FRAUGHT WITH FRICTION

Supporting second-grade students' thinking using the PEOE strategy

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PEOE (predict, explain, observe, explain) is a strategy that supports conceptual change (Dial et al. 2009). *Conceptual change* is a process through which students can change their understandings, ideas, or beliefs (diSessa 1993; Konicek-Moran and Keeley 2015). This style of lesson allows students to express their scientific ideas (predict, explain), see evidence that shows how their predictions do or do not align with scientific concepts (observe), and adjust their understanding accordingly (explain). To benefit from this strategy, students must be given cues to show them it is okay, even expected, that they will have made incorrect assumptions about scientific concepts. Teachers can do this through the wording and types of assignments they use. Often, students also need an experience that causes cognitive dissonance or that does not match their previous thinking in order to change or add to their ideas (Manz 2014). When students see how their thinking is incorrect or incomplete, they are able to modify their understanding and adjust their ideas to learn the concept being taught (diSessa 1993). Students who are simply told their ideas are incorrect and that they must relearn the information generally comply with what the teacher tells them, but never take ownership of the knowledge and tend to rely more heavily on their original thought processes (Campbell, Schwarz, and Windschitl 2016).

In this activity, a question is posed to second-grade students and they are asked to make predictions to answer it: "How will different surfaces affect the distance a toy vehicle travels?" Students observe how different surfaces affect the distance traveled by a toy car and are able to amend their predictions. They are then asked to think of reasons why the vehicle was affected the way it was. During this stage of the lesson, students are led to contemplate their understandings of science concepts, and teachers are able to assess changes in student understanding as a result of discussions and writings. Prior to this lesson, students learned how friction creates heat energy but had not discussed how the force of friction can affect the motion of an object. We broke this lesson up over three days (Table 1).

Description of the Lesson

The students conducted a whole-group investigation to discover the effects of friction on an object's movement. They were told they would be investigating how a wind-up vehicle's motion would be changed by traveling across different

TABLE 1

Lesson outline.

	DAY 1	DAY 2	DAY 3
Main Activities	Introduce concept, predict outcomes (30–35 min.)	Generate data through observation (30–35 min.)	Draw conclusions based on data (30–35 min.)

TABLE 2

Materials for lesson.

Materials	• self-propelled wind-up vehicle • tape measure
Surfaces	• smooth tile floor • beach towel • nonskid pad • woven rug

surfaces, such as a smooth tile floor, a beach towel, a nonskid pad, and a woven rug. We demonstrated how to wind the car up safely and release it in a safe manner. Depending on the type of wind-up cars used, safety goggles may be necessary.

Students were asked to predict how far the car would move on different surfaces and which surface would be the best for getting the car to travel the farthest distance. This

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FIGURE 1

Predictions made by students.

The car will continue to travel on the tile until it hits something.

It will travel at different speeds on the different surfaces, but go the same distance on all of them.

It will go to the end of the surfaces, except on the tile where it will go half the length of one tile.

It will not move much on the nonskid pad.

The rug will be too bumpy for the car, so the car will stop.

FIGURE 2

Sentence frames used for scientific discourse.

(Surface type) caused the vehicle to travel a (farther/shorter) distance than (surface type) because ________________.

I (agree/disagree) with _______________ because _________________________.

I think that ____________________ because ______________________________.

TABLE 3

Average distance traveled over three trials.

	TRIAL 1	TRIAL 2	TRIAL 3
Tile Floor	13 ft., 4 in.	12 ft., 9 in.	10 ft., 4 in.
Towel	4 ft., 1 in.	3 ft., 8 in.	6 ft., 4 in.
Nonskid Pad	5 in.	11 in.	0 in.
Rug	4 ft., 9 in.	1 ft., 11 in.	1 ft.

was the first time the concept of friction had been introduced, outside of rubbing their hands together to keep warm in cold weather, so many of our students had varying ideas about the effect the different surfaces would have on the car. We used the materials listed in Table 2 p. 45, to conduct our investigation.

