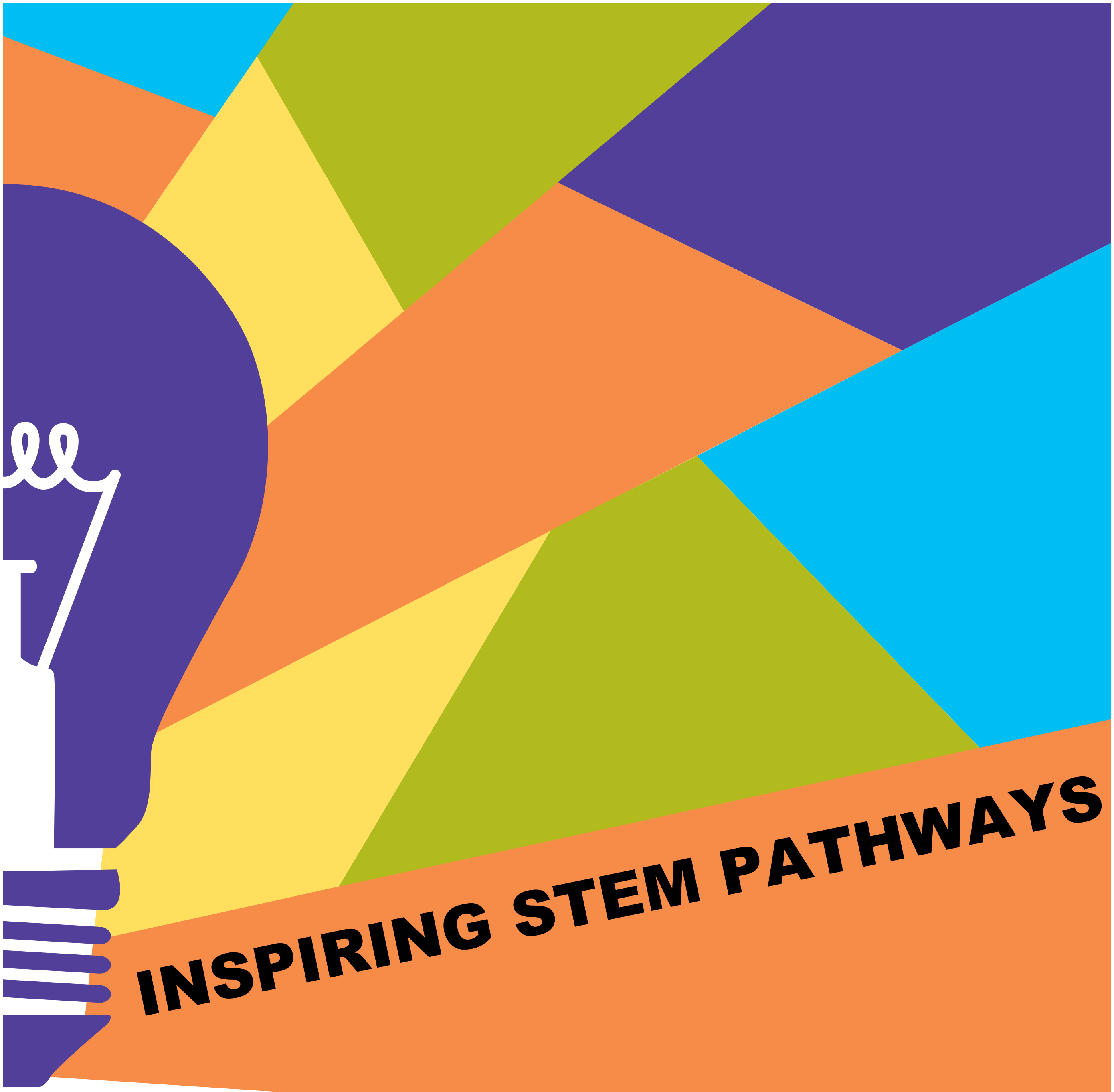


EDUCATOR GUIDE

THE LEMELSON CENTER
FOR THE STUDY OF INVENTION AND INNOVATION
Smithsonian

Inspiring STEM Pathways:
Contemporary Inventors as Role Models for the Next Generation

Educator Guide

Inspiring STEM Pathways presents first-hand accounts from interviews with living inventors who work in a variety of fields and organizations. The videos and accompanying learning materials are intended to encourage students to pursue STEM fields by seeing relevant role models speaking about their interests and passions, challenges they encountered and how they overcame them, and how they draw on curiosity and resiliency in their daily work.

