Activity 4: Data collection, Repeat and reproduce
The Swedish Road Service

Accessoires
- Act 4 presentation
- Act 4 worksheet & reflection
- Act 4 worksheet cups
- Marbles, rulers for incline, cups with a hole for the marbles, tripod (see picture)

Learning goals:
In this activity students learn that it necessary to repeat measurements as there is a natural variation in the measurements which directly influences the quality of the claim. Repeating measurements allows for calculating an average, estimating a spread in the measurements, and indicating the reliability of the measured values.
Students learn that it is wise to share and compare data. Similar results (reproducible values) lead to larger validity of the conclusions.
Students learn that a line of best fit is not always a straight line, it is a line that goes through as many as possible data points and the line allows to predict values outside the measured range as best as possible.
Students learn that when determining a relationship, one might first look at what happens with the value of the dependent variable when the value of the independent variable doubles.

Procedure activity 4:

1 The teacher introduces the activity by telling it addresses the necessity to repeat measurements.
2 The teacher introduces the problem experienced in Sweden which is dealt by the (fictitious) Swedish Road Service. Icy, curved roads may lead to dangerous situations. Guard rails are used preventing cars to end up in a ravine. However, stronger guard rails will do more damage to the cars, and to strong guard rails might even be dangerous for the driver (similar as driving against a wall). Weak guard rails are dangerous too. One might choose to place these guard rails further away from the ravine and then choose weaker guard rails, but this might be costly. So what is the optimum?
3 The teacher introduces the notion that in many studies first a small experimental setup is used to get a feel for the experiment and the variables under investigation. Such a prior study is easy, cheap and far more practical then crashing cars into a guard rail. In this case, the guard rails are the cups, more cups means a stronger guard rail. The marble represents the car.
4 The procedure is shown, the marble start each time from the same height, the marble rolls into the cup, the cup slides and where it ends a small line is drawn, the procedure is repeated four times (5 lines). Another cup is stacked, the cups are moved along the horizontal axes and the same procedure is repeated.
During the collection of data, the teacher walks around and asks the following questions:

a. I see a spread in measurements, do you follow the same procedure each and every time?

b. Are you able to minimize the spread in measurements?

c. If you cannot reduce the spread, what would be a reliable way to report your measurements in a report? Is only mentioning the average enough? (Outliers are measurements and might, in the given context, mean a car crashing into the ravine).

Once each student has collected the data, the teacher starts a discussion about repeating and reproducing measurements, using the following questions:

a. What is the ‘true’ value associated with 1 cup?

b. Why do you repeat the measurements?

c. Which values would you present in your report?

d. What is the relationship between the number of cups and the stopping distance?

e. Does your graph correspond with that of your neighbours? Indicate a possible cause for each difference.

f. Why is it sensible to compare your results with results of others?

g. Why is it sensible to determine how the data were collected, when you have to evaluate the trustworthiness of an investigation and its conclusion?

The teacher summarizes: Comparing data make sense as

a. The same outcomes means that the change you did a proper job increases, your outcomes are more convincing.

b. You obtained more data what increases the reliability if they match.

c. Factors influencing the outcomes (marble size, incline etc) might show up when comparing datasets and looking for explanations in differences between the dataset.

In answering the research question posed by the ISL, we have to look at the data. A possible way is to calculate the mean and use error bars to show the spread in measurements (minimum and maximum). The mean allows to look for a quantitative relationship.

Tip: When looking for a relationship, look what happens if you double the value on the horizontal axes...

The teacher introduces the first concept cartoon and asks students to write down who they agree with and why. The answers given by the students are discussed. (None of the answers are totally wrong, one lacks the context in which the measurements took place, what instruments are used etc. However, it would be wise to take a few extra measurements before deciding what to do).

The teacher introduces the second concept cartoon and asks students to write down who they agree with and why. The answers given by the students are discussed. (Again, a combination of answers would be best, first take some extra measurements and based upon the outcomes decide whether 0.78 can be disregarded).

Finally, the teacher asks the students to write down what they would like to change in the procedure used in the pirates investigation. Homework is to write a conclusion and advise to the Swedish Road Service.

Students fill in the general reflection form.