INTERACTIVE

FUN²

INNOVATIVE


# TEACHER'S REFERENCE GUIDE

INSPIRE

MathsAlive!®

Presented By Raytheon

*MathsAlive!* is produced by Evergreen Exhibitions and developed in collaboration with National Aeronautics and Space Administration (NASA), National Council of Teachers of Mathematics, MATHCOUNTS, National Society of Professional Engineers, Society of Women Engineers and MathMovesU.

Raytheon supports maths and science education through MathMovesU.

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# INTRODUCTION

Welcome to ***MathsAlive!*** This guide is designed as a resource for teachers who are interested in more information about what specific mathematics concepts are explored in the exhibit, and how they are presented. It is designed to help with planning a field trip, allowing you to identify relevant maths in advance of your visit, so that students can get the most out of the experience based on what they are currently learning. It will also help when encouraging students to experience the exhibit with their families, allowing you to suggest specific "don't miss" exhibits and activities.

A map of the exhibit identifies all the activities, organised by thematic gallery (sports, design, robotics, etc.). For each of the exhibit's interactive displays, this guide provides the following:

- A brief description of the experience
- The main idea
- The "maths at work"
- Curricula connection

For some, additional suggested activities are provided to create a more enriching experience.

Also, make sure to download the exhibit's Teachers Activity Guide, which can be found at www.mathsalive-au.com. ***MathsAlive!*** is developed in association with the MathMovesU program.

We hope you and your students enjoy ***MathsAlive!***

***MathsAlive!*** *is made possible by Raytheon. It is developed in educational collaboration with the National Council of Teachers of Mathematics (NCTM), National Aeronautics and Space Administration (NASA), MATHCOUNTS, National Society of Professional Engineers (NSPE) and the Society of Women Engineers (SWE). The exhibit is organised in association with MathMovesU.*

# *MathsAlive!*... Overview of the Exhibit

***Designed to be one of the most interactive and inspiring exhibitions exploring the world of mathematics ever to tour.***

***MathsAlive!*** is designed to inspire, to spark the imagination, to reveal not only maths at work, but the endless possibilities maths can offer. Primarily designed for kids ages 7–14, the exhibition brings to life the real maths behind what kids love most—games, sports, design, robotics, and more—and creates interactive and immersive experiences that bring to life the maths at work in each, whether in design, application or use.

In this exhibition that spans 465 $m^2$, visitors will ride snowboards in a 3D experience, create their own 3D animation, capture their 360-degree images in a unique interactive environment, jump into a binary dance party, even design a custom skateboard for "pop": the quick, snapping motion that allows a board to do the best tricks. Through a range of unique, interactive experiences, the exhibit takes maths from its native form into the applied worlds of design, engineering, technology and science.

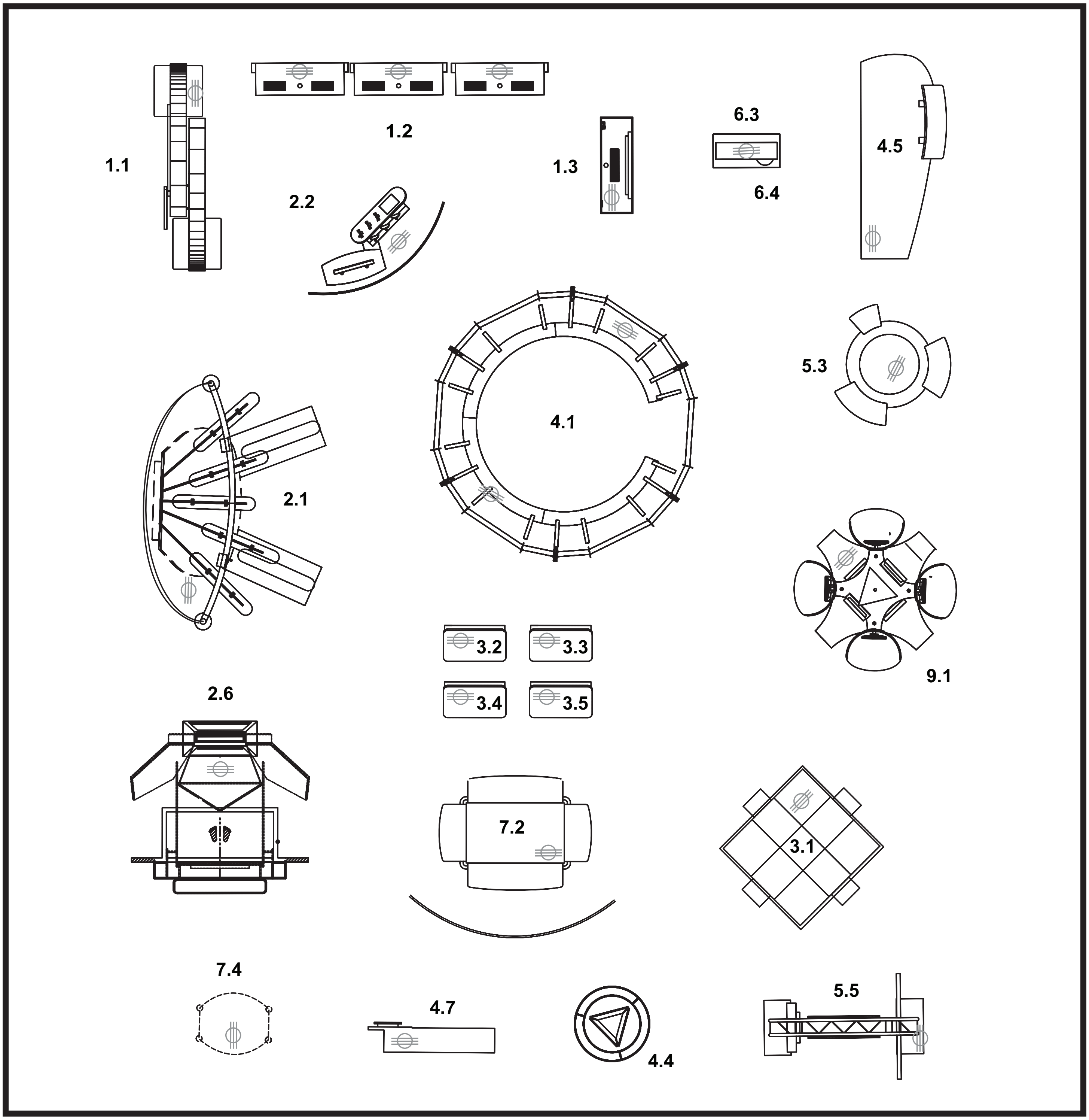
Visitors will also get to experience two new interactive exhibits… In *Extreme Weather Alert*, the visitor steps into the role of a meteorologist, forecasting an extreme weather event. From a remote weather lab, they'll collect and interpret weather data in simulated 'real time' and then record their own extreme weather alert video. The visitor can mail the video broadcast to him- or herself. Also the new *Cyber Security* lets visitors step inside an online computer game, where they are challenged to defend against invaders—like computer bugs and viruses—using computer passcodes, multi-factor authentication, and simple code sequences. Simulated fingerprint scans, card swipes and secret codes all help to create an exciting hands-on experience.

