ACTIVITY 1: REDUCING TRUCK EMISSIONS

Summary:

In this exercise, students will compare the emissions of a normal gasoline-powered vehicle with the emissions of a hybrid vehicle. They will calculate the percent of emissions (or pollution) eliminated, and the percent of fuel saved by using a hybrid electric vehicle. In the follow-up activity, they will calculate the total amount of fuel saved if a certain percentage of vehicles in Colorado were to be replaced by hybrid electric vehicles.

Activating Prior Knowledge:

Use a hypothetical situation, similar to those found in Section 3.2 of the Connected Mathematics unit *Comparing and Scaling*, to review how to calculate a percent increase or decrease. For example: If a dress normally priced at $50 is on sale for $20, then review with the students how to calculate that the sale price is 40% of the original price, and the discount is a 60% discount. Tell them that in this unit they will utilize this knowledge (how to calculate discounts) in a different setting.

Review the rate equation, $D = RT$, distance = rate $\times$ time, which they learned in the Connected Mathematics units *Variables and Patterns* and *Moving Straight Ahead*. Remind them that although the rate they used with $D = RT$ was miles per hour, rates can have denominators other than time, like hot dogs per student or gallons per mile.

Show the students a picture of a large truck. (A picture is included in the back of this packet if you can't find a better one.) Tell the students that most heavy-duty vehicles run on diesel fuel. Tell them that burning diesel fuel puts a lot of pollutants into the atmosphere, and that scientists have been working on ways to eliminate those pollutants. Ask them if they've ever seen clouds of smoke coming from a truck's exhaust pipe.

New Concepts:

Introduce the students to the word "*emissions*". *Emissions* is the word scientists use for the mixture of gases that comes out of a car's or truck's exhaust pipe.

Ask the students what benefits would come from successfully eliminating or reducing the emissions from a heavy-duty vehicle like a truck.

Introducing the Problem:

Show the students a picture of a hybrid truck. (A picture of a hybrid UPS truck is included in this packet.) Tell the students that, although a hybrid electric vehicle doesn't look any different on the outside, on the inside it includes an electric motor, so that the internal combustion engine doesn't have to do all the work to move the truck forward.

Give each of the students a copy of Tables 1 and 2 (see the handout master at the back of this packet). Table 1 compares the emissions from a normal diesel truck to the emissions from a hybrid electric truck. Table 2 compares the fuel mileage for a normal diesel truck and a hybrid electric truck.

Pollutant	Emissions from a regular truck	Emissions from a hybrid electric truck
Carbon dioxide	1700 grams/mile	1047 grams/mile
Carbon monoxide	8.1 grams/mile	6.25 grams/mile
Hydrocarbons (unburned fuel)	0.20 grams/mile	1.02 grams/mile
Nitrogen oxides	22 grams/mile	10.44 grams/mile

Table 1: Gaseous emissions from heavy-duty diesel and hybrid electric vehicles. (Source: National Renewable Energy Laboratory, Golden, Colorado)

Type of vehicle	Diesel fuel mileage
Internal combustion	3.5 miles/gallon
Hybrid electric	8.8 miles/gallon

Table 2: Fuel consumption from heavy-duty diesel and hybrid electric vehicles. (Source: National Renewable Energy Laboratory, Golden, Colorado)

The Colorado Department of Transportation reports that in 2003, cars and trucks drove more than *26 billion miles* on highways in the state ("Crashes and Rates on State Highways, 2003"). For the purposes of this activity, assume that half of that, or 13 billion miles, are truck miles.

Implementing the Lesson:

Students should use the Tables to answer the following questions.

1. If a single diesel delivery truck is replaced with a hybrid electric truck, what is the percent decrease in carbon dioxide emissions? (This is just like calculating the percent discount on a dress.)
2. Repeat question 1 for carbon monoxide, hydrocarbons, nitrogen oxides and particulates. Put your answers in a table.
3. Trucks drive 13 billion miles a year on Colorado roads. If all the trucks in Colorado were to be replaced with hybrid electric vehicles, how much carbon dioxide pollution would be eliminated?
4. If only 20% of the trucks in Colorado were to be replaced with hybrid electric vehicles, how much carbon dioxide pollution would be eliminated?
5. How much diesel fuel do all the trucks in Colorado consume in one year?
6. If all the trucks in Colorado were to be replaced with hybrid electric vehicles, how much diesel fuel would they consume in a year?
7. Calculate the percent reduction in diesel fuel consumption for question 6.
8. If only 20% of the trucks in Colorado were to be replaced with hybrid electric vehicles, how much diesel fuel would they consume in a year?

