Crash Test Dummies – Teacher Notes

By Louise Lopes

Introduction:

This investigation looks at a real-world application of motion and forces, and is designed to be engaging and flexible enough for a wide range of student ability/grade level. The four activities below look at various interactions of multiple unbalanced forces in order to explore the dramatic changes in motion involved in a car crash.

Students will gain a lot from considering how different forces, such as gravity, affect a familiar object, while advanced students will benefit from identifying these forces as forms of energy, such as kinetic and potential. During the analysis stage, students are casually introduced to Newton's Three Laws of Motion. These do not have to be explored or understood in-depth for junior levels, however Year 10 students will highly benefit from a discussion on these as they begin to describe the motion of objects using the laws of physics.

This investigation begins at a prescribed level due to the way the activities build on one another to explore various aspects involved in a crash, however the last activity asks the students to design and perform their own experiment with the knowledge gathered from the previous activities. The team-work and use of technology (video camera) add to the overall enjoyment. Students will be exposed to car safety engineering principles, such as the benefit of crumple zones. This can open up valuable discussion on how advances in science can affect people's lives and what STEM careers are available in this industry.

Aim:

Activity One

Students are presented with the following question: In this experiment, teddy is a passenger at the back of the car and the car crashed into a wall. Ted is not wearing his seatbelt. What happens to Teddy during the crash?

This is a good time to discuss what students expect to happen and formulate a hypothesis.

For Year 7 students, this question addresses their ability to **identify various unbalanced forces acting on an object**. They may be able to list some of the forces that will be at play in this collision, and have a general idea of how the passenger will move.

For Year 8-9 students, this question will address their ability to **understand how energy transformations and transfers cause change within systems**. Students may be able to predict the flow of energy from potential to kinetic to heat and sound energy. Students may already have an idea of conservation of energy, therefore having a better idea of how the passenger will move as all energy must be "accounted for".

For Year 10 students, this question will address their ability to **apply Newton's Laws in order to predict how a force affects the movement of an object**. They may be able to predict that the passenger will continue in a straight line until another force acts upon them; first gravity will cause a projectile movement, and then as the ground is reached movement will stop.

Activity Two

Students are presented with the following question: <u>In this experiment, teddy is the driver at the front of the car and the car crashes into a wall. There is no windscreen and no seat belt. What happens to Ted during the crash?</u>

This question is similar to the first; however a controlled variable (position of the teddy on the trolley) has been changed. Any changes to the movement of teddy in this case will be due to this isolated variable.

For Year 7 students, this question addresses their ability to **use information from a previous investigation in order to predict the expected results**. They may hypothesise that the driver will move in a similar fashion to the passenger.

For Year 8-9 students, this question will address their ability to **identify and explain the differences between controlled, dependent and independent variables**. Students may be able to predict that the driver will move in a similar fashion to the passenger, but with some notable differences. They may be able to understand the importance of conducting a "fair-test" in order to obtain an accurate comparison.

Year 10 students may be able to understand that the movement of the driver is highly predictable as there are **laws of physics** at play. As there is no windscreen or seat-belts on the trolley, the teddy is likely to land even further from the obstacle (if the back of the trolley does not flip up).

Activity Three

Students are presented with the following question: <u>In this experiment, you will add a crumple zone to the front of the trolley. Does the crumple zone lessen the impact on Ted?</u>

This may be the first time that students are introduced to the concept of a crumple zone. As such, this will be an exploratory investigation. It is not expected that students work from a hypothesis, however students may be able to predict that the paper crumple zone will make less of a difference to a collision than one made from cardboard.

Activity Four

Students are presented with the following question: <u>In this experiment, one trolley with Ted1 as passenger collides with the rear of a second stationary trolley with Ted2 as the driver. During the collision, what happens to both Teds?</u>

This activity adds to the complexity of the investigation as it contains more than one object with wheels.

For Year 7 students, this question addresses their ability to **understand that a change in an object's motion is caused by an unbalanced force**. They may be able predict that the front trolley will be pushed to move forward.

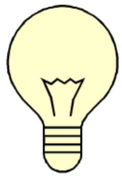
For Year 8-9 students, this question will address their ability to **understand how kinetic energy can be transferred from one moving object to another**. They may be able to predict that the front trolley will move forward at a slower pace.

