Creating Science – Dropping Rules; Reaction Times and Multiple Trials

Learning about our reaction times is interesting and important in and of itself – but learning about how scientific knowledge is created? Even moreso! #CreatingScienceDroppingRulers

Suggested outcomes

(NOTE: This is by no means an exhaustive list of possible outcomes, neither is it intended that ONLY these outcomes can or should be met. Science is a deeply interrelated activity; all outcomes at all leaves, when appropriate, should be integrated.)

- Plan and conduct: Measure and control variables, select equipment appropriate to the task and collect data with accuracy (ACSIS126)
- Evaluate: Reflect on scientific investigations including evaluating the quality of the data collected, and identifying improvements (ACSIS131)
- Use and influence of science: People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity (ACSHE121)

And also;

- Biological Sciences 5: Living things have structural features and adaptations that help them to survive in their environment.

Warning

- While dropping rulers isn't generally considered dangerous, some have sharp edges, so watch out for little fingers. Other rulers are surprisingly heavy, so covered shoes at least. DO NOT USE METAL RULERS.

Preparation

- A ruler for each student, or at least one between two.
- A space for recording multiple results
- A device for calculating averages. If you use a spreadsheet you can get a lot done at once.

Suggestions for other year levels

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

Younger:

This activity is not well suited to this age group. They will need a lot of scaffolding, and probably rulers much larger than 30 cm.

Middle:

This activity is well suited to this age group, however it is likely you will need to split it up over two sessions. Simply recording data in an ordered table will be a challenge for some, and convincing them that there's any point to writing things down even more so.

Teen:

While this activity is well suited to this age group, motivating them to see the point of testing is always a challenge. Remind them that reaction times are important to saving lives, as well as that *real* science uses multiple measures to create knowledge effectively.

Finding averages is pretty easy – perhaps this group might be ready for testing significance with t-tests (see the end of this document). This age group might enjoy specifically designing their own guided investigation to answer their own questions, for example, are boys better than girls, left hands faster than right hands? Creating scientific knowledge for themselves will really help improve the scientific literacy of the next generation.

Learning Intent (student friendly)

'We are learning to' (WALT).

Success criteria

'What I'm looking for' (WILF).

Student learning goals

Help students make a self-monitored learning goal for this lesson.

Evidence of learning

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

Engage

- ⇨ Make sure all students jot down any questions they may have generated during this phase.
- ⇨ Play with marble runs, or play catch with the students. Point out that things fall down and ask them to explain why. Don't correct their answers at this point. Ask them to describe the motion of falling things, is there more than meets the eye? Again, there is no need to correct student ideas at this point; simply encourage sharing and helping.

Explain: Almost everyone will learn to drive one day, either it's a car, bike or aeroplane. Sometimes unexpected things can happen, things that require you to react: and fast! Knowing about your reaction times, and having a good reaction time, can really help keep you safe. Not only is it good for travel, but it helps you to excel at sports, do well at some computer games, and helps you to keep your balance as you get into very old age.

Explore

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

Have one student hold a ruler at one end in one hand, allowing the ruler to point directly downwards with gravity.

Have another student hold their fingers just below the ruler, at the 0cm mark. They are not supposed to touch the ruler.

At a random moment, and without any warning, the first person drops the ruler and the second person must catch it.

Record the distance the ruler travelled before it was caught.

(While this activity is suitable for most visually impaired students, even completely sightless students can give this a go as the first student makes a sound such as a tap in the very moment the release the ruler as well.)

Perform the activity at least thirteen times and record the results.

Multiple trials

Explain: This is data. Of your 13 results, we have 13 pieces of data from our experiment.

Ask: How can we analyse this data? What does it mean?

- ⇨ Why did we do so many trials? Why not just take the best one?

Explain: we can, sometimes. But all of these results are data points of value. They all tell a little something about the situation, you mood, what was happening in the room. They **all** are valuable.

Remove the effect of practice

- ⇨ Ask, which do students think is their most accurate reaction time? How can we arrange this data to make it the most representative?

Explain: we all get better with practice. It is quite likely that the first result is among your worst. Is it fair to not count the first few results as 'practice'? Will this help improve our data accuracy?

Elaborate: while it does help, it also ignores the fact that those results are still examples of your reaction time. Sure, we may not like them, but they still count as examples of how you actually react to new situations. For this experiment it is fine to ignore the first three results as 'practice tests', but remember they still hold value as data.

