LEARN LIKE THE LEADERS SERIES

Dorothy Vaughan and Fortran

SUMMARY
Students learn about an inspiring leader in STEM, Dorothy Vaughan, and learn how to program math formulas, like Fortran, using Ozobot's Deconstruction Method.

OVERVIEW
Students will learn programming 'like the leader' Dorothy Vaughan, one of NASA's earliest programmers and an inspiring leader in STEM.

This lesson celebrates Dorothy's accomplishments in computer science and mathematics and in changing the cultural view that African Americans and women were less capable of leadership and technical expertise. In the 1950s, Dorothy taught herself IBM's new computer programming language FORTRAN, then taught her fellow black women computers (back then, it was humans who did the computing!) the language to continue to help launch rockets into space.

This lesson aims to inspire students of all backgrounds to explore worlds they never considered by reading about Dorothy Vaughan's life. Students will also explore the early programming language FORTRAN (now written as Fortran), which will give students further insight into the uses for, and power of, math formulas and algebra, especially as they are used for engineering.

The coding portion of this lesson follows Ozobot's Deconstruction Method, wherein students play a pre-made math program for Ozobot, then read the OzoBlockly program to see how it actually works. This helps students use Ozobot for math on their own or in future lessons (read more about Deconstruction here: https://ozobot.com/stem-education/deconstruction-series). Students will learn variables and math operator code blocks, and how they are used to create mathematical formulas.

LESSON OUTLINE

1. Learn about Dorothy Vaughan's accomplishments and struggles.
2. Discover IBM's Fortran programming language, and how it is used for engineering calculations, like at NASA.
3. Deconstruct a math formula Ozoblockly program for Ozobot to model a rocket with enough force to lift off.

PREREQUISITES

- Experience with OzoBlockly code editor. Use the OzoBlockly Mini Lesson to teach students how to use the editor portal.ozobot.com/lessons/detail/ozoblockly-mini
- This lesson discusses formulas by dissecting the formula for force and calculates competing forces on a rocket using weight and thrust. Students should know the basics of what a formula is and be able to appreciate cancelling forces.

GROUPING

Pairs or groups of three

MATERIALS

- Evo or Bit, by Ozobot, 1 per every 2-3 students
- Printed student worksheets (attached below)
- Pencils and blank paper
- Tablets or computers to use ozoblockly.com/editor
- *Optional* **OzoBlockly Getting Started Guide** for calibration and flash loading steps http://files.ozobot.com/stem-education/ozoblockly-getting-started.pdf

GRADE LEVEL

Grades 5 and up

DURATION

50 minutes

QUESTIONS ABOUT THIS LESSON?

Please contact us at ozoEdu@ozobot.com

LESSON

PREPARATION

- **Print** the handouts for each student (see attached). The "About" stories can be printed front and back because they are read together.
- **Prepare** computers or tablets for pairs or groups to access ozoblockly.com/editor
- **Charge** your class set of Bits or Evos (at least a 2:1 student to robot ratio).
- **Read** the student handouts and test the OzoBlockly program.

STEP 1 LEARN ABOUT DOROTHY VAUGHAN AND FORTRAN - 20 minutes

Explain the steps of this lesson:

1. Students will read about Dorothy Vaughan, an African American STEM leader who worked at NASA.
2. Students will read about Fortran, and early computer language that Dorothy taught herself.
3. Students will load an OzoBlockly program that demonstrates how Fortran works and uses the formula for 'force', especially as it relates to rockets (like what Dorothy Vaughan worked on).

You can choose whether the class reads the handouts together or in groups.

Students will answer the questions from the sheet using a separate piece of paper. The later worksheet also has questions to be answered on separate paper, so students can keep it handy.

Hand out the "About" pages to each student.

Students read the stories of Dorothy Vaughan and Fortran, the programming language, then answer the questions.

SAMPLE ANSWERS

ABOUT DOROTHY VAUGHAN

1 After reading about Dorothy's life, what do you think her quote at the top of the page means?

A: The quote means that she worked hard to change the perception of African American women as scientists, engineers and leaders at NASA as much as she could, but was limited by cultural perceptions of her, especially with Jim Crow laws still in effect.

