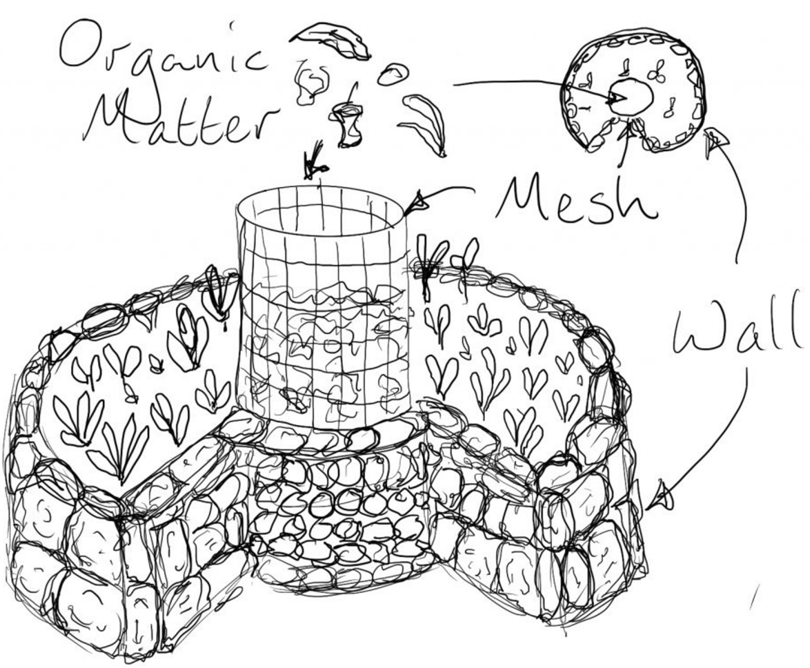
- Have we changed the number of holes?
- Did we change the pattern of holes? Should there be more at the top and fewer at the bottom have we
- Did we change the size of the holes?
- Other Questions
- Does the bottle drain at different rates in soil than in air?
- Does it make a difference if the soil is wet or dry?
- How can we use this to water plants more effectively?
- Cutting the bottom off a large bottle allows us to have a soak bottle inside another bottle which is hugely water efficient and also requires less watering. Some questions:
- What combination of bottle sizes works best?
- How many plants can be grown in the big bottle?

(3) Make a Water Bath – Hydroponics Watering System We can make a refilling bird or animal drinker from using a plastic bottle and a bowl (or bottom of another plastic bottle) The bottle needs to have a large enough hole in the cap or be mounted without a cap so that it empties without having to put another hole higher up. The bottle will fill the container up to the level that you put the hole. Why does it stop there? What have we learned already that will help us? Using this principle we can have several bottles filling a tray of water. We can add nutrients to these bottles in the form of Compost Tea or fertilizer. To prevent the plants from being waterlogged, capillary matting can be used or layers of cloth that absorb moisture. Covering the tray with a waterproof lid will reduce water loss by evaporation.

9.10: THE KEYHOLE GARDEN

Keyhole Garden

A very water, nutrient and space-efficient concept. A cylinder of wire mesh is put in the middle of a keyhole-shaped wall made from bricks, pallets, stones or glass or plastic bottles. Topsoil or compost (See the composter) is then added and plants can be planted as shown. Organic material is added to the centre inside the mesh. Wastewater is poured into the mesh basket. This retains water and nutrients that can pass through to feed the plants. The keyhole shape allows the organic material to be added easily.



Design Task You are to create the most efficient keyhole garden Some questions you may want to think about:

- What is the most efficient size to build?
- How deep should the soil be?
- How big should the cylinder be?
- What is the best way to stack the compost?
- How big should the compost basket be compared to the size of the garden
- What plants should be grown?

9.11: INSULATED FLASK - KEEPING THINGS HOT OR COLD

Insulated Flask

There are many ways of making a container that keeps things hot or cold. Silvered films such as the inside of crisp packets can reflect thermal radiation. Black objects absorb radiation and so get hotter if left in the sunshine. Substances that trap air, such as cardboard or bubble wrap reduce heat loss by conduction. Lids and stoppers reduce heat loss by convection. Evaporation creates cooling which is why sweating cools us down. What is the best combination and how might you find out?

Task: Create a container to keep a substance hot or cold

Equipment Provided: Plastic bottles, cardboard, bubble wrap or other packing material, silvered crisp packets/foil, scissors, tape Thermometers if available. If they are not then ice can be used to compare how long it takes to melt in the different containers.

