If the Shoe Fits – Teacher Notes

By Louise Lopes

Introduction

This investigation is an open-inquiry exploration into the dynamics of friction. It is safe and inexpensive to conduct in the classroom, and can even be done in the home. It presents a real-world problem and incorporates sport science in order to engage a wide variety of students. This investigation is designed to be flexible enough for a range of student ability and grade levels.

Friction is an important concept to grasp within Forces in Years 7 to 10. By doing this investigation, Year 7 students will be able to better understand how gravity and unbalanced forces act upon everyday objects, while Year 8 students will better understand why it is common that kinetic energy transforms into heat and sound energy (as friction "leaks" energy from that system). For Year 10 students, friction is an important factor when describing the difference of motion in an atmosphere versus an object moving in space (vacuum), as well as the loss of 'efficiency' (useable energy) in an energy system. This investigation will allow students to explain friction using laws of physics.

Moreover, the open-inquiry nature of this investigation guides students to develop their own scientific report and experiment. This encourages students to apply their knowledge and skills in working collaboratively, understanding variables, conducting a fair-test, using scientific measuring equipment and inputting results into tables and graphs for analysis. Suggestions for class discussion and extension activities are provided through-out.

Questions

Students will be asked to write their own questions. Students may start with questions such as the following: Why do dancers wear leather soled shoes and soccer players wear spiked shoes? Why is athletics performed on 'rough' surfaces?

However, as students need to pick one scientific question for their lab group, they will need to be more specific, such as: Will a spiked, rubber-soled or leather-soled shoe be the hardest to slide on sandpaper lined board? **OR** Which of the following surfaces, carpet, sandpaper or wooden, would be the easiest to slide on with a rubber soled shoe?

Teachers will guide students in this process by conducting a class discussion on what makes an appropriate scientific question for an experiment. You may wish to explain how this question needs to make clear what cause and effect actions will be planned (what variables will be manipulated and/or measured). Limitations need to be set so that the question only refers to what is being tested and nothing more.

Students will then be advised to write an Aim and Hypothesis for their experiment. The Aim can be based on the question with a small amount of additional details, such as the variables. The hypothesis can closely reflect the question by providing an answer to it with the student's predicted results.

Plan

Students are provided with a materials list and guided to focus on relationships between the various shoes and surfaces.

Year 7-8 students may need guidance on how to use the spring balances. A description could be provided such as the following: spring balances measure Newtons (unit of force) and can be used to measure the force of a "pulling" action.

Students will be asked to identify and distinguish between independent, dependent and controlled variables. For Year 7 students, it may be necessary to provide concrete examples of how they can answer in the spaces provided on the worksheet. For Year 8 students, it may be beneficial to provide definitions of what these terms mean, such as:

Variable: This refers to an element/component/part of the experiment that can be changed.

Independent Variables: You will change **this** in each test in order to see what happens (such as floor type).

Dependent Variables: You expect **this** to change as a result of changing the independent variable (such as Newtons on the spring balances).

*Controlled Variables***:** This refers to any other parts of the experiment which can be changed, and if changed will likely affect the outcome of the experiment. Usually these are meant to be kept as constant as possible over all tests (such as sandbag weights).

Students may choose to make the amount of sandbags an independent variable in order to explore how different weight causes more or less friction.

Students are instructed to develop a method. As a group, they will have to write down each step. Only guidance in formatting is recommended during this process, as students may discover problems in their experimental design on their own during the Conduct and Analysis phase of the investigation.

Conduct

Students can commence their experiments once their methods have been written. It is expected that there will be differences in the level of organisation and in the number of tests required amongst groups; therefore time to complete the experiment for each group may vary significantly. In this time teachers may motivate students to make as many additional observations as possible.

Guidance can be offered with the following suggestions:

Students are asked to use their fingers to feel the texture of the surfaces and soles. Can students describe their sensations in words?

Students are asked to feel the temperature of the shoe soles before and after rubbing them on the surfaces quickly to see if any heat energy can be generated. Is there a combination which generates the most heat? What about looking for any physical damage to the sole?

A fun extension to this activity could be to get students to perform this test at home with a wide range of shoes and surfaces. What about testing wet bathroom tiles compared to concrete, or testing stiletto shoes compared with Ugg boots?

Record the sounds that are made when the shoes are pulled along each surface and analyse this with a program that displays the audio as a wave. Can you compare the amplitudes of each sound test to definitively say which combination made the loudest sound?

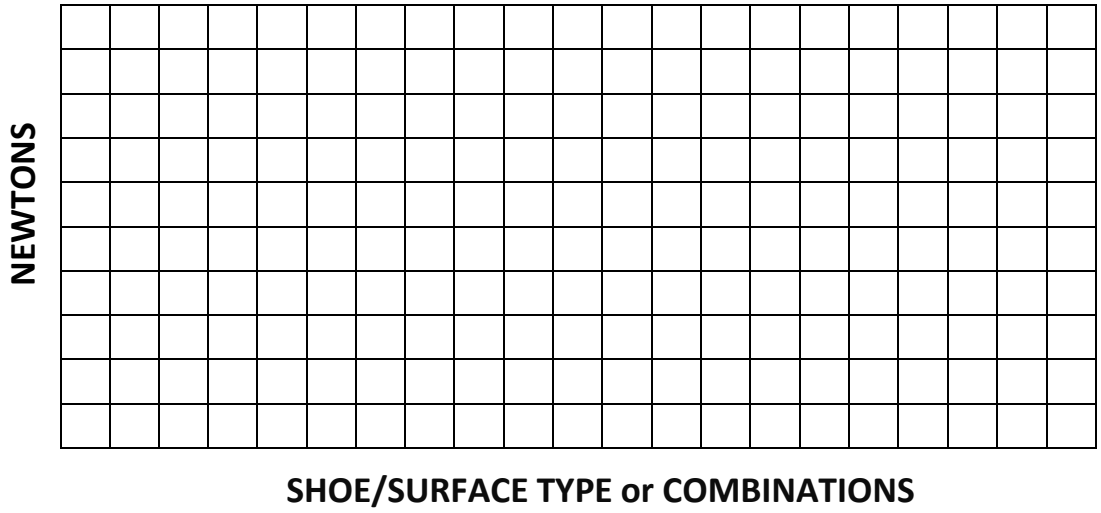
Both qualitative and quantitative results are asked for in the worksheet, motivating students to record visual, aural and tactile observations, as well as the measurements recorded on the spring balances.