This educator guide contains summaries of the 5-minute videos, a mix of "real-world applications" (math and science problems to solve in-class or as homework), discussion prompts for classroom dialogue or writing assignments, suggestions for video projects, and invention challenges that can be carried out by individuals or teams using simple available materials. All of these can be scaled to the appropriate grade and class level. The Appendices provide additional classroom use suggestions.

The engineers, scientists, entrepreneurs, and inventors featured in this project are employed at organizations ranging from large corporations to universities to small startups. They come from backgrounds ranging from immigrant families in the Bronx, New York, to small southern towns. Furthermore, they developed their interests in math and science at different points in time, ranging from elementary school to high school. But they also share important commonalities: they all had teachers or other adults who modeled a path to success; they all took risks in developing projects they were passionate about; and they all developed strong resiliency to overcome life challenges and invention failures.

Contents

Nathan Brooks

Description

Nathan Brooks, an engineer at Boeing, invents ways to improve antennas and other technologies for communications, signal jamming, and the detection of airplanes, rockets, and missiles in flight. Born in Louisiana, Nathan played sports throughout school and then became interested in math and science during high school in Missouri City, Texas. He attended Florida A&M, a historically black college/university (HBCU), and began raising a family of three sons with his wife Angela, who also majored in electrical engineering. Encouraged by the President of Florida A&M, he pursued graduate study and earned a PhD with research into electromagnetic systems necessary for hypersonic flight (5 times the speed of sound). Nathan continues to work on geolocation technologies, and has won numerous awards, including being named Boeing Defense Space and Security Engineer of the Year. He is Boeing's first African American Senior Technical Fellow.

Real World Application

- Satellites relay information using radio waves, which, like all electromagnetic radiation, travel at the speed of light: 186,000 miles per second. By knowing how long a signal takes to reach the GPS receiver in your phone, you can figure out how far away the satellite is. If a signal takes 0.06 seconds to reach the receiver, how far away is the satellite?
- Knowing the distance to a single satellite isn't enough to define your position, since you could be anywhere on a sphere with a radius of that distance. Trilateration requires a minimum of three satellite signals to define an exact position on Earth's surface. Why are three signals needed? Why not just two?

Group Discussion / Activity

- What would you like to ask Nathan that wasn't covered in the video?
- Nathan said that he was into sports when he was young. He also said that math and physics were his favorite classes in high school. Identify two things you are passionate about that seem very different from each other to most people. Can you think of some ways that those areas of interest overlap? How could your interest in one area (for example, sports) also help you in another (for example, math)?

- Visit this site to learn more about how GPS works: https://spaceplace.nasa.gov/gps/en/. After learning more about GPS, work together as a group to create a skit, presentation, or demonstration that teaches your classmates about GPS. Use sports, art, cooking, or some other activity—*but not travel*—as your example for the demonstration.

Video Project

- Create a video short: using the interview with Nathan and other images you find online about hypersonics or trilateration, make a 1-minute video that would excite other students about science and technology. Decide whether it is for kids your age or for younger students.

Invention Challenge

Invent something that uses someone's location to solve a problem.

- Explore It: Knowing where you are or being able to track a ship, car, or airplane has made possible many advances in scientific exploration. Whether using the stars to navigate a ship across an ocean, tracking your hike or bike ride on your phone, or using a rideshare app, triangulation and navigation are the basis for innovations in trade, business, and other areas.
- Sketch It: Design a system to track the location of your school backpack or favorite hoodie. Will your invention use GPS? Or will it use some other method of determining location? Who will use your invention? Is it for one group of people, or could different groups use it in different ways? You and just some of your friends, or people you've never met?
- Create It: Make a prototype version of your idea using paper, cardboard, tape, and other materials from your house or classroom.

