ORGAN FUNCTION GRINDER

Lesson Plan

GRADE 5

Brought to you by MoMATH

A Letter from the PSEG Foundation

My fascination with energy started at a young age.

The Arab oil embargo of the 1970's sent gasoline prices through the roof and made clear how closely tied our country's foreign policy is to oil interests. I began wondering whether we could produce energy in ways that didn't involve oil, and I wanted to be part of the quest to find the answer.

That passion led me to pursue years of study in the fields of physics and engineering. Graduate degrees in those areas allowed me to take on a variety of fascinating assignments in my career. I served as a research scientist at the Princeton Plasma Physics Lab, a Congressional Science Fellow in the office of U.S. Senator Bill Bradley, and a science, energy, and technology policy advisor to Governor Tom Kean before coming to PSEG where I work every day to create and deliver power responsibly.

This curriculum, developed by the Museum of Mathematics and funded by PSEG, is intended to help young people develop an interest in math and the technical fields–to spark curiosity, stimulate inquiry, and help students down a path of discovery that leads to fulfilling careers.

As issues such as climate change, energy independence, and national security demand increasingly comprehensive and technical solutions, the need for people with knowledge in science, technology, engineering, and math–areas known as the STEM subjects–will continue to grow.

At PSEG, we understand that our country's future depends on developing the insights, creativity, and dynamism of the next generation of innovators. This curriculum is one of many investments we've made in an effort to help young people discover their talents and develop a thirst for knowledge.

A math- and science-savvy workforce will lead the way to innovative technological discovery, a strengthened economy, and thriving new industries. And it is an important part of building a talent pipeline for the energy industry and our country as a whole.

Ralph Izzo
Chairman, CEO and President, PSEG

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Alfred P. Sloan Foundation

PSEG Foundation

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General Instructions for *Math Midway 2 Go*

Math Midway 2 Go (MM2GO) consists of six interactive mathematics exhibits that can travel to schools and other venues. Hands-on activities captivate and engage students, highlighting the wonder of mathematics. These exhibits were designed for use with individuals of all ages, and the mathematical topics they address range from topics in the elementary classroom to college-level mathematics. Students of all ages will benefit from open exploration of the exhibits. At the same time, the exhibits also tie into specific curricular topics for kindergarten through grade 12.

These lesson plans are provided by MoMath to support teachers like you. To help you and your students make the most of your time at *Math Midway 2 Go*, a focus exhibit has been selected for each grade from kindergarten though grade 12. The Grade 5 focus exhibit is the *Organ Function Grinder*.

MM2GO is designed to accommodate one class of up to 36 students at a time.

It is ideal to have only a small group of students at each exhibit while visiting *Math Midway 2 Go*. Break your class into six groups and have them rotate through the exhibits, with one group at each exhibit at a time. Before starting, make sure that students understand basic rules for interacting with the exhibits:

- Walk in the area surrounding the exhibits; don't run.
- Handle the exhibits gently.
- Do not hang or lean on the *Number Line Tightrope*.
- Handle *Ring of Fire* shapes gently.

Ideally, school support staff and/or parent volunteers will be available for the duration of the visit to *Math Midway 2 Go*. These adults can circulate throughout the exhibits, while the classroom teacher remains at the focus exhibit. At the five exhibits that are not the grade-level focus, students can explore and play.

Information about the *Organ Function Grinder*

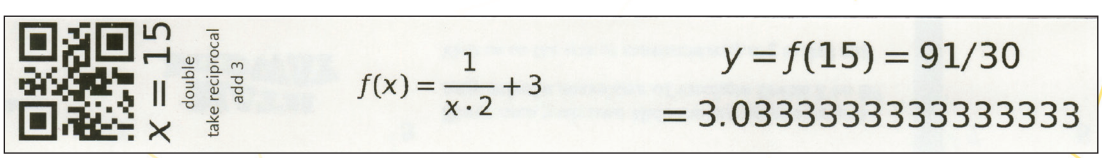
About the exhibit:

The *Organ Function Grinder* comes with an assortment of tickets representing different numbers. Students feed a ticket into the *Organ Function Grinder* as the input to a calculation, turn three dials on the front of the exhibit to select operations to be performed, and turn the crank. The *Organ Function Grinder* plays a song based on the input and the selected operations, calculates the resulting output value, and then delivers a ticket summarizing the input, operations, resulting formula, and output value. Older students can link this experience directly to their study of functions, while younger students can explore rules and how they can be applied to numbers. The music provides another element to explore: how do the different operations change the tunes? What is the connection between the number being processed and the tune?

Why visit the *Organ Function Grinder*?

Upper elementary students already understand numbers and operations. They may also be familiar with the concept of "machines" changing one number to another based on a rule, a concept that prepares them for the study of functions. The *Organ Function Grinder* takes those mental machines and rules and turns them into a physical machine which can change an input to an output in a variety of ways. Even if students find the calculations formidable, the challenge of producing the goal number keeps them engaged.

Please note–the *Organ Function Grinder* has two settings. It can print tickets with simplified or unsimplified functions. These lesson plans assume that you will use unsimplified functions with 5th graders and other upper elementary and middle school students who are not yet formally studying functions. The unsimplified version, shown below, is designed to help younger students see how the dials they selected created the output shown on the ticket.



Integrating MM2GO Into Your Unit Plans

Consider the following key questions, class topics, and elements of the Common Core State Standards when considering how to link the *Organ Function Grinder* to the study of mathematics taking place in your classroom.

Key questions inspired by the *Organ Function Grinder*:

- How do rules change numbers from an input to an output?
- Will a given rule and a given input always produce the same output?
- Does the order in which operations occur change the output?

This lesson plan will be useful with the following classes:

- Classes preparing to study functions
- Classes practicing operations and learning about order of operations
- Classes studying number properties, including the commutative and associative properties
- Classes studying squares and square roots for the first time

Relevant connections to the Common Core State Standards:

Learning Standards

5.OA: Analyze patterns and relationships.

Generate two numerical patterns using two given rules. Identify apparent relationships between corresponding terms. Form ordered pairs consisting of corresponding terms from the two patterns, and graph the ordered pairs on a coordinate plane.

Standards for Mathematical Practice

- Make sense of problems and persevere in solving them.
- Reason abstractly and quantitatively.
- Construct viable arguments and critique the reasoning of others.
- Attend to precision.
- Look for and make use of structure.

Organ Function Grinder Pre-Activity

Description

In this activity, students play a guessing game with a partner to mentally practice turning one number into another according to a rule of their choice.

While this activity is designed for use before visiting the *Organ Function Grinder*, the activity can be enjoyed independently of a visit from the Museum of Mathematics' *Math Midway 2 Go*.

Materials

- There are no specialized materials required for this activity.

Key Terminology

- **Rule**
- **Operation**
- Optional: **Input** and **Output**

Conducting the Activity

1. Have each student work with a partner. For clarity, have each pair of students identify one partner to be Partner A and the other to be Partner B. Explain that they will be playing a game where they guess what rule their partner is using to change one number to another.

2. Partner A should come up with a rule. Give students an example; "My rule is multiply the number by four." Have Partner A think of a rule she will keep as a secret in her head. The rule should apply one arithmetical operation to the given number. Partner B can also think of a rule at this point, which he will use later.

3. Now, tell Partner B that his job is to guess the rule. He will tell Partner A an input number. Partner A will perform the secret calculation in her head and tell him the resulting output number. For example, if the rule were "multiply by four" and Partner B said "13," then Partner A would respond with "52." Based on this information, Partner B guesses the rule. Two possible guesses that Partner B might make based on this example are "Add 39 to the number" or "Multiply the number by four." Make sure the students playing the role of Partner B understand that they may not

Organ Function Grinder Pre-Activity (Continued)

yet be able to figure out exactly which rule Partner A is using, but that they should try some rule that works–it's OK to experiment and then get more information.