For Year 10 students this question will address their ability to **apply Newton's Second or Third Law to describe the interactions between objects.** They may be able to predict that as the front trolley moves forward, the back trolley will move backwards or experience a dramatic change in acceleration/slow-down. They also may be able to predict that the teddy in the front trolley will end up safer in some ways.

Plan:

The materials list is provided to students as well as prescribed instructions. Due to the space required to perform this investigation and the danger of fast moving objects, considerable team-work skills will be needed. This may be assisted with teacher allocations of groups and roles (such as camera-man, "driver", car engineer, ramp engineer, time-keeper, OHS officer, video technician).

For advanced/higher-grade students that wish to calculate the forces at play, measuring the weight of the trolley, teddy and brick will be useful.



A common problem is having teddy fall off the trolley before collision. This can be minimised by ensuring students make the cardboard seats high and wide enough to push teddy all the way down the ramp.

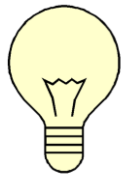
Conduct:

Students are given step-by-step instructions on how to conduct the first three activities. There are two phases of this activity, first the physical trials and then watching back the video. Students should be encouraged to make observations during both phases, drawing and writing notes as they go along.

Guidance can be offered with suggestions such as the following: Students are asked to feel the temperature of the wheels before and after the collision to see if there has been any transference of energy into heat energy. A noise level meter can be used to show a peak in decibels during the crash or software can be used to visually display the sound recorded on the video in order to see a peak of amplitude at the moment of the crash. This would be evidence of a transference into sound energy. Inspect the site for any physical impact damage, including the obstacle.

As Activity 4 is an open-inquiry investigation, students will be allowed to create their own steps. From what they have learnt from the previous investigations, students should have a good idea that the front trolley needs some kind of marker to set-up each test fairly.

Advanced/higher-grade students can imagine that they are a road-safety detective. Advise them to inspect the site and see if they could put clues together in order to explain what happened after-the-fact. These students could also be guided into incorporating more measurements of distance in their analysis. A distance that would be helpful to know is how far back the trolley moved from the obstacle/front trolley.



A fun extension to this activity could be to instruct students to design a seatbelt for teddy. Providing only a minimal amount of materials to use would increase the challenge.

Analysis:

The analysis section of the activities is open-inquiry with the addition of focus questions. Students have to decide how to represent their data, as no tables or graphs are given to record results. Lower grades may choose to write and draw their observations with arrows, giving an opportunity to later discuss how their notes can be put into a more structured representation.

There are two sections were observations are recorded which correspond to the 2 phases of each activity. Examples of results tables for the first phase are as follows:

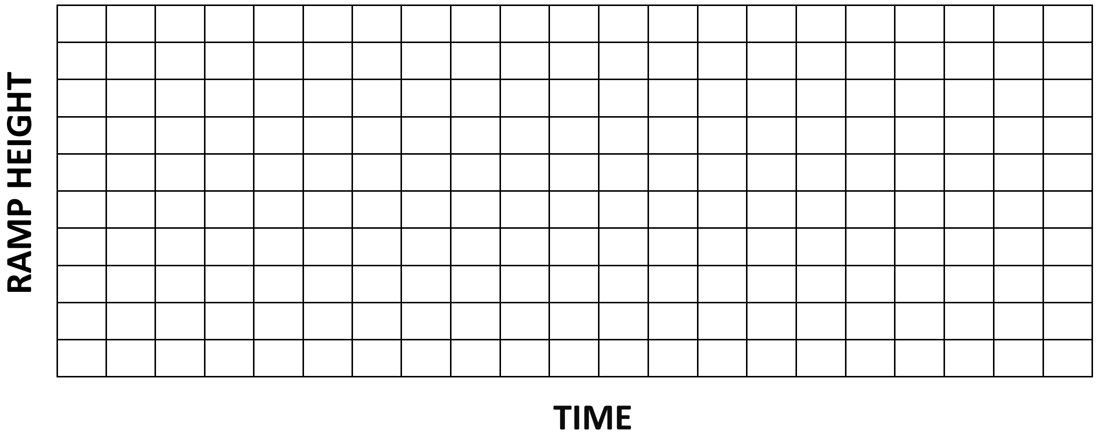
Ramp Height	Observations of Trolley	Observations of Ted
.5m (Slow)		
1m (Fast)		
1.5m (Fastest)		