2 What do you think it was like for Dorothy to work in a segregated office in the 1940s-1960s?

A: It was probably harder to get noticed for her hard work because she was put out of the way of main operations. She also probably did not get recognized for her accomplishments and her great mathematic and engineering skills.

3 What would NASA and STEM be like now if women like Dorothy had never fought hard for their beliefs and passions?

A: Today, NASA might not have a sense of equality like it does now, and might not be pushing for more minorities in leadership and science roles. As well, there might not be as many women and African Americans in engineering and science since, without Dorothy, many of her peers might not have become the engineers and leaders they did without her support. Therefore, there might be fewer role models without Dorothy's work.

ABOUT FORTRAN

1 Computer programs were first used for mathematical computations. What do we do with computers that isn't math?

A: We use computers for everything these days, like for taking notes, taking pictures, sending messages, and playing games. For these applications, we use our computer screens, which weren't necessarily needed when we used computers for computations.

2 Describe how one thing you enjoy doing on a computer might use math.

A: I love to take pictures with my phone and tablet. Since computers understand 1s and 0s, and colors are represented by numbers, too, there is probably lots of math involved in creating and saving photographs.

3 What are some other scientific uses for formulas and large computations, besides the example of launching a rocket?

A: Astronomy uses lots of mathematical formulas to calculate the distance of celestial bodies, their brightness, and their movements. Chemistry uses formulas to calculate the energy going into or coming out of reactions, and how much of a chemical is needed to produce something new.

STEP 2 DECONSTRUCT MATH FORMULAS IN PROGRAMMING – 30 minutes

Explain that students will work with a completed program that models what a rocket needs to lift off. This program is a simplified version of what calculations are actually required. This program will cause their Ozobot to move if there is enough 'thrust' to move the robot against its weight.

Ask students if they know how rockets work. **Explain** that rockets fire gas (exhaust) from the bottom of the rocket, which causes the rocket to move up (the exhaust is pushing against the ground or the air). The rocket will only go up if the force of the thrust, the

power of the exhaust, is stronger than the rocket's weight.

Explain that the activity requires groups to read a "manual" about creating formulas in OzoBlockly, much like Fortran. Students will teach themselves, and each other, what is happening in the program and understand how to program formulas in the future.

Separate students into groups of 2-4, if they aren't already.

Hand out one tablet or computer and an Ozobot to each group, and worksheets to each student.

Students read the "Manual" and answer the Questions before beginning the activity.

SAMPLE ANSWERS
QUESTIONS – BEFORE YOU CODE

1 "Math is the key to how the world works." What does this statement mean, especially when you consider formulas?

A: Math formulas explain how nature works. For example, $e=mc^2$ explains that energy is related to mass and speed of light. Or, *pi* is the ratio of circumference and diameter. Math shows the relationship between different forces or attributes that create the world around us.

2 Imagine you are pushing a box. If you increase your pushing force, will "m" or "a" go up or down?

A: a (acceleration) will go up, because we are increasing the speed, therefore acceleration.

3 How might the formula for force help NASA get rockets into space?

A: when NASA engineers know how much force is on a rocket, they can make sure they can build it safely so it won't explode, and make sure it will actually lift off.

4 If the variables for weight are all set to zero, what condition would that represent?

A: This represents being in space, where all objects are (relatively) weightless.

5 What other forces act on a rocket while it leaves Earth?

A: there is drag, which is the air rushing past the rocket and slowing it down because air is made of matter. There are also different forces depending on the angle of the rocket, like lift.

Lead students through screen calibration and program loading. Use the OzoBlockly Getting Started Guide for the steps: http://files.ozobot.com/stem-education/ozoblockly-getting-started.pdf

Groups load the program for their robot onto their tablet with the following links:

Evo: https://ozoblockly.com/editor#pty3ms
Bit: https://ozoblockly.com/editor#4iogwt

Students play the program to see what it does to their robot.

Students edit the different values for the variables of weight and thrust to see changes to Ozobot's speed, using the Activity prompts on their Manual. They can explore other values, as well. **Make sure** students reset the values of the variables before doing a new test by hitting the "undo" button or revisiting the link to the program.