ACTIVITY 2: HOW CATALYTIC CONVERTERS WORK

Summary:

In this exercise, students will use linear functions to determine the total amount of hydrocarbons emitted by a vehicle depending on its catalyst temperature. For this exercise, students will use a table to create a graph, and then answer questions based on the graph.

Activating Prior Knowledge:

Use a hypothetical situation, similar to those found in Section 3.2 of the Connected Mathematics unit *Moving Straight Ahead*, to review linear relationships.

For example, a bicycle touring group knows that it will have to spend $800 to rent a van no matter how many people go on their tour, plus an additional $130 per client. Students should be able to identify number of clients as the *independent variable*, and expenses as the *dependent variable*. Students should know how to create a table of values for number of clients and expenses, with $800 as the *starting point* (or *y-intercept* of the linear function, if students are advanced) and $130 per client as the *rate* (or *slope* of the linear function, if students are advanced). Students should also know how to create a graph and an equation for the linear relationship.

New Concepts:

Review the concept of *emissions* with students. Ask students for ideas on how to reduce emissions from vehicles. They may use ideas from Activity 1, or come up with new ideas. Some ideas are: drive less, drive a more fuel-efficient vehicle, drive a hybrid electric vehicle, take public transportation, get a job closer to home, and so on. One student may come up with the idea of somehow cleaning up the exhaust gases.

Tell the students that cleaning up the exhaust gases is the idea behind a *catalytic converter*. If they look under their family car, they will find two bulges on the tailpipe. The bulge nearest to the end is the muffler, which makes the engine sound quieter. Between the muffler and the engine, usually under the front passenger seat, is the catalytic converter. A *catalyst* is a chemical substance that causes a chemical reaction to happen, or to happen faster

Tell the students that on an automobile, the catalytic converter is used to turn poisonous carbon monoxide into the less dangerous carbon dioxide, unburned hydrocarbons into carbon dioxide and water vapor, and nitrogen oxides into nitrogen and oxygen. Water vapor, nitrogen and oxygen are natural components of the atmosphere and are non-polluting emissions. Although carbon dioxide in large quantities is a greenhouse gas and therefore a pollutant, it's much less dangerous than carbon monoxide.

If it's important and timely, help the students to understand the poisonous properties of carbon monoxide by finding a story in a recent newspaper about deaths caused by a defective fireplace, gas heater or indoor charcoal burner.

Introducing the Problem:

Scientists measured the concentration of carbon monoxide in a vehicle exhaust, compared to the temperature of the catalyst. Their results are shown in Table 3 (see the handout master at the back of this packet).

Catalyst temperature (°C)	THC (parts per million)
408	650
423	594
480	398
474	391
509	263
525	205

Table 3: Hydrocarbon Emissions vs. Catalyst Temperature
(Source: National Renewable Energy Laboratory, Golden, Colorado)

Implementing the Lesson:

Students should use Table 3 to answer the following questions:

1. In the table, which variable is the *independent variable*?
2. Which variable is the *dependent variable*?
3. How does the concentration of hydrocarbons change if the catalyst temperature goes up by 10 °C? Does the concentration go up or down? By how much?
4. Using your qanswer to question 3, calculate a rate of change for the hydrocarbon concentration in the exhaust.
5. On a piece of graph paper, draw a coordinate graph of these two variables. Make sure the independent and dependent variables go on

the proper axis. Plot the points from the table on the coordinate graph.

6. Look at the table and at the graph. Is the relationship between temperature and concentration a linear relationship? How do you know?
7. What would you expect the hydrocarbon emissions to be at 300 °C?
8. What would you expect the hydrocarbon emissions to be when the engine is first started on a crisp autumn day?
9. At what temperature would you expect hydrocarbon emissions to go to zero?