Remove the effect out outliers

- ⇨ OK, so what about some other data points, the 'outliers' – maybe you lost focus and the ruler fell all the way to the floor, or maybe you just guessed presciently and the ruler didn't get a chance to move at all.

Explain: Outliers are often tricky things. They 1/ either tell us something really valuable and unique about our situation or, 2/ more often they belong to another set of data. Sometimes even both. It is often common to ignore outliers in data for these reasons. That is, we can't test reaction time if what you were completely distracted at the time; that comes under the broader study of focus, attention, and reaction time. Or perhaps the ruler grabber managed to spy out an unconscious clue the ruler dropper was ignoring, which is another study again (perhaps 'unconscious cues and reaction times.') Extremely wild results are often ignored unless they keep happening – then we know we're dealing with some other variable here! For this experiment it is fine to remove outliers as examples of something other than reaction time.

Take the average

- ⇨ With 10 or so other reaction times, which is the most accurate?

Explain: they all are, we hope, but they are also all valuable. But so that we can deal with only one piece of data and not 10, we may take the average. This is very common in science, and we call the result the 'average reaction time' – not to be confused with 'reaction time'!

Average reaction time = <u>the total of the results of every trial that you're going to include,</u>
divided by the total number of trails that you have.

For example, if your ten remaining results were (and with no outliers): 8,10,11,9,13,10,10,10,7,12 cm. You average is 10 cm (or 8+10+11+9+13+10+10+10+7+12 = 100. Divide 100 by 10 for the number of results we have, equals 10.)

Extending average – the influence of variables

Another important reason to use multiple trials is to help neutralise the almost infinite number of random variables that might have influenced your results. We call these the controlled variables. Can you think of other variables that might have affected the results?

- Gender
- Body mass index
- Time and quality of sleep
- Time of day
- Humidity and finger grip
- Weight of the ruler

- Colour of the ruler and unconscious colour reactions

There's so many extra variables involved and no reasonable way to control all of them.

This is actually quite common in science. We want to be very confident of what we're saying, and yet we have so many variables involved it's very hard to account for them all!

Sometimes the best we can simply do is to do an experiment as many times as practically possible and then average the results. That way, if there are some extra variables, it is hoped the large number of trials will average out their influence as well.

Calculate your reaction time

The equation to calculate the reaction speed is **t = Sqrt(2d/a)**

- d = distance in metres
- a = acceleration due to gravity = 9.81
- t = time in seconds

In other words, convert your reaction time to meters, then double your average reaction distance, and divide by 9.81 (the force of gravity on earth). Then find the square root of the answer (usually given by the symbol √).

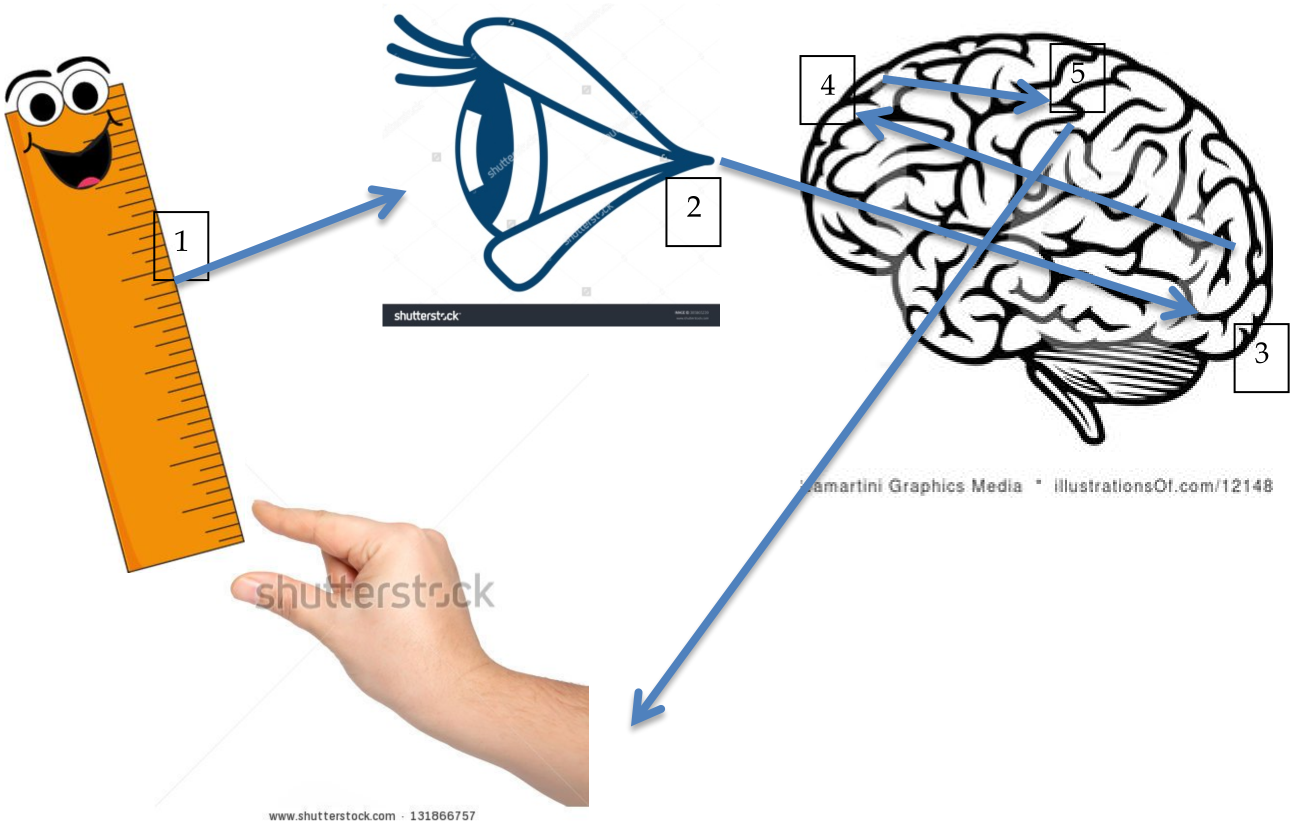
Please note: This number represents an *approximation* of your reaction time, taken by the average of the trials we did today. It does **not** represent your *actual* reaction time in a real life situation.