Visitors will explore and operate simulations of NASA's latest robotics, including Curiosity Rover. Around a large-scale supertall design interactive, learn how engineers work to make a city hum while taking on different engineering roles to design a more sustainable infrastructure.

Visitors are accompanied by fun and quirky virtual guides, and along the way, they'll meet and hear from professionals, visionaries and inspiring personalities as they talk about maths in their work across the fields kids are most interested in exploring. The exhibit addresses all maths topics and themes for the end of primary school and start of secondary school.

This innovative exhibit responds to the global movement towards greater focus on STEM development and STEM career awareness, and inspiring kids to make maths a priority, reaching them in that window of vulnerability when maths gets more challenging and kids begin to lose interest.

***The exhibition is designed to help answer the age-old question: "Will I ever use all this maths they're teaching us?"***




# MAP OF EXHIBIT

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## TEACHER'S REFERENCE GUIDE TO EACH ACTIVITY IN THE EXHIBIT

The following outlines provide an explanation of the interactive experiences, the main idea behind each, the maths at work, and samples of the text on panels or screens that accompany each. Where personalities are featured representing each gallery, sample narrative is provided; the personalities all appear in an interactive, touch screen video display called *Math+People*.

### 1. INTRO GALLERY – Marquee Title and Entry Passage

An overarching passage introduces the exhibition. A freestanding video introduces the BotZ characters who "hand you" the magical maths goggles that allow you to see the maths behind all actions and objects you encounter in the exhibition. Enter a darkened space punctuated by a dynamic montage of bold, vibrant images which dissolve and cycle to reveal the underlying maths graphically, emphasising how maths is a part of the world around us, and that maths opens doors and takes you places.

*Who are the BotZ:*
Three character guides who act as a cool and creative team throughout the exhibition, using humour, clear communication and useful tools to help visitors discover how maths relates to the world around us. The BotZ introduce how the interactive activities work, with fun exchanges and small details that bring out their personalities and relationships. Each Bot has expertise in at least two subjects covered by the exhibition galleries, so a Bot helps explain the featured mathematical concept in many of the activities. They provide humour, communication and helpful tools or devices.

### 2. *OUTDOOR ACTION*... ADVENTURE SPORTS

#### 2.1 *Boardercross...* Snowboard Experience

**Description:**
Race others in a snowboard ride. Jump onto a pivoting snowboard and twist and torque your body, angle your board, and fly over obstacles while you race against other players. Watch the action on an immersive screen to coordinate your body movements along with the action.

**Main Idea:**
This interactive gives visitors a better understanding of angle size and provides concrete comparisons of different sized angles. The idea of "acute" angle is emphasised.

**Text Panel:**

*On Your Mark…*
*1. Press START.*
*2. Swerve to avoid obstacles.*
*3. Watch your speed and your angle each time you turn.*

**Maths at Work:**
Precision
The straighter your path down the slope, the faster your speed.
Swerving to avoid obstacles slows you down. Too wide and you lose speed. Too tight and you risk wiping out.
The angle of your turn will probably be less than $90^0$—an acute angle.
Think ahead to finish first—always hit the turn at the best angle.

**Curricula Connection:**
This interactive provides practice in identifying angle types, including acute, right, and obtuse angles.
It connects with students' study of the measurement of angles.

- Geometry: Use visualization, spatial reasoning, and geometric modelling to solve problems; draw geometric objects with specified properties such as side lengths or angle measures. (Years 6-8)
- Draw and identify lines and angles, and classify shapes by properties of their lines and angles.
- Measurement: Understand measurable attributes of objects and the units, systems, and processes of measurement. (Years 6-8)

**Ideas for the Visit:**
Encourage the players to talk with each other about strategy as they do their runs down the slope. As they describe their strategies, encourage them to communicate about the size of the angles that were most effective, using mathematical terms like "acute" and "obtuse" and connecting them with everyday language like "sharp" and "wide" angles.

## 2.2 *Ramp It Up...* Build a Skateboard with POP

**Description:**
At a virtual design station, using real skateboard parts as the interface, design a skateboard that performs an Ollie and set the variables to perform the best tricks with your board. Determine the best shape and length of your board; choose the best wheel size and position of the trucks. A skateboard is a kind of lever and the wheels and trucks act as fulcrums. Test the ability of your board to perform an Ollie.

**Main Idea:**
Two variables can be manipulated and tested in combination to get closer to the optimal effect.

**Text Panel:**

*Get Rolling*
*1. Touch the screen to start.*
*2. Select your height to determine the length of your board.*
*3. Touch a board to choose the shape you want.*
*4. Touch one of the wheel sets to select your wheel size.*
*5. Determine the position of your trucks.*
*6. Hit TEST to see your board do an Ollie.*

**Maths at Work:**
Optimisation
Set the variables to perform the best tricks with your board.
- The diameter of your wheels affects how high the nose of the skateboard rises when you push down on the tail.
- The trucks are the fulcrums of your board. A fulcrum is a fixed point where something pivots, or turns, like a seesaw. Optimise your board by placing the trucks in the best location.
- Hit the ground quickly with the tail of your board and it has more energy to move forwards.