Follow-up:

It may be worthwhile to explain to students that this is not really a linear relationship, but that the small piece of it we have selected for this activity is approximately linear.

ACTIVITY 3: HOW MUCH DOES IT COST?

Summary:

In this exercise, students will conduct research to find the sale price of a hybrid electric vehicle. They will conduct research to find their family car's fuel mileage and average monthly miles traveled. (As an alternative, the teacher can supply them with a few examples, like the ones provided in this activity.) Students will then calculate the dollar value of fuel savings per month by switching to a hybrid electric vehicle. Finally, using the purchase price of a hybrid electric vehicle and the monthly savings rate, they will create a linear function using an equation a table and a graph, and calculate the payback period for purchasing a hybrid electric vehicle.

Activating prior knowledge:

As with Activity 2, use a hypothetical situation, similar to those found in the Connected Mathematics units *Moving Straight Ahead* and *Variables and Patterns*, to review linear relationships.

For example, a boy talks his parents into loaning him $300 to buy a Xbox 360 game system on Ebay. He agrees to pay them back at the rate of $25 per month. Students should already know how to create a table of values, a graph and an equation showing how much money the boy owes.

New Concepts:

Explain to the students that one of the problems with adopting new technologies like hybrid electric vehicles is that they are more expensive than the old technologies, and many people and companies feel that they cannot afford them.

Explain to students that investors don't just look at the initial cost of an investment; they also look at the *payback period.* In the example given in "Activating Prior Knowledge," the parents have invested $300 in the boy's Xbox 360 system. Their *payback period* is the amount of time it will take them to recover their $300, or how long it will take their son to *pay them back,* at a rate of $25 per month.

Introducing the Problem:

In this activity, students will do some independent research to calculate the payback period for their family to switch to a hybrid electric vehicle. This activity may be used as the summary assessment for the unit. A rubric is included in the back of this packet.

Implementing the Lesson:

Students will write a report answering the following questions (included on a handout in the back of this packet). For each question, students must show their work or tell how they got their answer.

1. Describe the vehicle your family uses as "the family car." If you have more than one, choose the one that usually has more than one person in it. For example, you may say: "Our family car is a 2005 Ford Explorer. It has seat belts for seven people."
2. Find out how many miles your family car goes in a month. You can just ask your parents for this number.
3. Find out your family car's fuel mileage, in miles per gallon. You may have to ask your parents for this, or have your parents help you look it up on the Internet. If your family car is a Toyota Camry, Honda Accord or Saturn S400, you will probably have a number between 25 and 32 miles per gallon. If your family car is a van or an SUV, you will probably have a number between 12 and 20 miles per gallon. If your family car is a Hummer or a Ford Expedition, you will probably have a number around 12 miles per gallon.
4. Find out the price per gallon for gasoline or diesel, whichever fuel your family car uses. In the summer of 2007, both gasoline and diesel are hovering around $3.00 per gallon.
5. Using your answers to questions 2, 3, and 4, calculate the cost of fuel for one month.
6. Use newspaper advertisements or contact a car dealership to find the price of a new hybrid electric vehicle to replace your family car. You may need your parents' help for this step. In the summer of 2007, a new 2007 Toyota Highlander Hybrid 4x4 with a third-row seat costs $36,624 from Burt Toyota in Denver. A new 2007 Toyota Prius costs approximately $23,000.
7. Now, suppose that you trade in your family car to buy the hybrid electric vehicle. If you trade in a minivan or SUV, subtract $8000 from the hybrid electric vehicle's price. If you trade in a regular car, subtract $5000 from the hybrid electric vehicle's price. How much did you spend?