Health and Safety: You must carry out your risk assessment (Rubbish Science accept no liability) Note: Do NOT use the container for food or drink as it may be contaminated.

Things you might need to know / Questions you might ask:

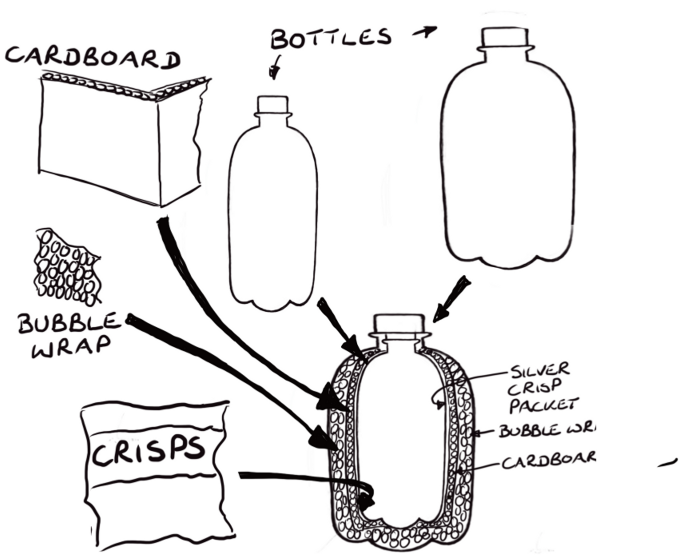
- How does trapping air help reduce heat transfer?
- How can silver and light coloured objects be used to reflect heat?
- Should we use black materials at all?

- Why does ‘heat’ rise and how may we reduce heat loss by these methods?
- Is it easier to prevent heat loss in bigger or smaller volumes?
- What combination of materials might work?

Prototyping: Using a thermometer or the time that ice melts to compare systems. Explore what combinations of materials seem to be most effective at preventing heat loss or gain.

Modifications: Having seen others ideas is there anything you might want to change?

Prediction: How well do you think your container will work?



Insulated Flask Idea

Do it: How can you ensure it is a fair test. How will you record results?

What happened?: Did your results support your prediction

Tell Someone: Explain what went well and what you think might be improved. Listen to others ideas and decide if they have value.

What did you learn? What do you know now that you didn't know at the start of the investigation?

Extension/Modify/Do it again: What would you do differently? How can you use the ideas you have learned to solve different problems?

9.12: SOLAR STILLS

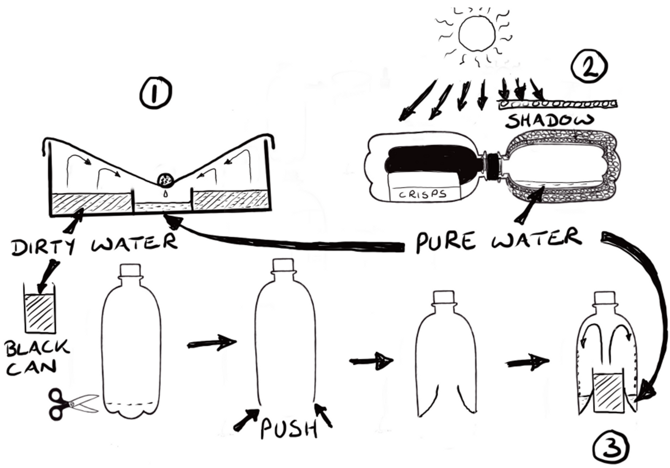
Solar Stills

Solar stills use sunlight to evaporate dirty or salty water and then condense the water vapour to be collected. There are many models for this but which one is the most effective? **Note: It is probably worth doing the Insulated container and the hand washing station before you do this experiment as the concepts can be combined in this one.**

Task: You are to make a solar still that can produce clean water from dirty or salty water. Either as quickly as possible or the maximum possible in a set period.

Equipment Provided: Plastic bottles of various sizes, tin cans, plastic bags, plastic trays, string, tape, scissors, silvered crisp pockets, black paper, black ink

Health and Safety: You must carry out your own risk assessment (Rubbish Science accept no liability) Note: Do NOT drink the 'clean' water you have produced! Be careful cutting



Things you might need to know / Questions you might ask:

- ✻ How can you make water evaporate quickly?
- ✻ How can you get water vapour to condense effectively?
- ✻ How can you combine evaporation and condensation to make a system that works?
- ✻ How much dirty water should you use? Does the volume or the surface area have the most effect?
- ✻ Does making the water black affect its evaporation rate?
- ✻ What do commercial solar stills look like?
- ✻ Can you use ideas that were learned in the hot water hand wash station and Insulated container to help with this task?