The investigation aligns with *Next Generation Science Standard* 2-PS1, which states that students should "analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose" (NGSS Lead States 2013, p. 16; see *NGSS* table on p. 48). During the lesson described, we scaffold students' understanding about the force of friction by showing them that an object is able to travel a further distance when the force of friction acting on that object is less. A car toy is wound up the same amount in each trial so that the car has the same amount of energy to start. Students observe that, with the same amount of input energy applied to the object, the distance the object travels decreases because as the object moves forward, its friction increases.

Day 1

On the first day, students examined the different surfaces we would be using during the investigation and discussed how they thought the wind-up vehicle's movement would be affected by each surface. Students completed a simple handout (see NSTA Connection) to help them think through and record their predictions. Their predictions were recorded (Figure 1) and students were encouraged to use sentence frames to practice agreeing and disagreeing with each other politely (Figure 2). Prior to this lesson, students had learned about standard units of measurement so they were able to estimate distances; however, if students have not learned about standard units of measurement yet, then it would be appropriate for them to use comparative language (e.g., not that far, very far).

One student remarked, "It will go to the end of the surfaces, except on the tile where it will go half the length of one

FIGURE 3

Vehicle on a rug.

tile." From this response, it is clear she was not considering the effect the different surfaces would have on the vehicle. She was merely thinking about the fact that we had picked the surfaces for the car to travel on and so it must stop when it reaches the end of them. Although she was not able to articulate it clearly, we believe she meant that the vehicle's range of motion would be more limited on the tile floor because there was no clear ending point marked off for it like there was for the other surfaces we experimented with. Another student thought the car would keep going on the tile floor forever unless an obstacle was in the way. We can tell from this response that she lacks an understanding of the forces acting on the car. Her selection to restrict her response to the tile floor shows that she is aware there is less friction on that surface than the other ones presented, but she may not be certain how that will play a role in the distance the vehicle travels. Several students thought that the rug would be too bumpy for the car to run on at all.

Day 2

On the second day, we reviewed the predictions from the day before and our students added to or revised their ideas if they desired. Students were asked if they wanted to keep their original predictions or not and had an opportunity to discuss with their group. After a brief period of consideration with their group and then the whole class, they decided to keep their original predictions. We then tested the predictions by running the car on each of the surfaces three times (Figure 3). At this point, we discussed why three trials were appropriate.

For consistency, the wind-up vehicle was carefully wound completely before each trial. This way, the only variable we observed was due to friction, not variables in the force applied to move the toy forward. The teacher led a discussion about these variables prior to testing and decisions were made by the class about how far to wind the car and where to release it. Students then took turns winding and releasing the car. The control variables were then reviewed as students completed their lab handout. The same wind-up vehicle was used for each trial, so all factors, such as tire traction and weight of the vehicle, remained constant. One student per group recorded results on a clipboard, and we kept track of the results as well. These were then recorded on the board to ensure all students had the same results. Our results are shown in Table 3. At the end of day 2, we discussed the trends they noticed about each surface, what was the same in every trial, and why they thought the vehicle went different distances. Students were asked to think carefully about these ideas before we came back this lesson the next day.

Day 3

After conducting the investigation, students were asked why they thought the vehicle was able to move farther across some surfaces than others (see NSTA Connection). They concluded that the vehicle's motion was affected by how bumpy or smooth the surface was. Students drew conclusions from the data collected in Table 3. They were given the following sentence frame to help guide their discussion: "(Surface type) caused the vehicle to travel a (farther/shorter) distance than (surface type) because ________________." Students wrote one sentence for each surface. We looked to see if students recognized the texture of the surface affected the motion.

Although the results from our investigation (Table 3) show that the vehicle was able to travel over the rug during each of the trials, there was an instance where it did not move on the nonskid pad. The data included in Table 3 was collected as a whole group, and students discussed them in pairs. After viewing and discussing with partners the data collected, students were able to grasp that the difference in distances traveled was due to how "bumpy" or "smooth" each surface was. For example, "If [the surface] was flat [the vehicle] would go fast; if [the surface] was bumpy [the vehicle] would

Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

Standard

2-PS1 Matter and Its Interactions

www.nextgenscience.org/dci-arrangement/2-ps1-matter-and-its-interactions

- The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.
- The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectation listed below.