SAMPLE ANSWERS
Test the current program: What does it do? Why?
move forward (100 mm) at a speed created by the difference between weight and thrust.

Variables	What happens? Why?
1 m weight = 30 a weight = 20	This program makes Ozobot not "lift off" or move because the weight is greater than the thrust.
2 m thrust = 30 a thrust = 20	This program makes Ozobot go faster than the initial program because thrust is higher than before
3 m weight = 0 a weight = 0	This program makes Ozobot go very fast because it is weightless.

Discuss what each variable for mass and acceleration has to do with the weight and thrust.

Ask the class these questions:
Why is weight a force?
Why is thrust a force?
What is mass, and why does force change when you change the mass?
What is acceleration, and why does force change when you change the acceleration?
Did students have any other observations or questions?

If there is any extra time in the lesson, students can choose, or look up, other formulas they know and create a program for their Ozobot with it.

Students can save any programs they make by creating a link or saving the file to their personal folder (not available on tablets).

QUICK TEACHER'S LESSON CUES

Dorothy Vaughan and Fortran

PREPARATION

- **Print** the handouts for each student (see attached). The "About" stories can be printed front and back because they are read together.
- **Prepare** computers or tablets for pairs or groups to access ozoblockly.com/editor
- **Charge** your class set of Bits or Evos (at least a 2:1 student to robot ratio).
- **Read** the student handouts and test the OzoBlockly program.

STEP 1 LEARN ABOUT DOROTHY VAUGHAN AND FORTRAN - 20 minutes

4. **Explain** the tasks for the lesson:
    a. Students will read about Dorothy Vaughan, an African American STEM leader who worked at NASA.
    b. Students will read about Fortran, and early computer language that Dorothy taught herself.
    c. Students will load an OzoBlockly program that demonstrates how Fortran works and also uses the formula for 'force', especially as it relates to rockets (like what Dorothy Vaughan worked on).
5. **Hand out** the student worksheets about Dorothy Vaughan and Fortran.
6. **Students read** as a class, or in groups.
7. **Students write** answer the questions on a separate sheet of paper.
    a. Suggested answers are in the lesson above.

STEP 2 DECONSTRUCT MATH FORMULAS IN PROGRAMMING – 30 minutes

1. **Separate** students into groups of 2-4, if they aren't already.
2. **Hand out** one tablet or computer and an Ozobot to each group, and worksheets.
3. **Students read** the "Manual" and answer the Questions before the activity.
4. **Lead** students through screen calibration and program loading:
    a. Use the OzoBlockly Getting Started Guide for the steps: http://files.ozobot.com/stem-education/ozoblockly-getting-started.pdf
5. **Groups load** the program for their robot onto their tablet with the following links:
    a. Evo: https://ozoblockly.com/editor#pty3ms
    b. Bit: https://ozoblockly.com/editor#4iogwt
6. **Students play** the program to see what it does to their robot.
7. **Students edit** the different values for the variables of weight and thrust to see changes to Ozobot's speed, then conclude what each variable for mass and acceleration has to do with the weight and thrust.

ABOUT DOROTHY VAUGHAN

"I changed what I could. What I couldn't, I endured"
- Dorothy Vaughan

What do you think this quote from Dorothy Vaughan might mean? Read about her life below to discover its meaning.

Dorothy Vaughan studied mathematics in college, and was encouraged to pursue **graduate studies** in the field. As an adult in the 1930s, she got a job as a math teacher, which was one of only a few good jobs available to African American women.

Graduate studies: after college, graduates study their field more to become experts and discover new findings and knowledge

During World War 2 (1939-1945), the US needed to hire more people for the war effort, like airplane manufacturers and test pilots, **computers**, engineers, and scientists. The government was forced to hire women and African Americans, who were normally excluded from these 'good' jobs.

Computer: a person who completes complex math formulas by hand

At this time, the US was also **racially segregated** by what are known as Jim Crow laws, which are a series of laws that segregated schools, transportation, restaurants and workplaces so that whites and blacks would not mix.

Racially segregated: when space is separated to keep people apart based on their race.