Prototyping: Design some systems to answer the questions above.

Modifications: Having seen others ideas is there anything you might want to change?

Prediction: How well do you think your solar still will work and why?

Do it: What results are you going to take? How will you record them.? Where is the best place to site your still?

What happened?: Did your results support your prediction

Tell Someone: Explain what went well and what you think might be improved. Listen to their ideas and decide if they have value.

What did you learn? What do you know now that you didn’t know at the start of the investigation?

Extension/Modify/Do it again: What would you do differently?

9.13: WARM STERILE WATER HANDWASH STATION TIPPY TAP

Warm Sterile Water Handwash Station

Washing hands is far more effective with warm water than cold. In some areas sterile warm water is not available for washing hands so how can we create a system from rubbish? Bacteria colonies can grow much faster in warm water so we could make the problem worse. You can use Solar Water Disinfection (Solis method) which uses the Sun's Ultraviolet light to kill bacteria, protozoa and viruses. There are two ways it works. One is if the temperature rises to above 70C which denatures enzymes and the second is the action of the Ultra Violet radiation itself. UV light kills microorganisms by disrupting their DNA. It is thought that this is one of the reasons why we get fewer colds and flu in summer than in winter. As the UV light penetrates water it becomes less intense and so is only effective for a short distance. So this will not work if the bottle is too big. All ponds would be sterile if the penetration was intense enough.

The SODIS method only works with plastic bottles as UV cannot penetrate glass

So how might we produce a potentially clean warm hand wash station? **Note: Unless you can verify the water is sterilised you cannot drink it as it may cause infections**

Equipment Provided: Plastic bottles, silver foil/crisp packets, (agar plates, microscope, thermometer and UV beads (if available) tape, scissors

Health and Safety: You must carry out your own risk assessment (Rubbish Science accept no liability) Note: Do NOT drink the 'clean' water you have produced!

Things you might need to know / Questions you might ask:

- ✻ How might you ensure the suns rays penetrate the water to the maximum distance possible?
- ✻ How can you work out the path of the sun from shadows a stick makes?
- ✻ How might we use reflectors to increase the temperature of the water in the bottle?
- ✻ How might we know the water is sterile? **Remember you cannot drink the water**
- ✻ How might you record results to compare systems?
- ✻ What colour should the bottle be? Note: Painting it black will make it hotter, but there will be no UV penetration.
- ✻ How might you use UV beads that change colour in the presence of UV light to aid you with this investigation?
- ✻ Could you automate this system?

Prototyping: Develop some ideas and try them out. If a thermometer and/or UV beads are available then collect data. Which design seems to give the highest temperature rise?

Modifications: What modifications are you going to do based on what you learned from your prototypes?

Prediction: What do you think will happen and why?

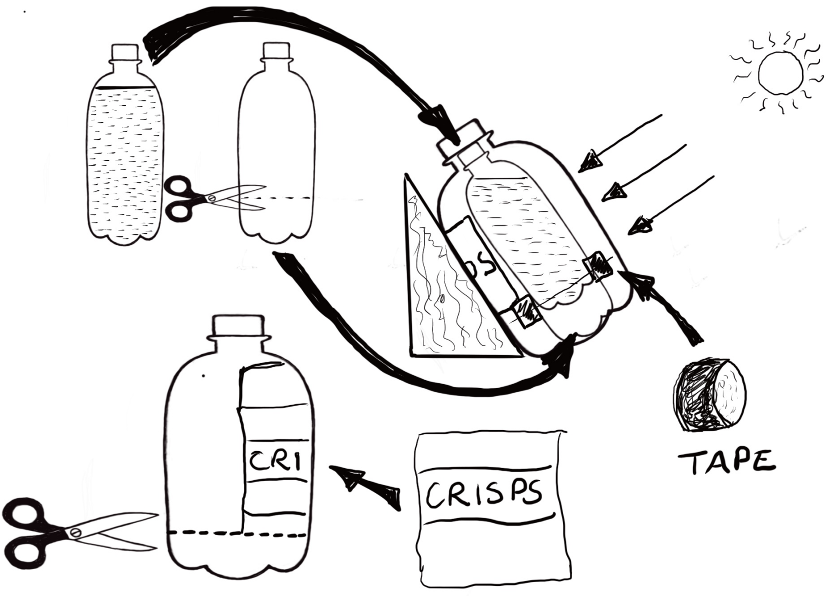
Do it: Carry out your investigation

What happened?: Did you get results that supported your prediction?