Ramp Height	Crumple Zone	Observations of Trolley	Observations of Ted
.5m (Slow)	Paper		
	Cardboard		
1m (Fast)	Paper		
	Cardboard		
1.5m (Fastest)	Paper		
	Cardboard		

Ramp Height	Front Trolley	Front Ted	Back Trolley	Back Ted
.5m (Slow)				

1m (Fast)				
1.5m (Fastest)				

The second phase includes observations made of the play-back video. These measurements can be recorded on a plot graph with the following axis:



A good homework activity could be to input this accumulated data into excel in order to create a master graph which represents each test with a different coloured line. Students can then see that the over-arching trend is that a higher ramp height means an increase in time.

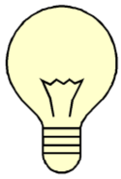
Problem-Solving:

Students will be advised to consider which Newton's Laws are at play. Of course, all three will have some application. Motivate Year 10 students to explain how each law applies, for example:

Newton's First Law: Trolley is stationary as the force of gravity and the grip of our hands are balanced. Once the trolley is let go, the force of gravity dominates, causing the trolley to move in a straight line until stopped by the obstacle.

Newton's Second Law: The obstacle outweighs the trolley considerably, meaning only the trolley will move backwards.

Newton's Third Law: When a trolley runs up the rear of another trolley, it slows-down, stops or moves back. This is because the front trolley has exerted an equal and opposite force backwards.



Years 8-10 students will benefit from a discussion about how **friction** is always at play, "stealing" energy from the system and always acting against the force gravity.

During Activity 4, see if the students can isolate a video frame which shows whiplash occurring to the Ted in the front seat. Print-screen this image to use later for a discussion on car safety and why it is legislated in Australia that all cars must be manufactured with head-rests.

Focus Question: *Discuss which results you got that were expected and which were unexpected.*

Think back to the initial hypothesises that students made before commencing each activity, including any apparent gaps in their ability to make predictions based on their grade-specific outcomes. Can you help the students understand how the theories of balanced/unbalanced forces, closed systems of energy transference and transfer **OR** laws of physics explain any unexpected results?

Focus Question: *Refer to the drawings you made, can you think of any problems with the experimental design which could have impacted the results* ***OR*** *what else could have been done to make the experiment more reliable (a fairer test)?*

The students were instructed to draw the apparatus of the experiment. It would be valuable to discuss with students if their experiment could be replicated by someone else if they were to look at their diagram only. What qualitative considerations could be made to improve this? Example questions are as follows: Are all components of the experiment included? Are there clear labels? Is the diagram drawn to scale and if not, how could that be done?

In order to draw a diagram to scale, many items in the experiment would also need to be measured such as ramp length, ramp height, trolley length, obstacle distance, etc. How would keeping these measurements consistent for all tests help with the reliability of the experiment? Could damage to the seat over time also be a consideration?

Conclusion:

Focus Question: *What can you conclude about what happens during a front collision car crash?*

Can students conclude the following? In the case of a vehicle with no roof/seat-belt and windscreen, if that moving car is dramatically stopped, any passengers will continue the move as fast as the car was until they are also stopped.

Focus Question: *What is the difference of sitting at the front versus sitting at the back in a car during a collision?*

Can students conclude the following? The front person will fly out of the car a further distance as their path has a head-start.

Focus Question: What can you conclude about designing a car to better protect passengers during a crash?

Can students conclude the following? Re-read the first paragraph in the introduction; Can you now understand why designing cars to take more of the damage during a collision will keep the drivers and passengers safer? Conservation of energy means that Ted experiences less force as energy is being redirected to bend the material.

Focus Question: *What can you conclude about what happens during a car on car collision?*

Can students conclude the following? When a car crashes into the rear of another car, the back car will experience a force that will push any passengers out of their seats. The person in the front car will stay in their seat, but it they don’t have a head-rest then they will experience whiplash that could be very dangerous.