In this climate in 1943, Dorothy Vaughan joined NACA (the National Advisory Committee for Aeronautics, which became NASA) as a **computer**. Her department was called the West Area Computers, which was where all of the black women computers did their work. Bathrooms, eating areas and offices at NACA were all segregated by skin color. Some white employees didn't know they existed.

After the war, Vaughan continued to work at NACA, and even became the head of West Area Computers. However, she was not officially given the title, or the pay, until years later.

Much of Dorothy's work was towards the Scout Launch Vehicle Program, which was a family of rockets with an exciting pedigree. These rockets launched satellites and scientific experiments for over 30 years, and have a very high success rate.

In the 1950s, IBM machine computers, which were so big that one could fill a large room, began to arrive at NASA. Dorothy quickly recognized that these machines would replace the human computers, so she taught herself, and her fellow female black computers, how to program them. The IBM's programming language FORTRAN is still used for large calculations in engineering.

Because of her hard work in learning computer programming, she became the head of the programming section of Analysis and Computation Division of NASA in Langley, Virginia.

Dorothy's push towards learning computer science and programming has had a big effect on the field. Due to her perseverance in having women and African Americans recognized for their work and get high level assignments, she helped the push towards equality in the US and in STEM fields.

Some of the women she supervised also left their mark on space flight. Katherine Johnson did **vital** computations on **trajectories** of Astronauts Alan Shepard and John Glenn (who was the first to orbit Earth). Mary Jackson become NASA's first black female engineer after working in West Area Computers and returning to university to study engineering.

Vital: important, life or death

Trajectory: the flight path of a craft, or person, in air and space

Dorothy Vaughan died in 2008 at age 98, working at NASA and NACA for a total of 28 years. During her career, she also raised her 6 children, one of whom would also work at NASA.

Sources: *1)* http://schools.cms.k12.nc.us/dorothyjvaughanes/pages/who-was-dorothy-j.-vaughan.aspx

2) Shetterly, Margot Lee. 2016. Hidden figures: the american dream and the untold story of the black women mathematicians who helped win the space race.

ABOUT FORTRAN

FORTRAN is an early text-based programming language that languages like Python and JavaScript possible. It was written by John Backus's team at IBM, which built computers for use in companies and science labs.

The purpose of FORTRAN (now written as Fortran) is to accurately compute large calculations for engineers and scientists. To launch a rocket, for example, there are many numbers engineers need, like how much force the rocket's body can handle, the amount of energy the engines produce, the direction of the forces so the rocket goes up, and the effect of gravity on the rocket. Then, the engineers put these numbers together to make sure the rocket works.

To program in Fortran, a programmer will first give the computer the numbers that the programmer knows. Then, the programmer writes the formula using those numbers, called variables. The answer will equal the number that is needed. Here is an example of Fortran:

```
      INTEGER N1, N2, NEW, SUM, ANSWER
C
      N1  = 1
      N2  = 1
      SUM = N1 + N2
C
      DO 10 I=3,10
          NEW = N1 + N2
          N1  = N2
          N2  = NEW
          SUM = SUM + NEW
 10   CONTINUE
C
      ANSWER = SUM
      END
```

Fig. 1 This program creates the Fibonacci sequence

While this program doesn't look very understandable to a general reader, it's a much better way to code than before.

The ancestors to Fortran forced people to write in machine language. This means that the programmer had to write the program in only ones and zeros (binary), which is what computers understand.

Fortran allowed humans to write in "natural" language, which at the time was a break-through and has influenced all languages.

Similar to previous languages, though, Fortran programmers had to hole punch cards and feed the card into the computer to tell it the program. One program might need many cards, and any mistakes by the programmer would be unknown unless the program failed or was retested. For launching humans into space, the numbers must be 100% accurate.

Today, programming languages make coding easy. They alert the programmer to any errors, and potential reasons for it. Everything is done digitally on a screen and is easy to fix. We no longer need physical pieces of paper to pour into a machine (which, by the way, only had switches and lights - no screen!).

New updates to Fortran allow you to compute large calculations on your computer using the graphical interface, your screen. Fortran is still used by engineers and scientists around the world because it is straightforward and can be personalized to the type of work they do.