Jessica O. Matthews

Description

Jessica Matthews is the Founder and CEO of Uncharted Power, a renewable power startup company that harnesses energy from motion to create sustainable power systems for communities around the world. Jessica grew up in New York City as the child of Nigerian immigrants. During a visit to Nigeria when she was 17, she noticed the use of generators and kerosene lamps to provide electricity and lighting at night. She then looked for quieter and less polluting solutions, and invented "Soccket," a soccer ball that captures and stores energy. From there, she created other energy-generating toys and devices before turning to invent new ways to create and store power on a larger, community or city-wide scale. Jessica is the named inventor on more than 10 patents and has been listed in *Fortune* magazine's "Most Promising Women Entrepreneurs" and *Inc.* magazine's "Top 30 under 30."

Real World Application

- Jessica's invention, Soccket, converts kinetic energy to stored (potential) energy. After an hour of active play, Soccket could power an 8-watt LED lamp for 3 hours. If you and your friends played with the Soccket soccer ball for two hours instead of one, how long could it power a 12-watt lamp?
- Fully charged, the Soccket can provide 72 hours of power for its LED light. That's about 0.4 kilowatt-hour. (The energy equivalent of a ¾-cup serving of premium ice cream.) If the average home uses about 30 kilowatt-hours per day, how many fully charged Soccket balls would it take to power an average home for a week?

Group Discussion / Activity

- What would you like to ask Jessica that wasn't covered in the video?
- Jessica shares the story of her cousins telling her she would get used to a noisy and smelly generator, which inspired her to want to invent something better. What do you think you would have done in that situation? List two things in your life that you've "just gotten used to" that you could work to change instead.
- Jessica talks about "infrastructure." Infrastructure is at the heart of what makes a system work, like the power grid that sends electricity to your home or the road system that allows you to easily

travel from place to place. As a class, or in small groups, think of something that is at the heart of what makes your classroom a functional space for teaching and learning. Brainstorm ideas that could make this infrastructure component better. Do your best to find a way for your idea to be an improvement that is positive for everyone in the class, including your teacher.

Video Project

- Create a video short: using the interview with Jessica and other images you find online about kinetic energy, make a 1-minute video that would excite other students about science and technology. Decide whether it is for kids your age or for younger students.

Invention Challenge

Invent something that solves a problem that other people don't even notice.

- Explore It: Not every invention comes about because people can't live without it. Inventors often think creatively beyond what exists to what could be, in order to improve lives or help people have fun. Think about some things in your life that don't work the way you think they should, but that everyone else seems to ignore because they are used to them.
- Sketch It: Write a list of at least 3 things that need improving. Sketch solutions for 2 of the improvements on your list.
- Create It: Pick one of your solutions and build a prototype out of paper, cardboard, and tape that would work at larger scale. Focus on at least one aspect of the problem you identified that your invention improves upon.
  - What made you notice this problem?
  - Is there an easy solution? Or does it take a lot of hard work to come up with something?
  - Are you focusing on function, safety, appearance, use, or some other feature?

Tahira Reid

Description

Tahira Reid is an Associate Professor of Mechanical Engineering at Purdue University. Growing up in the Bronx, New York, Tahira loved Double-Dutch jump rope, and then developed an interest in math and science. At Rensselaer Polytechnic Institute (RPI), she worked with Professor Burt Swersey to build a Double-Dutch machine that was featured in the news and earned a patent. Her invention has not yet made it into production, but she pursued a graduate degree in engineering and then became a professor at Purdue University, where she is head of the REID (Research in Engineering and Interdisciplinary Design) Lab, which develops new human-machine interactions. She also does pathbreaking work to include minority communities that are frequently left out of technology development.