**Curricula Connection:**
The understanding of "variables" is crucial to algebraic thinking and should be developed starting in the primary grades and continuing into formal algebra.

Algebra:
1. Investigate how a change in one variable relates to a change in a second variable.
2. Develop an initial conceptual understanding of different uses of variables.

## 2.6 *Penalty Save*

**Description:**
Visitors are given the opportunity to step into the role of goalie, and defend against multiple kicks. The experience explores the relationship of angles to predicting where the ball will likely enter the net, so the visitor can block it.

**Main Idea:**
Paying attention to angles can help keepers estimate the path the ball will take as it approaches the goal. To determine where to block, keepers judge the up- and-down vertical angle and the side-to-side horizontal angle at which the ball is launched.

**Text Panel:**
<u>*Making the Save*</u>
*Saving a penalty kick is very challenging. Keepers can cover up to 9% of the goal at a time, and kickers shoot the ball at around 100 kph/61mph. Only about 10% of shots are blocked in professional games. For the keeper, predicting where the ball will enter the goal could be a big help.*

**Maths at Work:**
<u>Probability and Variables</u>
By analyzing angles, speed, and gravity, an object's path can be determined

## 2.7 *Featured Personalities in OUTDOOR ACTION:*

- Eric "Tuma" Britton, Professional Skater/Instructor, Venice, California, USA

- Liza Brooks, Co-owner and Technical Director at True Snowboards, United Kingdom

    ***I hated maths until I studied ENGINEERING.***
    *My **dyslexia** wasn't diagnosed until I went to university. No matter how hard I worked in English lessons, I didn't see the results. I did well in maths but it felt so irrelevant.*

    ***It's all about PRECISION.***
    *As a vibrations engineer, I investigate the natural frequency of materials. Snowboards and snow each have their own frequency. When the two frequencies match—when they're both at their resonant frequencies—the snowboard hits SPEED WOBBLE.*

    *Speed wobble is what happens when a board reaches a certain speed and wobbles out of control. To prevent this happening, you can add carbon fibre. The carbon fibre stiffens the board and changes its natural frequency.*

    ***Maths is a universal language.***
    *I can read through a scientific article in Japanese and follow the maths even though I don't understand the words.*

- *Skip Garibaldi, Mathematician and Rock Climber from Emory University, Atlanta, Georgia, USA*

    ***While at university I thought I was going to be a computer scientist.***
    *Every year I took part in maths competitions. They were hard and I wasn't very good, mostly because I didn't practise. But I enjoyed them and slowly realised that I would enjoy a job doing maths.*

***Maths doesn't need fancy lab equipment.***
*Being a mathematician gives you a lot more independence than most other jobs. All it takes is your brain and maybe some paper and a pencil. You can do maths anywhere—while out on a hike, lying on a beach or back in camp after a day of climbing.*

***Stick with it.***
*It's never too late to turn things around. I didn't do so well in maths class. Then, when I was 15, I started doing my homework. After that, class got a whole lot easier.*

***Like rock climbing, maths requires focus.***

## 3. ***BUILD YOUR WORLD...*** **ENVIRONMENT**

### *3.1 Supertall... Skyscraper Design Studio...* The Engineered City

**Description:**
Visitors design their own 'supertall' skyscraper by making several choices about the building's function, structure and design. Once the design choices are made, the visitor will test a model of the building. If the design passes the test, it will be 'built,' triggering an animation on the stacked monitors that simulates time-lapse photography of construction of their building. It ends with a high quality, full-colour concept rendering. The skyscraper display is surrounded by stations where visitors take on different engineering roles as they design a more sustainable infrastructure for a city.

**In This Area:**

***Systems Engineering***
*Engineers design virtual models, so they can test how the building will withstand various forces. The engineers study the test results, change one variable at a time, and re-test. They do this over and over to optimise the design. So now, you get to design and test your own model of a supertall.*

### 3.2 *Keep on Moving...* Transportation

**Description:**
As the city keeps growing, the TRANSPORT network has to ensure traffic circulates efficiently.
At this design challenge station, try to come up with a plan to reduce gridlock and fuel consumption.

**Main Idea:**
Mathematics enables us to simultaneously consider several "what if" questions about the impact of several variables.

**Maths at Work:**
<u>Modelling</u>
Complicated problems have a large number of factors, or VARIABLES. Engineers, mathematicians and other experts create a MATHEMATICAL SIMULATION, or MODEL, to help find solutions. They use the model to adjust the variables and observe the effects. This helps them identify the factors that are most important and understand what happens when the QUANTITY, or amount, of each variable changes.

**Curricula Connection:**
Algebra includes an emphasis on modelling. Working with transportation systems is an important application of modelling.

- Algebra: Use mathematical models to represent and understand quantitative relationships.
- Model and solve contextualized problems using various representations, such as graphs, tables, and equations.
- Model with mathematics: Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace.

**Ideas for the Visit:**
Ask students to predict which variables might make the biggest difference in terms of energy savings. Also ask them which variables might be easiest to influence through public service announcements.

## 3.3 *Power Play...* Energy

**Description:**
Reducing ENERGY USE keeps down costs and improves air and water quality. A major storm is racing toward the city. Which essential services need a constant supply of power? At this design challenge station, minimise disruptions in power supply during extreme power surges by coming up with plans such as when and how to apply rolling blackouts to maintain essential services.

**Main Idea:**
Examining real-time graphs of electrical use provides engineers with immediate mathematical information that is used to maintain the functioning of the grid in emergencies.

**Maths at Work:**
<u>Real-time Graphing</u>
A real-time graph shows the total amount of electricity used in the city.

During an emergency, electrical workers consult a real-time graph to determine how much power needs to be cut to maintain essential services.

By reading the graph, workers can flip power switches on and off to see the impact of their actions. They keep consumption within the allocated kilowatt range and all the services keep running.

**Curricula Connection:**
The science of energy conservation is connected with the ability to read and interpret graphs that change in real time. Science laboratory "probes," such as those that measure temperature, motion or electrical energy usage, demand that students use real-time graphs.