Tell Someone: Explain what you did and why you felt your design was effective or not. Listen to others do they have any good ideas?

What did you learn? What were the key things you learned from the task? What would you do differently next time? Could you use what you learned to solve other problems?

Extension/Modify/Do it again: What would you do differently?

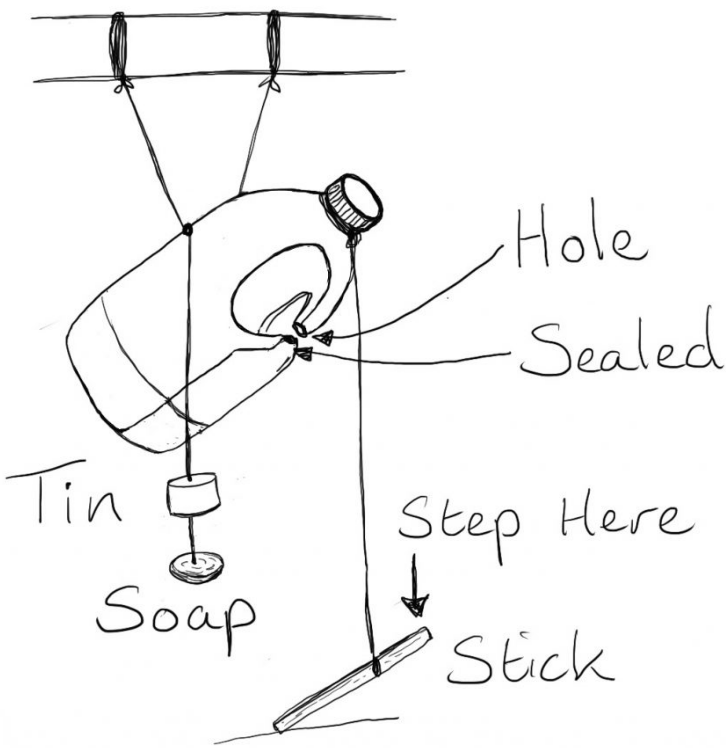


SODIS Method

Tippy Tap

Ideally used in conjunction with the Sterile water, these can be installed outside public latrines or other areas where handwashing is important.

The design means there is no direct contact between the bottle and the hands, stopping cross infections.



A Tippy Tap

9.14: BOTTLE BIRD FEEDER

Bottle Bird Feeder

Feeding birds in winter is essential to ensure their survival, but what is the best feeder? This depends on the type of bird that you want to feed. A good place to start is the RSPB survey of garden birds. Try to pick those whose numbers are in decline. There is a huge amount of research that can be done

Task: You are to find the perfect bird feeder for your chosen garden bird.

Equipment Provided: Plastic Bottles, scissors, bird food, string,

Health and Safety: You must carry out your risk assessment (Rubbish Science accept no liability) Note: Be careful when cutting, wash hands after handling bird food

Things you might need to know / Questions you might ask:

- What size bottles would be best?
- What colour? Opaque or translucent?
- How will you ensure that the test is fair
- What bird food could you use?
- How could you ensure the food does not fall out?
- What variables can you not control??

Prototyping: Try to answer the questions above using small scale experiments. Like the ones below

Modifications: How might you modify your designs based on what your preliminary results look like? What have others done and what can you learn from them?

Prediction: What do you think will happen and why?

Do it: How are you going to see if your bird feeder is successful?

What happened?: Was your bird feeder effective?

Tell Someone: Explain what you did and why you felt your feeder was effective. Listen to others do they have any good ideas?

What did you learn? What do you know now that you didn't know before you started this investigation?

Extension/Modify/Do it again: How could you extend this to other birds?

10: THE END OR THE BEGINNING?

What have you learned?

What are you going to do next?

How can you share what you have learned with others?

Thank you for getting involved in Rubbish Science and we hope you continue to stay in touch and shange the World for the better one plastic bottle at a time.