Real World Application

- In Double-Dutch jump rope, two people twirl two ropes between them in opposite directions, and a third person jumps as each rope passes underneath. If the ropes are 180-degrees out of phase (one rope is extended upward when the other is extended downward), and the rope turners take 2 seconds for a full rotation of each rope, how many times would the jumper jump in 1 minute?
- Imagine it were possible for the two Double-Dutch rope turners to turn the ropes at different speeds. If they reduced the rotational frequency of one of the ropes by 50%, now how many times would the jumper jump each minute?

Group Discussion / Activity

- What would you like to ask Tahira that wasn't covered in the video?
- Tahira talks about working with others on her inventions, as a student and now as a professor. What different skills do you think people working as an invention team might have? What role do you think you would take on an invention team, given your interests?
- Divide into groups of 4-6 people. Assign each person in the group one of the following roles:
  - Inventor
  - Engineer / Scientist
  - Product Designer

- Marketing Expert
- Investor (Funder)
- Public Relations and Communications Leader

As a group, think of one product that could have a positive impact on the physical activity of young kids. On paper come up with a design, a way to create and test the idea, a way to finance the idea (by explaining who will buy it and for how much relative to what it costs to make it), and a way to advertise and market the idea. As a group, organize this into a presentation that involves everyone and share it with the class.

Video Project

- Create a video short: using the interview with Tahira and other images you find online about the human-machine interface (for example, factory robots or assistive technology for people with disabilities, or another area entirely), make a 1-minute video that would excite other students about science and technology. Decide whether it is for kids your age or for younger students.

Invention Challenge

Invent something you would have wanted to play with as a kid.

- Explore It: Growing up, you may have noticed how your life was different than other kids around you. Whether you had many siblings or none, a big backyard or no yard, went to a big school or were homeschooled, there was probably something other kids had or did that you wished you could have.
- Sketch it: In school, Tahira drew a poster of a Double Dutch jump rope machine that she would later build in college. Sketch a machine you wish you had that would make it easier for you to play a sport or do your favorite hobby.
- Create It: Make a version of your idea using paper, cardboard, tape, and other materials from around your house or classroom.
    - Is your invention an object, like a toy; an idea, like a new way to play a game; or a machine like Tahira's jump rope device?
    - Do you think your idea will change when you get older?
    - What kind of materials would you need to build a working version? Who could help you achieve your goal?

Tony Ruto

Description

Director of Research Engineering at the design software firm Autodesk, Anthony Ruto grew up in a small town in rural Kenya, Africa, before moving to the city of Nairobi and then to Britain when he was 17. Tony attended Cambridge University, where he studied computer-based design and developed new ways of scanning human bodies that made it possible to build improved avatars for movies, video games, clothing designers, and other applications. In his first job, Tony created a way to continuously monitor tiny movements by patients undergoing radiation treatment for cancer, making the process much safer. He now works in “generative design” at Autodesk and has led engineering projects ranging from totally new designs for chairs to improved Formula 1 racecars.

Real World Application

- Tony talks about filling a stadium with virtual characters for a movie like *The Gladiator*. Suppose you had 4 hairstyles, 4 face variations, 3 skin colors, and 5 body shapes to work with. How many different characters could you make? If your stadium is showing 18,000 people in a scene, how many times would the same character repeat?
- If you had a cylinder that was 5-feet tall and had a radius of 1 foot and then draped fabric on every surface except the bottom, how much material would you need?

Group Discussion / Activity

- What would you like to ask Tony that wasn’t covered in the video?
- Tony talked about taking things apart and putting them back together as a child. How do you think that influenced his ability to think inventively? What have you taken apart that you’ve been surprised by? Were you able to put it back together?
- Tony mentions that he worked to reduce the number of data points in body scans to represent the human shape. You will try to do the same for the shape of a chair. Each group is to take measurements from 2 differently shaped chairs. After taking those measurements, determine the specific measurements that the chairs have in common and the key measurements that make them different from each other. How could your team use this information to develop a line of chair covers that, with minor tweaks, could be made to fit the shape and size of different chairs?

Video Project

- Create a video short: using the interview with Tony and other images you find online about generative design, make a 1-minute video that would excite other students age about science and technology. Decide whether it is for kids your age or for younger students.