- Algebra: Explore relationships between symbolic expressions and graphs of lines, paying particular attention to the meaning of intercept and slope.

**Ideas for the Visit:**
Ask students to "tell the story" of the graph that they see unfolding.

## 3.4 *Going Viral...* Communications

**Description:**
Find out how much server space is needed when your video goes viral through digital networks. At this design challenge station, work through a linear animation that demonstrates the powers-of-ten formula through digital communication.

**Main Idea:**
Exponents are a key way of expressing the size of numbers and provide a way to simplify calculations involving very large and very small numbers.

**Exhibit Text:**

*Access arrival predictions on the go.*
*GPS, digital mapping and mobile phones are used to collect information in different areas:*

- *the actual location of a bus or train*
- *the distance from there to your stop*
- *other planned bus stops along the way*
- *information about traffic and road conditions.*

*All this information gets factored into a mathematical formula, called an ESTIMATION ALGORITHM, and is then delivered straight to your device to help you determine the best route.*

**Maths at Work:**
Exponentials
Astronomers use huge numbers to describe distances in space. Physicists use tiny numbers to describe the size of atoms. Maths provides a simple way to express numbers that are extremely large or small without having to use a long string of zeroes. Using POWERS OF 10 provides an easy-to-read shorthand. The EXPONENT (the little number beside the 10) tells you the place value. Negative exponents are used to show values less than 1, and positive exponents are used to show numbers greater than 1.

$10^3 = 1000$
$10^2 = 100$
$10^1 = 10$
$10^0 = 1$
$10^{-1} = 0.1$
$10^{-2} = 0.01$
$10^{-3} = 0.001$

**Curricula Connection:**
Secondary school study of maths and science depends upon having a solid understanding of exponents.

- Number and Operations: Develop an understanding of large numbers, and recognize and appropriately use exponential, scientific, and calculator notation.
- Expressions and Equations: Know and apply the properties of integer exponents to generate equivalent numerical expressions.

## 3.5 ***Test the Waters...*** **Water**

**Description:**
Make the city's river water safe enough for swimming. At this design challenge station, virtually test water samples, and using the data provided, determine whether the natural balance of the river's ecosystem has been restored to safe levels for swimming.

**Main Idea:**
Very small numbers can be expressed in multiple ways, using the notions of "parts per million" decimals and scientific notation.

**Maths at Work:**
*Giardia* is a bacterium that causes diarrhoea. Swallow contaminated water from a pool or a river and you may get sick. Just ONE PART PER MILLION (ppm) of *Giardia* in a glass of water is harmful.

One part per million is tiny. If you put four drops of ink in a 200-litre water barrel and mix it thoroughly, the ink concentration would be one part per million.

A litre of water weighs 1 kilogram (kg)
1 kilogram (kg) = 1000 or $10^3$ grams (g)
1 milligram (mg) = 1/1000 or $10^{-3}$ grams (g)

A milligram is one ppm — or one millionth — of a kilogram.

You can write this in three different ways:

$$\frac{1}{1{,}000{,}000} \quad \text{or} \quad 0.000001 \quad \text{or} \quad 10^{-6}$$

Quick ways to write tiny amounts:
• Bacteria vary in size from $5 \times 10^{-4}$ mm to $5 \times 10^{-3}$ mm (0.0005 mm – 0.005 mm)
• A wavelength of green light is $5.5 \times 10^{-7}$ m (0.00000055 metres)

**Curricula Connection:**
Secondary school study of maths and science depends upon having a solid understanding of exponents. Understanding of parts per million is especially important in the study of biology, as well as in the emerging field of nanotechnology.

- Number and Operations: Develop a deeper understanding of very large and very small numbers and of various representations of them.
- Expressions and Equations: Write and evaluate numerical expressions involving whole-number exponents.

## 3.6 Featured Personalities in BUILD YOUR WORLD:

- Rondi Davies, Geologist and Champion Marathon Swimmer, New York, USA

*As a geologist, I study how the Earth works.*

***Since I was a young kid, I've loved swimming and being outdoors.***
*Marathon swimming unites my two passions.*

***A Big Challenge***
*In the 1970s, the Hudson River in New York was too polluted for swimming. After decades of clean-up work, the river is now swimmable most days.*

*To raise awareness about water quality, I organised a 200-kilometres, seven-day swim between eight bridges on the Hudson. There were 21 swimmers and we swam 20-32 kilometres every day.*

***Calculations***
*To figure out how long we should swim each day, I had to calculate*
- *when the ebb tide started*

- *the average speed of the current during the ebb tide*
- *the speed of each swimmer.*

- Tanya Martinez, Electrical Engineer, Albuquerque, New Mexico, USA
- Christine Outram, Director, City Innovation Group, Los Angeles, California, USA, and Research Associate, Senseable City Lab, Massachusetts, US Institute of Technology (MIT), Cambridge, Massachusetts, USA

***I use TECHNOLOGY to imagine what the FUTURE will look like.***
*As a kid, I was obsessed with playing Sim City, where you built a town from scratch. If you made a mistake, disaster hit and wiped out everything.*

*My obsession with computers and design led me to study architecture and technology. These days, I'm designing the real city of the future.*

***The Copenhagen Wheel*** *transforms regular bikes into HYBRID E-BIKES with motors. You lock the bike, unlock it, change gears and control the motor using your phone. The bike provides feedback on pollution, road conditions and traffic—all delivered in real time as you ride.*

***The power of TEAMWORK***
*I work with a team of architects, city planners, engineers, computer scientists, data processors and interactive designers. We speak the same language and all know the basics of MATHS, science and design.*

- Yemarshet Yemane, Engineer and Business Owner, Ethiopia

***I work on systems that deliver CLEAN WATER to communities.***
*When I was in Year 10, my favourite maths teacher went to the US to study ENGINEERING. Right then, I decided to become an engineer.*

*I was good at maths and studied civil engineering, water supply and sanitation overseas. Now I have my own business designing water projects and supervising the construction of water systems.*