4. If Partner B has guessed incorrectly, he gives a new input, listens to the new output, and guesses again. This repeats until Partner B has correctly guessed Partner A's secret rule.

5. Then, partners switch. Now Partner A has to guess Partner B's secret rule.

6. If a given pair finishes quickly, they can start over again with new rules, until each pair in the classroom has had enough time to guess each other's rule at least once.

7. Once this has happened, have a class discussion about the game–what happened?

8. Listen for student comments that relate to functions and explain terms as they come up–**input** is the number before the rule is applied and **output** is the number after the rule is applied. Students will learn about functions in greater depth in future years; introducing the words "input" and "output" now will support that later learning. Make sure to stress that the output is completely and uniquely determined by the function and the input. Ask students, if my rule was add four and my input was three, would my output always be seven? This concept–that a given rule and a given input always give the same output–is essential to understanding functions.

9. End the class discussion by telling students that they will be exploring a physical machine called the *Organ Function Grinder* during their visit to *Math Midway 2 Go*, where they can transform inputs and use one, two, or even three rules to produce an output.

Organ Function Grinder Pre-Activity (Continued)

Extension: Two Step Rules!

1. Have students come up with a rule that has two parts. If students are already familiar with negative numbers, this will be easier. If not, you might want to suggest that they use addition and multiplication rules only. You can include division as well if you want to practice working with parts of a whole.

2. Ensure that students understand a two-step rule. Practice one example as a class. If your two-step rule is “add four and then multiply by three,” practice with a sample input of five. Take five plus four to get nine, and then multiply that by three to produce the output of 27. Ask students, if they only knew the input (5) and the output (27), would it be easy to figure out what the two steps are? Make sure that students know this will be more challenging and that it may take much longer to guess.

3. Once students understand, break them up again into pairs composed of Partner A and Partner B, and have them guess each other’s rules.
   If students are struggling, you can add an intermediate step, in which Partner B states out loud what the input becomes after the first step of the two-step rule, to reduce the guessing difficulty.

4. After students have had sufficient time to try guessing the two-step rules, have a class discussion: how easy or hard was this task? What strategies did students discover that made this task easier? If a friend were to try guessing a two-step rule for the first time, what advice would students give to that friend?

Organ Function Grinder Activity

Description

In this activity, students will explore the *Organ Function Grinder*, examining how the machine works and learning about the relationship of input to output.

Materials

- There are no specialized materials required for this activity, other than the exhibit itself.

Key Terminology

- **Rule**
- **Operation**
- Optional: **Input** and **Output**

Conducting the Activity

1. Allow students to interact with the exhibit at their own pace first. Students can take turns setting the dials, picking an input, and examining the output ticket.

2. Once students have examined the exhibit for a few minutes, bring the group back together. Ask students what they have noticed so far.

3. Have a discussion about the *Organ Function Grinder*. How does it work? What does it do?

4. As a group, pick an input and set all three dials. Insert the ticket and turn the crank. Before students examine the output, have them work together to predict what will happen. Then, check their prediction against the output ticket–was the prediction correct? If not, why not? Try again until you see that all students have a mental understanding of what will happen to a given input ticket based on how the dials have been set.

Organ Function Grinder Activity (Continued)

5. Depending on your goals for the *Organ Function Grinder*, here are some specific questions you might explore with students:

   - Some of the dial settings may be unfamiliar, like "square," "take the square root," and "take the reciprocal." Have students set two of the dials to "leave alone" and try out one of these unfamiliar dials. Start with small inputs–what happens to a number when it is squared or when you take the reciprocal? Can students figure out what square and take the reciprocal mean? As your students may not be familiar with square roots yet, you might have them try this setting after trying "square." Five of the input tickets are perfect squares–4, 9, 16, 64, and 81. Have students try to take the square root of these numbers and see what happens.
   - If you set the dials and don't change them and insert the same input twice, would you always get the same output? How do you know? This idea–that a specific operation always takes a given input and turns it into one and only one output–is essential to understanding functions and can be learned even before students are formally introduced to functions.
   - How does the order of the dials change the output? Are there times when you can change the order of two or three dials and it changes the output? Are there times when changing the order does not change the output? Ask students if they can draw any conclusions about when order does and does not matter.
   - Listen to the music. Ask students if they notice any patterns to the music. Set the first and third dials to "leave alone" and set the second dial to one of the other operations. Now run the machine with different inputs. What sort of change to the music does the setting on the second dial make? Listen carefully and try to find sound patterns. A mathematical musician named Vi Hart made specific music for each input, and made the music change in certain ways for each of the different operations. See if students can figure out some of her musical ideas.

6. End by explaining to students that they will think about how an imaginary *Organ Function Grinder* works when they are back in the classroom.

Organ Function Grinder Post-Activity

Description

In this activity, students will act out their own imaginary *Organ Function Grinder*.

While this activity is designed for use after visiting the *Organ Function Grinder*, it can be used with students who have not had the opportunity to experience the Museum of Mathematics' *Math Midway 2 Go*.

Materials

- There are no specialized materials required for this activity.

Key Terminology

- **Rule**
- **Operation**
- Optional: **Input** and **Output**

Conducting the Activity

1. Start with the question: how can we make our own *Organ Function Grinder* in the classroom using only people and their brain power?

2. Have a class discussion and take student ideas.

   If your students come up with an idea that is different from the MoMath suggestion below, feel free to try your students' idea!

3. One way to make a human *Organ Function Grinder* is to split students up into groups of four; one student will be an input number and the other three will be operations. If your class does not divide evenly into groups of four, you could have groups with three or five students, and have each group apply fewer or more operations accordingly.

Organ Function Grinder Post-Activity (Continued)

4. With the list of *Organ Function Grinder* operations written somewhere in the classroom, each student portraying an operation picks one. The possible settings for the dials are:

   Leave alone, add three, subtract three, square, take the square root, take the reciprocal, double, halve

   If you think your students will struggle with some of the operations, like "take the square root," you can replace them with rules of your choice.

5. Have the students who are acting out operations stand side by side in a row. The student representing the input number will have to pass through the human machine to become an output number. Ask each group to come up with a physical action they will do as the input number passes through, such as spinning the number student around one full turn.

6. Once they are ready, have the three operations line up side by side. Then, the student playing the part of the input picks a number and enters the function machine. The number student goes through each operation in sequence. One way to do this would be to have the input person speak his or her number, like "seven." Then, the first operation would speak his or her rule ("add three") and perform the physical action. The number student then says his or her new value after the operation had been applied, in this example "ten," and walks along to the next rule, until he or she has gone through all the rules and announced the final output.

7. Once your class understands, have each group practice for a while and then perform their personal *Organ Function Grinder* for the whole class. End with a class discussion about the similarities between your personal *Organ Function Grinder* and the one used in the *Math Midway 2 Go*. Use this opportunity to reinforce the language that will prepare your students for the concept of functions, stressing input and output.

Organ Function Grinder Post-Activity (Continued)

Extension: Physical Function Guessing Game

1. Two teams of four (Team A and Team B) will play the physical *Organ Function Grinder* as a game.

2. Each team meets secretly and decides what their three operations will be, but does not reveal their rules to the other team.

3. When Team A is ready, they ask Team B to pick an input number. The student from Team A playing the role of the input goes through the machine, revealing his or her new value after each operation. However, the other students do not announce their operations, but instead only do the physical action that they have chosen to represent the transformation. Team B then has to determine which operation was used at each step. If Team B cannot figure it out, they can try the whole process again using a different input number to provide more information. For subsequent runs of the Team A machine, any operations which have been correctly guessed should announce themselves, but any that remain unknown should stay silent as before.

4. Once Team B has guessed correctly, the teams reverse roles and repeat.