Analysis

There are nine shoe/surface combinations possible for the students to test. Students may have chosen to structure the tests based on shoe sole types or ground types, and not all shoes or surfaces may have been included. Below is an example table that students may use to display their qualitative results:

Shoe Type	Surface Type	Observations
Studded	Carpet	
	Sandpaper	
	Wooden	
Rubber	Carpet	
	Sandpaper	
	Wooden	
Leather	Carpet	
	Sandpaper	
	Wooden	

Quantitative results may be plotted on a graph with the below axis. If different sandbag weights were included in the testing, then students can plot these results in a different colour and create a key to go along with it.



Students could input this data into excel in order to generate a graph. What graph would be the best representation for these results? A bar graph is a good choice to compare a specific feature of different objects. Which bar stands taller, which is the shortest? Can you sort the results in excel so each shoe/surface type or combination is shown in descending order in terms of its "pull" force? What relationships now become apparent?

Problem-Solving

At this stage students can evaluate whether their experimental design was satisfactory. Did they test the correct things in order to obtain an answer to their question? Did they conduct a fair-test? Did students ensure that the controlled variables remained consistent throughout, such as sandbag weights? Is the weight of the shoes used a consideration? Did students check to see that the table they used was flat? Were any markers used to keep tests consistent throughout? Discuss these issues with students as they assess the reliability of their results.

An interesting homework activity could be to research the fastest ice-skater on record. How are these fast speeds possible on the ice? How does the combination of the ice-skate blade and surface ice cause the small amount of friction to make this movement possible?

From analysing the results, the students will begin to see which shoe/surface combination needed the most pulling force. They can now compare these results to the predictions made in their hypothesis. Discuss which results they got which were expected and which were unexpected.

Students are asked to give explanations for the results they obtained. Year 7 students may be able to identify the balanced and unbalanced forces at play and see a relationship between the smoothness of a surface and the resistance it causes other objects which move against it. Year 8-9 students may be able to explain that kinetic energy transferred from the experimenter's arm to the shoe and that some energy was transformed into heat and sound energy. Students can be asked to produce a flow diagram explaining this energy system. Year 10 students may additionally explain their results by using Newtons Laws.

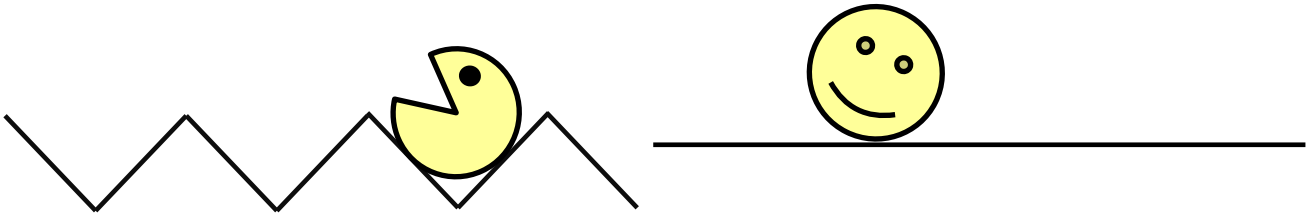
Encourage students to describe what friction is by using their results and theoretical explanations, such as the following:

The weight of the sandbags put a downwards force onto the surface mat due to the gravity of the earth. The surface mat which has been propped up by a table or floor is creating an upwards

force. At first, these two forces are balanced (are of equal magnitude and in opposite directions) as the shoe is not moving.

Once the shoe is pushed along the surface, the student is imposing an unbalanced force. The shoe will begin to move in one direction. However, the sandbag weights are still exerting a downwards force due to gravity. Therefore, the shoe is moving both sideways and downwards, causing the effect of friction.

Surface texture is made up of imperfections in the form of very small crevices, ridges, troughs and peaks. These imperfections can be felt with a finger, and they cause resistance to anything that moves over it, as there are things to 'catch-on'; if these imperfections are hard and not malleable (like sand grain versus carpet fibres), the resistance can be substantial. Therefore, the overall smoothness of a surface is related to the friction that it produces. A useful aid is for students to imagine a bug moving across a zigzag line versus a straight line.



The more imperfections on the surface there are, the more resistance there will be acting against an object that is pushed across it. Therefore, more force is required to move the object in order to 'overcome' this resistance. This causes friction.

Additionally, the more friction there is, the more energy loss there will be in the form of heat and sound energy, all adding to the amount of force required to push that object across. This is due to the Law of Conservation of Energy.

Conclusion

In this section students will be able to answer their initial question, making a short statement about what their overall findings were.

Were students successful in answering their question? How many groups were able to show that their hypothesis was correct?

Can friction happen in the air? A fun extension activity could be for students to research what a shooting star is. Can students understand why objects burn-up as they enter the earth's atmosphere?

If students are interested, teachers may conduct a discussion on why some sports require more surface friction than others. Friction allows runners to go faster as there is no back slippage on the foot that propels them forward, while dancers use smooth surfaces to perform gliding movements. Students may research this topic in more depth.