***Every aspect of my work involves maths.***
*Many projects start with creating a dam to store water. The water is treated and then distributed to residents through a system of pipes.*

*I use MATHS to calculate everything from the volume of water stored in the dam to the size and length of pipes, to the costs of labour and materials.*

*The MATHS you study in school is used to DESIGN and BUILD your home, the roads you use every day, your family car, your computer, even your video games.*

- Francisca Rojas, Communication/Migration Specialist, Cambridge, Massachusetts, USA

***In the 1980s, when my family moved from Chile to Washington, DC phone calls home to Chile were expensive.*** *Today, wireless technology and the Internet help everyone stay connected. Calling relatives and friends in Chile several times a week is affordable, and we can video chat any time.*

***Maths helps us understand the world from social and cultural perspectives.***
*I'm curious to discover how wireless technology is changing how cities work. As a social scientist,*

*I use maths to analyse numbers and discover PATTERNS and TRENDS. For instance, did you know that New Yorkers call the Dominican Republic more than any other international destination?*

***I've always been fascinated by how cities work.***
*Public transport authorities in Boston and New York City use mobile phones and computers to collect DATA—in the form of NUMBERS and PATTERNS. My job is to talk to people about how they use mass transport. By interpreting and explaining all the data, I can help transit agencies build more efficient systems.*

## 4. ***FUTURE STYLE...*** **STYLE AND DESIGN**

### 4.1 *Style Revolution...* 360-degree Photo Shoot

**Description:**
Step onto a photo stage, pose and have your image captured in 360 degrees, using the same freeze-motion technique made famous in contemporary action movies. On a monitor, manipulate your image and choose to play back your shots in either a clockwise or anticlockwise sequence.

*It's Showtime*
*1. Sign up here and get your secret code.*
*2. Step into the ring.*
*3. Be ready to strike a pose.*
*4. Exit after the cameras go off. Find your pictures at an open workstation.*

**Main Idea:**
There is an inverse relationship between the number of cameras taking photos and the size of the angles between the cameras.

**Maths at Work:**
Sequencing
Each camera is in a fixed position. The distance and the angle between each pair of cameras are equal.

If there are x cameras,
the angle (y) between each pair of cameras is

$$\frac{360}{x} = y$$

The more cameras you use, the smaller the angle between each pair of cameras.

All the cameras shoot at exactly the same time. The computer puts the camera images together IN SEQUENCE to create a seamless animation in 360˚.

**Curricula Connection:**
The study of geometry, number and measurement are integrated in this interactive.

- Geometry: Make and test conjectures about geometric properties and relationships, and develop logical arguments to justify conclusions. (grades 3-5)
- Measurement: Understand, select, and use units of appropriate size and type to measure angles, perimeter, area, surface area, and volume. (grades 6-8)

**Ideas for the Visit:**
Walk around the perimeter of the circle and ask one student to call out the angle size between steps while another keeps track of the number of "steps." The number of steps multiplied by the angle size should equal 360 degrees.

### 4.4 *Make It Fit...* Tessellations

**Description:**
Work with edge-lit acrylic shapes on a backlit table lined with mirrors. Move shapes to create tessellating patterns that fit together and repeat without gaps or overlaps.

**Main Idea:**
Identifying the attributes of certain two-dimensional shapes which, in combination, tessellate or fit together without any overlaps or gaps.

**Maths at Work:**
Tessellations
Shapes TESSELLATE when they fit together perfectly like a tiled floor, without overlapping or gaps.
In any shape that tessellates, the angles at any corner—or vertex—add up to 360˚.
Find different tessellating shapes inside patterns. Some shapes, like pentagons, octagons and hexagons, have equal angles but cannot tessellate on their own.

**Curricula Connection:**
Geometric shapes can be used in combination to create pleasing artistic patterns that have defined mathematical properties.

- Geometry: identify, compare, and analyse attributes of two-and three-dimensional shapes and develop vocabulary to describe the attributes.
- Reason with shapes and their attributes.

**Ideas for the Visit:**
Encourage students to create their own tessellations with different combinations of shapes. A variation of this activity can be continued with pattern blocks once students return to the classroom.

### 4.5 *Nature's Numbers...* Nature's Patterns

**Description:**
Spectacular patterns from the natural world with a mathematical foundation are featured. At the attached workstation, discover how to calculate numbers in the Fibonacci sequence.

**Main Idea:**
Some number patterns can be represented by a ratio that has interesting geometric properties.

**Maths at Work:**
Ratio
Like a fraction, a RATIO is a way to compare two values or numbers.

The ratio of the sides of this rectangle is 8:5, or $\frac{8}{5} = 1.6$.

This rectangle is called a GOLDEN RECTANGLE because the ratio of two adjacent sides is approximately 1.618, a number called the GOLDEN RATIO.

All golden rectangles can be divided into a square and a smaller rectangle that is also a golden rectangle. This can be repeated over and over again.

Drawing a curve through the corners of the squares forms a LOGARITHMIC SPIRAL, a strong but compact shape often seen in nature.

The Ancient Greek mathematician Euclid first showed this calculation around 300 BCE About 2,000 years later, in 1835, the German mathematician Martin Ohm described it as "golden." Ohm never explained why he chose this term. <u>The Fibonacci Series</u>
This number sequence is often found in nature. It is seen in the growth patterns of leaves on a branch or in the chambers in a nautilus shell. The series is named after an Italian mathematician called Fibonacci who lived around 1175-1250.

Try to discover the next Fibonacci number in the puzzle on screen.

<u>Golden Numbers</u>
1. Select the numbered rectangle that comes next.
2. Watch the Fibonacci series fill up.

**Curricula Connection:**
This interactive connects number theory, namely the relationship in the golden ratio, with geometry.
It enables students to make connections between different areas of mathematics.

- Number and Operations: Understand and use ratios and proportions to represent quantitative relationships.
- Understand ratio concepts and use ratio reasoning to solve problems.
- Geometry: Use geometric models to represent and explain numerical and algebraic relationships.

**Ideas for the Visit:**
Encourage students to find as many examples of the golden ratio as they can in the panels in this interactive. Where else might they expect to see the golden ratio in nature?