Performance Expectation

2-PS1-2. Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.

DIMENSIONS	CLASSROOM CONNECTIONS
Science and Engineering Practice	
Analyzing and Interpreting Data	Students analyzed data from their own observations and measurements of how far the vehicle traveled, then compared the results. Students connected the properties of surface materials to increased friction that slows down the vehicle.
Disciplinary Core Idea	
PS1.A: Structure and Properties of Matter Different properties are suited to different purposes.	Students observed the effects of different surfaces on distance traveled. Students developed an argument to explain the variance of distance traveled.
Crosscutting Concept	
Cause and Effect	Students compared and contrasted data from tests. Students developed an argument to explain the variance of distance traveled. Students discussed the impact of the different surfaces on the distance travelled by the vehicle.

Connecting to the *Common Core State Standards* (NGAC and CCSSO 2010)

Mathematics

MP.2: Reason abstractly and quantitatively.

MP.4: Model with mathematics.

MP.5: Use appropriate tools strategically.

2.MD.D.10: Draw a picture graph and a bar graph to represent a data set with up to four categories. Solve simple put-together, take-apart, and compare problems using information presented in a bar graph.

2.MD.A.4: Measure to determine how much longer one object is than another, expressing the length difference in terms of a standard length unit.

go slower." They were also able to articulate that smoother surfaces were a better choice for traveling farther distances. Some students thought the materials would stick to the rubber tires and affect the motion of the vehicle. Others were able to recognize that the texture of the surface (smooth or bumpy) was causing the differences they were seeing.

In our discussion, we talked about how the car's spring stores energy that is changed into a kinetic force that moves the car forward. The material the car drives on provides resistance to this force. This resistance force is *friction*. Depending on the readiness of students, this discussion could be extended to talk about how one can change the surfaces or vehicle to reduce friction. The teacher could start by asking students, "What are some ways our roads are changed depending on the weather?" Students would be expected to say rain, ice, or snow. This could then be investigated by waxing or covering the surface with water or baby oil to simulate wet surfaces in everyday conditions. With snow, students could consider how to "salt" the surface to simulate salted roads in winter. In addition, the teacher could ask about how the vehicle could be modified to increase or reduce friction. Students may suggest increasing the mass or increasing the size of the tires to change the amount of friction and how far the vehicle travels.

Assessment

Using predictions gathered on student worksheets, teachers can compare student understandings gathered on the conclusions worksheet to check for conceptual change by the end of the lesson. Our students' responses to the predictions worksheet revealed that they were unaware rougher surfaces would result in a greater amount of friction and reduce the distance traveled by the vehicle. From responses to the conclusions worksheet, we saw that students were able to articulate an understanding that smoother surfaces allowed the vehicle to travel farther. To assess student understanding, a rubric was used (see NSTA Connection) to evaluate student responses gathered on their conclusions worksheet.

Conclusion

We believe participating in this activity helped scaffold conceptual change for students. Students' initial predictions were changed by engaging in the activity and resulted in more accurate understanding of the concepts. They practiced discussion strategies that allowed them to agree or disagree with each other in a constructive manner. Because we asked students for their predictions before conducting the investigation, they thought more about the activity and were more actively engaged during it to find out whether their predictions matched their observations. We were also able to find out how advanced their scientific reasoning skills were as they pertained to the given task. By setting the tone that students would have misconceptions before conducting the investigation, we were able to create an environment where students did not feel embarrassed that they did not yet know the content. They were able to discuss their ideas with each other in a constructive, nonjudgmental manner. The PEOE strategy opened the door for this to happen in a way that other lesson structures never would have allowed. The PEOE strategy can be applied to many lessons to increase student involvement and provide insight into their scientific reasoning skills. ●

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NSTA Connection

Download student worksheets and teacher rubric at *www.nsta.org/SC1903*.

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