8. A Toyota Prius gets approximately 60 miles per gallon. A Highlander Hybrid gets approximately 32 miles per gallon. Use one of these numbers, and your answers to questions 2 and 4, to calculate the cost of fuel for one month for the hybrid electric vehicle.
9. Look at your answers to question 5 and question 8. How much money does the hybrid electric vehicle save you in one month?
10. The answer to question 7 is the amount of money you invested in the hybrid electric vehicle. The answer to question 10 is the rate at which the hybrid electric vehicle saves you money. Make a table with two columns. Label the first column "Months" and the second column "Cost." On the first row of the table, put a zero (0) in the "Months" column and your answer to question 7 in the "Cost" column.
11. In the next row, put a one (1) in the "Months" column. Subtract one month of savings from the cost of the vehicle and write your answer in the "Cost" column. Repeat this step for 2, 3, 4, and on up to 12 months.
12. On a sheet of **graph paper**, plot the data from the table. Make sure you use the correct *independent variable* and *dependent variable*. Make sure your time axis is long enough that a line drawn through your data will eventually cross the axis.
13. Write a rule (or equation) that describes the cost of your hybrid electric vehicle based on how long you have owned it.
14. When the cost reaches zero on the table or in the equation, or when the line crosses the time axis on your graph, you will have found the *payback period* for your purchase: the time it takes for you to get paid back for all the extra money you spent on a hybrid electric vehicle. What is the payback period for your new family car? (Remember to show your work or tell how you found your answer.)
15. Investors usually like a payback period of two years (24 months) or less – they don't like to have their money tied up someplace for longer than that. Based on the payback period in question 14, is a hybrid electric vehicle a good investment for your family?
16. The average new-car buyer keeps a car for four years. This means that if your hybrid electric vehicle has a payback period of less than four years (48 months), it may still be a good investment for your family – it will have paid for itself. So if you use 48 months instead of 24 months as your goal, is a hybrid electric vehicle a good investment for your family?
17. What would the cost have to be, for your vehicle to have a payback period of 48 months?

GLOSSARY

Emissions	The mixture of gases that comes out of a vehicle's tailpipe.
Fuel mileage (or gas mileage)	The amount of fuel a vehicle consumes in order to travel one mile. In Europe, the reciprocal of this rate is used: the distance a vehicle can travel while consuming one litre of fuel.
Heavy-duty vehicle	A truck. A diesel truck is a *heavy-duty diesel vehicle.* A hybrid electric truck is a a *heavy duty hybrid electric vehicle.*
Hybrid electric vehicle (or HEV)	A car or truck that uses both an internal combustion engine and an electric motor to move forward.
Internal combustion engine	The type of engine found in most cars and trucks today.
Payback period	The amount of time it takes to get "paid back," in savings or interest, the money you invested on something.
Pollution	The contamination of air, water, or soil by substances that are harmful to living organisms. In the 21st century, this definition has been expanded to include noise pollution, light pollution, and thermal pollution. (Perhaps one day the definition will include junk mail and obnoxious people in movie theatres.)


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Student handout

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Answer the following questions on a separate sheet of paper.

1. If a single diesel delivery truck is replaced with a hybrid electric truck, what is the percent decrease in carbon dioxide emissions? (This is just like calculating the percent discount on a dress.)
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ACTIVITY 3 – ASSESSMENT RUBRIC

	7 Unsatisfactory or Incomplete	**8 Partially Proficient**	**9 Proficient**	**10 Advanced**
Content	Less than 70% of the questions are answered.	At least 70% of the questions are answered.	At least 90% questions are answered completely.	All questions are answered completely, and answers are plainly marked or circled.
Correctness	The answers do not even come close to the correct answers.	Some of the answers make sense or come close to being correct.	The answers make mathematical sense or are mathematically correct.	The answers are mathematically correct and show evidence of having been verified.
Communication / Clarity	Most answers are given without any explanation.	The answers include brief or cryptic explanations of how they were obtained.	Each answer includes an explanation of how the answer was obtained.	Each answer includes an explanation of the strategies involved in finding the answer.
Comprehension	The answers demonstrate no understanding of the concepts.	The answers demonstrate a partial understanding of the concepts.	The answers demonstrate a nearly complete understanding of the underlying concepts.	The answers demonstrate a mastery of the concepts.

Content: _____

\+ Correctness: _____

\+ Comm/Clarity: _____

\+ Comprehension: _____

= SUBTOTAL: _____ → divide by 4 = TOTAL SCORE: _____