## 4.7 ***Shadow Play*... Shadows**

**Description:**
Artist KUMI YAMASHITA uses the light shining on this seemingly random arrangement of numbers to throw shadows that produce the unexpected.

<u>Shadow Play</u>
Press here and step back to find out what is revealed.

## 4.8 Featured Personalities in FUTURE STYLE:

- Theo Jansen, Artist and Designer, Netherlands

***Beach Beasts***
*To create wind-powered kinetic sculptures that look and behave like fantasy animals, Dutch artist THEO JANSEN fuses physics, engineering, technology and his imagination to make robotic STRANDBEESTS or beach animals.*

*These mesmerising creatures come to life through Theo's mastery of computer maths programs. By running the data, he can work out essential details, such as the size and movement of the Strandbeests' legs.*

## 5. ***KICKIN' IT*... ENTERTAINMENT**

### 5.3 *Flicker Fusion*... Make a Movie

**Description:**
Artful figures are attached to a circular platform visible through viewing windows. Turn a dial and watch the figures as the platform rotates. Create a perfect animation by choosing the optimum frequency of rotation and optimum frequency of flashing light.

**Main Idea:**
The idea of frequency, both with respect to number of light flashes per second and with respect to number of times a platform rotates, is explored. This is a particular type of ratio, namely the number of flashes per second.

**Maths at Work:**
Frequency
The smoothness of the image depends on

1. the FREQUENCY, or number of times, that the light flashes per second
2. the speed, or FREQUENCY, at which the platform rotates in a given period of time.

When the rotating platform moves at slower speeds, you clearly see the light flash and the individual figures. As you increase the speed, the image becomes smoother. This is because at around 24 flashes per second the light begins flashing too fast for the eye to see. Above that rate, the animation appears perfectly smooth.

Because the flashing light and spinning platform are synchronised, the figures move forwards one position each time the light flashes. The platform appears to stay in place.

**Curricula Connection:**
Rate of change is an important topic in algebra as well as in science, and this interactive provides grounding for the study of rate of change.

- Algebra: Identify and describe situations with constant or varying rates of change and compare them.
- Understand ratio concepts and use ratio reasoning to solve problems.

### 5.5 *Step Up*... Dance Motion

**Description:**
Step up and dance. As you dance, watch rainbows and effects fan out from your reflected silhouette. Discover how mathematical functions can be used to create moving colour effects.

**Main Idea:**
Transformations in real time. Move your body and watch the changes on screen.

**Maths at Work:**
Binary
How does this work?

A camera linked to a computer program assigns a binary number—numbers made up of 1s and 0s—to your silhouette. That number corresponds to a colour, or frequency, in the colour spectrum. The background number always equals zero.
The program compares each pixel on the silhouette with the pixel above, below or beside it. If there is no pixel, it means you've moved and created a new outline. The program assigns the edge of the new silhouette a new number and colour.

Adding the silhouette images together creates an animation in real time.

### 5.6 *Featured Personalities in KICKIN' IT:*

- Daniel Ferguson, Imax Film Director and Screenwriter, Montreal, Canada

    ***I first became obsessed with movies as a very young kid.***
    *It was a career that combined everything that interested me: writing, photography, music, drama and technology.*

    ***All you need to do to make a movie is just pick up a camera, right?***
    *Wrong. Like hundreds of others I did just that when I finished university. Then I realised that no one else my age wanted to wrestle with spreadsheets or cash flows. I changed strategy and went into movie production instead.*

    ***Maths became the way for me to make movies.***
    *First, maths and I had to get reacquainted. It was not my strong point. Although I never imagined my artistic pursuits including figures and formulas, I broke into movies by working on the financial and scheduling side of the industry. Later, I moved to directing.*

    ***Movies take me to unexpected places.***
    *I have filmed on top of the highest waterfall in the world, followed the Tour de France in a helicopter and shot footage of elephants all over Asia.*

- Ajay Kapur, Musician and Computer Scientist, California Institute of the Arts, Valencia, California, USA

    ***My life revolves around my two passions: computers and music.***
    *Ever since my parents bought me my first computer, I've been glued to a screen. Soon after, I got a red Pearl drum kit and I've never stopped beating the drums, the walls, the dinner table.*

    ***As a musical scientist I constantly ask myself "How?"***
    *How does a sitar make that sound? How does a drum resonate? How do people play music together? How can I design programs that enable computers to improvise with human musicians?*

    ***Jamming 21st-century style***
    *KarmetiK, the robotic orchestra I direct, is made up of musicians, composers, scientists, engineers and artists who use their hands, heads, lights, lasers, gestures and computers to communicate with each other and with robots.*

    ***Music and maths are a lot alike.***
    *They both have their own language made up of symbols and numbers. Rhythm, harmony and tempo can all be explained using maths. Although maths might seem hard at first, don't give up. Like music, it gets better with practice.*

## 6. ***GAME PLAN...***

### 6.3 *Crack the (Binary) Code*

**Description:**
Five large switches correspond to the first five binary bits, or digits 16, 8, 4, 2 and 1. Turn the switch on to indicate "1". Turn it off to indicate "0". Challenge yourself to create binary equivalents of the "Target Number." See how many codes you can crack. The target number is in Base 10. Translate it into Base 2 (binary).

**Main Idea:**
There are different number systems used for different purposes: Binary or base 2 is commonly used in computer programming.

**Text Panel:**

*(Don't Get) Lost in Translation*
*The target number is in Base 10. Translate it into Base 2 (binary).*
*• To display a 1, slide the switch to ON.*
*• To display a 0, slide the switch to OFF.*

**Maths at Work:**
Bases
BASE 10 or the decimal system is the most commonly used number system. The numbers in the decimal system are 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9.

The position of the numbers determines their value,

| | | | | |
|---|---|---|---|---|
| 100 + | 10 + | 1 | | |
| 3 | 2 | 1 | = | 321 |
| 100x3 | 10x2 | 1x1 | | |

BASE 2, or the binary number system, uses only two digits, 1 and 0.
The value of binary digits also relies on their position.

| | | | | | |
|---|---|---|---|---|---|
| 8 + | 4 + | 2 + | 1 | | |
| 1 | 1 | 0 | 1 | = | 13 in the Base 10 system |
| 1x8 | 1x4 | 0x2 | 1x1 | | |

Base 2 is used in computing because an electrical circuit is either switched "on" or "off."
1 = "on"
0 = "off."