Explain

Our brain is always interpreting the information that we sense, and it's usually a huge amount of information. The way the 'catch the ruler' activity works is something a little like:

1. The ruler begins to drop, light travels almost instantaneously to the eye.
2. The eye organises and interprets that light, very quickly, into information.
3. The occipital lobe interprets that information and makes sense of it, something along the lines of 'the ruler is moving'. It sends that information on to the frontal lobe.
4. The frontal lobe decides what to do about that information, checking short term memory to find a very loud 'catch it in the fingers' instruction.
5. The frontal lobe instructs the motor area of the brain to form a pinch manoeuvre, which it has been primed and ready to do.
6. The signal travels down the spinal cord to the muscles in the forearm, and,
7. The muscles in the forearm contract.

However, this is a very oversimplified description.



Elaborate

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

Can students explain the reason as to why we use multiple trials?

School zones and driving

If a car is moving at 60 kmph, how far will it go during the average reaction time?

V=d/t where velocity is 16.66 meters per second, time is your reaction time, solve for d.

A car at this speed will travel around five meters before it even *begins* to slow down, which can mean the difference between life and death for a pedestrian. This doesn't even count the time it takes to depress the brake pedal, or the time it takes the car to start slowing down and eventually stop.

Can you see any benefit to driving at 40 kmph in school zones?

Keeping safe

How much worse is our reaction time when we're not even expecting danger? Try talking on a mobile phone or playing a game while waiting for the ruler to drop.

Most people who aren't paying attention allow the average ruler to fall all the way to the floor. It takes time to react, so pay attention when driving!!!

Other uses of the reaction test

What are some other uses of this test?

- To test for concussion. A severe blow to head can hamper our reaction times.
- To review commercial claims of 'reaction time' herbal supplements, etc.

Other uses of multiple trials.

key section

=> Ask students if they can think of other important times we might want to use multiple trials in real science?

- The Large Hadron Collider, when looking for the Higgs Boson, faced a major problem – the Higgs bosun was too small to measure. So they had to take literally *millions* of collision measurements, and average out the data across many months, before the data was considered detailed enough for a conclusion.
- When testing a new medicine, we can't account for every kind of body chemistry there is, so we need to test the medicine many, many times. Multiple volunteers are needed, and they are usually taking the medicine for months, and then have to stop again for months, before the data is considered collected.

=> The key point of all this is that science almost NEVER decides its mind on the basis of a single piece of evidence. <=

This is not only great news for science, its great news for the creation of every day knowledge.

- You text your boyfriend, he does not text back. Does this mean he doesn't like you anymore? What use could multiple trials be in this situation?

But it's good news for science as well.