Sources: *1) IBM, Fortran Manual* bitsavers.informatik.uni-stuttgart.de/pdf/ibm/704/704_FortranProgRefMan_Oct56.pdf
2) "FORTRAN", Encyclopedia Britannica https://www.britannica.com/technology/FORTRAN

Answer these questions on a separate sheet of paper:

ABOUT DOROTHY VAUGHAN

1 After reading about Dorothy's life, what do you think her quote at the top of the page means?
2 What do you think it was like for Dorothy to work in a segregated office in the 1940s-1960s?
3 What would NASA and STEM be like now if women like Dorothy had never fought hard for their beliefs and passions?

ABOUT FORTRAN

1 Computer programs were first used for mathematical computations. What do we do with computers that isn't math?
2 Describe how one thing you enjoy doing on a computer might use math.
3 What are some other scientific uses for formulas and large computations, besides the example of launching a rocket?

THE OZOBLOCKLY FORTRAN MANUAL

WELCOME TO THE OZOBLOCKLY FORTRAN MANUAL. In this short manual, we will go through how we use computers to solve mathematical problems.

FIRST, WHAT ARE FORMULAS?

Formulas are like sentences about nature, but with simple letters and symbols instead of words. For example, "force", as in pushing something, has the formula

F = ma

or,
force = mass x acceleration.

That means force is what you need to increase the speed of an object of a certain mass. The dictionary says force is: *to drive or push into a specified position or state using physical strength.*

Why is pushing "force"? Because you move a weight by increasing the speed, so F = ma

All formulas give scientists numbers for real situations to compare and find out if, for example, an airplane is light enough to fly, or a robot is able to pick up a heavy object.

USING FORTRAN TO SOLVE CALCULATIONS

Normally, there is only one number we don't know in a formula, which is the answer to the calculation.

A **variable** is a letter that represents a number in a formula.

To find that unknown number in Fortran, we have to: 1, tell (declare) the computer the value of all of the '**variables**' that we already know, and, 'declare' variable we don't know (which will be the answer to our calculation), 2, build the formula from these variables to tell the computer how to solve the problem for us, then 3, run the program to get the answer.

Example:

STEP 1 Declare variables of formula:
m = 5 kg
a = 10m/s^2
F = (blank)

STEP 2 Create the formula:
F = m x a

STEP 3 Run the program:
(5 x 10 = 50)
F = 50 kg x (m/s^2)

F = 50 Newtons (kg• m/s²)!

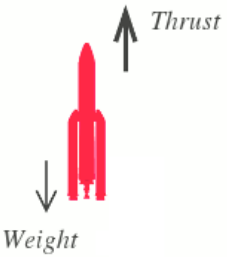
USING OZOBLOCKLY LIKE FORTRAN TO SOLVE CALCULATIONS

Your Ozobot can tell you answers to calculations, too. Even better, you get to choose how that answer is communicated. It can be with motion, lights, or sounds.

https://ozoblockly.com/editor#pty3ms (for evo)
https://ozoblockly.com/editor#4iogwt (for bit)

This OzoBlockly code calculates the thrust (upward) force of a rocket (from the engine exhaust) that lifts it off of Earth, and the weight force of the rocket, which pulls it down to Earth. To launch a rocket, you want thrust to be greater than the weight!

In the program, your bot will move if the thrust is bigger than the weight, and its speed is based on how much more thrust there is.



Source: http://www.explainthatstuff.com/spacerockets.html

QUESTIONS – BEFORE YOU CODE

1 "Math is the key to how the world works." What does this statement mean, especially when you think about formulas?

2 Imagine you are pushing a box. If you increase your pushing force, will "m" or "a" go up or down?

3 How might the formula for force help NASA get rockets into space?

4 If the variables for weight are all set to zero, what condition would that represent?

5 What other forces act on a rocket while it leaves Earth?

ACTIVITY –CODING

Test the current program: What does it do? Why?

Change the values of "a" and "m" in weight and thrust. Return them to initial values before the next test.

Variables	What happens, and why?
1 m weight = 30 a weight = 20	
2 m thrust = 30 a thrust = 20	
3 m weight = 0 a weight = 0	