**Curricula Connection:**
Mathematics is rarely connected with computer science in elementary and middle school. This interactive provides an important opportunity to connect number theory (mathematics) with real life applications in computer science.

- Number and Operations: Recognize equivalent representations for the same number and generate them by decomposing and composing numbers.

**Ideas for the Visit:**
Encourage students to be code-breakers: Ask one student to write a binary numeral that represents a base-10 numeral between 1and100. Other students "break the code" by translating to the base-10 system.

## 6.4 *Flip It...* Probability

**Description:**
Zero out the counter on a monitor. Strike a pressure point to flip a disc inside a tube. The result of the flip is recorded with a camera. Repeat several times. A display shows your results. Compare these with the results for the flips and for the entire life of the exhibition (or some combination). The more times the coin is flipped, the closer the probability moves to 50%.

**Text Panel:**

*Heads or Tails?*
*1. Press the reset button.*
*2. Punch the button to flip a disc.*
*3. Compare your results with the running tally.*

**Main Idea:**
Coin flipping is an important context for understanding independent events: The probability of a fair coin coming up heads remains ½ no matter how many times it is flipped.

**Maths at Work:**
Probability
Each time you flip a coin there are two possible outcomes: heads or tails.

The probability for each outcome = 50%.

Each flip of the coin is an independent event. Flip it 5 times and you may get 5 heads. Flip it 500 times and your results will come much closer to the expected frequency of 50%. The greater the number of flips, the closer you get to 50%.

Plot your results on a graph to show how many times you get "heads" when you flip a coin 10 times. If many people do this, the results form a bell curve. Most results centre around 4, 5 and 6, with the greatest concentration at 5.

**Curricula Connection:**
Probability is an important part of the study of many types of data. For example, understanding genetics depends on understanding the notion of independent events.

- Data Analysis and Probability: Use proportionality and a basic understanding of probability to make and test conjectures about the results of experiments and simulations.

**Ideas for the Visit:**
Within a minute, every student in the class can flip a coin 10 times and record the results to make their own distribution. Does this distribution resemble a bell curve?

## 6.7 Cyber Security

**Description:**
Step inside an online computer game, where you are challenged to defend against invaders—like computer bugs and viruses—using computer passcodes, multi-factor authentication, and simple code sequences. Simulated fingerprint scans, card swipes and secret codes all help to create an exciting hands-on experience.

**Main Idea:**
Probability, statistics and coding are central to cyber security in defending and protecting against computer bugs, viruses and other cyber threats.

**Math at Work:**
Strong passcodes and multi-factor authentication, which are the basics of cyber security, depend on understanding and being able to use probability and statistics. Coding is also a key part of cyber security work.

Authentication, or the ability to verify a person's identity, is central to cyber security. A combination of passcodes, biometric data, and other data possessed only by the user, provide a way of authenticating a user's identity.

**Curricula Connection:**
Probability, statistics and coding:

- Selecting passcodes that have a low probability of being guessed by others or by computers.
- Understanding that multi-factor authentication processes use several steps, which in turn decreases the probability of hacking or identity theft.
- Learning that different modes of authentication involve different types and sizes of databases.
- Understanding that large numbers can represent the uniqueness of an individual's biometric markers, like fingerprints.
- Using graphical programming blocks to add an additional layer of security.

### 6.8 *Featured Personalities in GAME PLAN:*

- Robin Hunicke, Game Developer, Los Angeles, California, USA

***All games—board games card games, and video games—are about numbers.***
*Change something in a board game—like the number of turns you take — and see how it changes the experience. That's game design. Everything that happens in a video game is the result of a number being tracked and changed. Maths shapes all aspects of the game—from the way the light looks to the way gravity behaves.*

***If you can imagine it, you can probably use maths to build it.***
*To come up with a great game, find the sweet spot between what computers do well and what a knowledgeable and passionate team of people can create.*

***Be curious and ask questions.***
*The most interesting maths and science I've learned comes from asking "WHAT IF?", "HOW?" or "WHY?". The world is full of fascinating, interconnected systems. The more you investigate, the more you discover.*

***Use your curiosity like a compass to explore the world in all its detail.***

- Michael Mateas, Game Developer, University of California, Santa Cruz, USA

***Making ideas real***
*It takes science, maths, art and design to develop a game. Computers need to do things that seem impossible, like creating characters that talk to you, virtual opponents that adapt to your play and new game levels that appear automatically.*

***Writing a computer program can help you to work out what you really think and feel.***

*You figure out how to take something that is complicated, even messy, and turn it into something precise enough that a computer can do it.*

***Maths can get a bad rap.***
*People sometimes think that it's the opposite of art and expression, but making a game involves turning everything into maths. Maths is not just about numbers. It's about SYSTEMS—structures, symbols and algorithms.*

***Games are a new art form.***
*Creating a game can be just like writing a story or painting a picture. And every time you create a game with new game mechanics, you're doing some mathematical creation.*

## 7. *ROBOTICS AND SPACE*

### 7.2 *Curiosity Rover*

**Description:**
Control the movements of a virtual Curiosity Rover on a flat tabletop touchscreen as it moves across a Mars landscape. Enter a series of commands and manoeuvre past obstacles to collect rocks for analysis.

*Get Ready to Rock*
*1. Touch START MISSION.*
*2. Enter direction and number of moves.*
*3. Each time you change direction, also enter the number of moves.*
*4. Hit LAUNCH to run the sequence. Does the Rover reach the rocks?*

*25 Minutes to Mars*
*Because of the massive distance between Mars and Earth—ranging from about 45 million to 400 million kilometres (about 249 million miles) depending on how far apart the two planets are at a given moment—there's a gap of approximately 25 minutes from the time a message is sent from Earth to the time it reaches Mars.*

**Main Idea:**
Programming a robot involves carefully planning a sequence of steps. In programming, mathematical language is used to make communication clear and efficient.