- A dinosaur fossil is found out of order, and older fossils are found on top of younger ones. Do we ditch the ENTIRE theory of evolution? Not so fast, we need more exploration, and evidence here first.
- Kepler's laws of motion described the planets motion almost perfectly – except for the planet Mercury. Did one planets misbehaviour make *all* the theory wrong? It wasn't until Einstein turned up and used non-Euclidian geometry that we can now explain and predict the behaviour of all our planets.
- In 1989, electro-chemists Martin Fleischmann and Stanley Pons published experimental results suggesting that they had achieved cold fusion – which could mean free, cheap energy worldwide. Yet after decades of trying to repeat their results, no one succeeded. Many think they may have stretched, or even faked, their results. Nothing like multiple trials to weed out great science from the fake!

- Tectonic theory was unpopular and lacked solid theory. But as more and more evidence mounted: magnetism in rocks from across the planet, fossils in places that could not currently support that life – it took thousands and thousands, if not millions, of pieces of evidence to slowly convince science to embrace a theory that is still working today – even though we've still never "seen" tectonic plates!

Rely on multiple trials to help you create reliable knowledge in life and science.

Comparing tests

Compare your results against computer generated reaction time tests, such as at http://www.humanbenchmark.com/dashboard or http://www.topendsports.com/testing/reactionquiz.shtml?view_results

Evaluate

Success criteria

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

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

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

Assessment

Prior Learning:

Have students write down questions at the beginning to explore student thinking and writing skills.

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

- How many times should a scientist do an experiment?
- Why do things fall down?
- How fast can you react?

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

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

- "Scientists only do an experiment once". Scientists actually do most experiments as many times as they reasonably can, to make sure their science is the best they can create, and that it will work under multiple conditions.

- "This experiment didn't work," or "Sometimes experiments don't work". Experiments always work – their job is to teach us something new, even if all we learn is how NOT to set up our equipment next time.

Formative:

Help students to chart results, using the time to demonstrate effective tabling of results.

- ⇨ Can students explain the reasons as to why we use multiple trials?
    - Practice effects
    - Outliers
    - Taking the average can improve accuracy
    - It helps to control random variables

Summative:

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

- ⇨ Have students prepare a repeat of this experiment with a focus on a new variable, such as gender or dominant hand.
    - Have them discuss if they think they did the experiment enough times, and why they might think this?
    - Have them answer if they think their results are accurate enough, and why.

So what?

Science uses multiple trials - "Science" based on one trial is often wrong, or a lie.

Having a good reaction time by doing the speed limit and paying attention can save lives.

Appendix – calculate reaction time

Taken 12 feb 2016 from http://www.brianmac.co.uk/rulerdrop.htm

The algorithm to calculate the reaction speed is **t = Sqrt(2d / a)**

- d = distance in metres
- a = acceleration due to gravity = 9.81
- t = time in seconds

Example

- d = 9cm
- t = sqrt(2 × 0.09 ÷ 9.81)
- t = sqrt(0.01835)
- t = 0.135 seconds

Normative data for the Ruler Drop Test

The following are national norms, adapted from Davis (2000)[1] for 16 to 19 year olds.

Excellent	Above Average	Average	Below Average	Poor
<7.5cm	7.5 - 15.9cm	15.9 - 20.4cm	20.4 - 28cm	>28cm

Some interesting online help for t-tests of significance.

How to do a t-test for significance in Microsoft excel: http://www.statisticshowto.com/how-to-do-a-t-test-in-excel/

How to load the Microsoft data analysis tools : http://www.statisticshowto.com/how-to-load-the-microsoft-excel-data-analysis-toolpak/

Or

Calculate a standard deviation in excel : Use the Excel Formula =STDEV( ) and select the range of values which contain the data.

Calculate significance between two data sets (i.e., are boys better than girls) : http://www.quantitativeskills.com/sisa/statistics/t-test.htm

Creating science

Key outcomes:

- Plan and conduct: Measure and control variables, select equipment appropriate to the task and collect data with accuracy (ACSIS126). Via the skills of multiple trials.
- Evaluate: Reflect on scientific investigations including evaluating the quality of the data collected, and identifying improvements (ACSIS131). Via multiple trials.
- Use and influence of science: People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity (ACSHE121) in that:
  - Science uses multiple trials to improve the accuracy and reliability of results.
  - Our reaction time is an important and interesting fact to know – especially for drivers.
  - Simple science activities can be used to illustrate important processes used in leading edge science.

Use multiple trials to help you create reliable knowledge in life and science.