**Maths at Work:**
Programming
Curiosity Rover, like all robots, is a specialised computer that can move independently and perform tasks. Like any computer, robots have to be programmed by human beings. Maths is the basic language used in all computer programs.

Using a series of commands, the program moves the Rover from its starting point. The information entered—the number of moves and the direction—is the INPUT. The OUTPUT is the response you see when the Rover moves across the landscape.

Program the Rover to turn through 45, 90, 135, 180, 225, 270, 315 and 360 degrees.

**Curricula Connection:**
A variant of the Logo programming language, designed to enable children to learn rudimentary programming and its connection to maths, is highlighted in this interactive.

- Geometry: Specify locations and describe spatial relationships using coordinate geometry and other representational systems.

**Ideas for the Visit:**
Primary students enjoy practicing "commands" by directing each other to physically move a certain number of steps and turn in a given direction. Put a target on the floor and encourage them to "program each other" while they wait for a turn to program the Curiosity Rover.

## 7.4 ***Robot Rally*... Robot Artefact Display**

**Description:**
Winning entries from the First Robotics or other robotics competitions are on display.

## 7.8 Extreme Weather Alert

**Description:**
Step into the role of a meteorologist, forecasting an extreme weather event. From a mobile weather lab, collect and interpret data and record your own extreme weather alert video. You can then email the video broadcast to yourself (where available).

**Main Idea:**
Making a weather forecast requires careful analysis and interpretation of data. Meteorologists use mathematical data, including data from maps and satellites, to examine weather patterns. Mathematics helps them determine the intensity of storms and to examine several weather variables to make forecasts.

**Math at Work:**
The mathematics in this component involves reading and making sense of maps and data visualizations. Visualizations are powerful because they can show many variables at once, including big data sets. These include variables that are changing over time and location. Weather variables may include temperature, wind speed, and wind direction at different altitudes and in different locations.

**Curricula Connection:**
- Reading and making sense of state-of-the-art data visualizations.
- Attending to multiple variables simultaneously.
- Using data that change over time to make a prediction.
- Interpreting mathematical and weather symbols, such as wind vectors.
- Synthesizing and communicating weather data in the form of messages to the public.

**MATH + PEOPLE**
[All the videos of featured personalities relating to the above sections are collected and displayed here, in one interactive touchscreen video center. Visitors swipe through a variety of personality screens to choose short videos of featured individuals who each use mathematics in their work, craft or art.]

## 7.9 Featured Personalities in ROBOTICS AND SPACE:

- Robonaut 2, Dexterous Humanoid Robot, NASA

*The state-of-the-art humanoid Robonaut 2 works side by side in space with human astronauts. Skilled at using tools to do work that involves fine hand control and movement, R2 is a DEXTEROUS crewmate.*

*This new-generation robot has an added advantage over earlier robot prototypes. As well as being a valued onboard colleague, R2 can work in space without a pressurised suit or oxygen supply. Like a rover, R2 is designed to move across the lunar or Martian landscape collecting rock samples and gathering data.*

- Dennis Hong, Robotics Engineer, Blacksburg, Virginia, USA

***When I was 7 years old, I went to see Star Wars.***
*All those spaceships and robots in the movie took my breath away. That day, I decided to become a ROBOT SCIENTIST.*

***How does C3PO do chores?***
*In my lab we think about the different ways robots MOVE, how we can make them LOOK AND ACT like humans, and how they can interact with and help humans.*

***I consider myself an expert in SYSTEMS INTEGRATION.***
*To build and design a robot, it's crucial that everyone can "SPEAK MATHS." I work with a brilliant team with expertise in mechanical designing, software development and robot vision.*

***The most fun part of our work is testing our ideas.***
*When one of us comes up with a smart theory, we put it to the test. First, we design an experiment; then, we design and build a robot and try it out. If it works, we know it's a good idea and we keep going. If not, we try again.*

- Robin Murphy, Robotics Engineer, College Station, Texas, USA

***When I was a kid I was convinced that one day I would live on a space station and do useful things.***
*At university, I studied mechanical engineering and then computer sciences. I fell in love with computers when I realised I could use them to solve all kinds of problems.*

*I was in heaven when I started working on ARTIFICIAL INTELLIGENCE.*
*A.I. is based on ideas of how people think, make decisions and solve problems. Computer scientists convert these ideas into MATHEMATICAL SYMBOLS.*

***Emergency helpers***
*Robots can go places where human rescuers like firefighters, police or medical personnel cannot go. For instance, a robot can determine if a building is structurally sound. This makes it a valuable addition to the larger emergency response team.*

*The first time I used robots in a real situation was in New York City after 9/11. Since then, my robots have helped in the aftermath of hurricanes, mine collapses and mudslides.*

- Kathryn Gray, Student and Supernova Searcher, Fredericton, Canada

***In summer we have STAR PARTIES.***
*My dad's an astronomer. Every year he takes us camping with other astronomers, off somewhere where the sky is dark enough to really see stars.*

***A supernova is an exploding star that blinks on and off as it burns and dies.***
*So far, dad has found six supernovae. When I was 10, I heard about a 14-year-old girl who found one and I thought, "HEY, I CAN DO THAT!"*

*Dad put me to the test. I looked through his images of galaxies and found five of his six supernovae—that's an 80% success rate.*

***Scrolling through pictures of different galaxies, I spotted a blinking star in the fourth picture.***
*It was a new supernova. I became the youngest person ever to find one.*

***Since then, I've looked at over 2,500 more photos.***
*When I think I've found a supernova, I use MATHS to plot it on a GRAPH based on its brightness. So far I haven't found a second one but I'm still looking!*

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**TEACHER'S REFERENCE GUIDE**

Edited by Sabrina Koll
Mathematics overview for Reference Guide by Jan Mokros, Ph.D.
Design by Joel Don Laney
Illustrations by Dennis Smith
Consultants:
Lori Murach
Jan Mokros, Ph.D.
Advisors:
National Council of Teachers of Mathematics
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