Invention Challenge

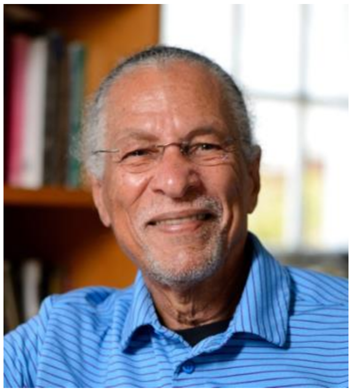
Invent a way to take something physical (a sketch on paper, a pet, something you made in art class, etc.) and make it digital.

- Explore It: Whether it's taking a physical object and creating a digital representation of it, or taking a drawing and knowing how to build it physically, the interaction between the two methods is changing fast at present and being used in many different ways.
- Create It: Design a way to digitize something physical.
    - What are you digitizing? Why will this be a useful invention, and who will it help?
    - What problems might you encounter?
    - Why is a digital version more useful than a physical version? Does it save space, convey information, or something else?

Invent a new furniture design

- Explore It: Furniture serves a variety of functions, ranging from a place to sit to storage for clothes, dishes, or other items. Some pieces are enclosed, others are open; some are heavy, others are light. Sometimes the function is obvious, but sometimes there are hidden compartments.
- Create it: Sketch a piece of furniture you would want to build. Using a free account on Tinkercad www.tinkercad.com, create a digital, 3-dimensional (3D) model of your design. How is your digital design different from your sketched design? Now that you have a 3D model what are some ways you could turn your design idea into reality? If you chose to change the shape or size of your design, how could you do that in the digital version?

Jim West



Description

James West grew up in the American South under disciminatory “Jim Crow” laws that legalized racial segregation, but with an interest in science and engineering from the time he took apart his father’s pocket watch as a child. After serving in the Korean War, he studied at Temple University in Philadelphia and had an internship, and then was employed at the renowned Bell Labs research facility in New Jersey. After studying how microphones and speakers worked and noticing an anomaly in the then-new material Teflon, he invented the electret microphone, now used widely in cell phones and other electronics. He also co-founded the Association of Black Laboratory Employees, which helped advance careers of African American scientists in research. After retiring from Bell Labs, he was named a professor at Johns Hopkins University and continues to invent and mentor young African American scientists and engineers.

Real World Application

- Sound waves are a type of energy. The amplitude of a sound wave determines how loud it sounds, its volume. The overall energy of a sound wave is proportional to the square of its amplitude. If sound wave one has an amplitude that is 4 times the amplitude of sound wave two, how much more energy does the first wave have?
- In electret condenser microphones, acoustical signals, which are longitudinal “pressure” waves, vibrate a thin foil diaphragm. These movements continuously change the amount of energy stored (capacitance) inside the microphone, while a special material provides an embedded “permanent” charge to power the microphone. The resultant electrical signals match the audio input. What would happen to the output signal if the space between the diaphragm and the rest of the microphone was increased?

Group Discussion / Activity

- What would you like to ask Jim that wasn’t covered in the video?
- Jim talks about his education, from childhood through Temple University, and how the people who taught and supported him were very important in influencing the course of his life. How do you think his life would have been different if he hadn’t had those mentors? How do the people in your life—teachers, coaches, parents or guardians—influence your interests?

- Jim observes, "systemic racism is difficult to keep out of any system here in this country." While at Bell Labs, he and several colleagues formed the Association of Black Laboratory Employees to raise awareness and improve the quality of life and work for African American scientists and engineers. What do you think they did, and what difficulties did they face? Do you think that would be different today, and if so, in what ways?
- Divide into groups of 3-5 students. Each group has 2 minutes to come up with an idea that they think could, in some way, improve the sound quality of music. After your 2-minute brainstorm, meet up with another group to share the ideas. After the first group shares, provide one challenging question about their idea, along with 3 things you like about their idea. Now swap rolls. Let the other group share out and your group will listen, provide one challenging question, and 3 things you like about their idea.

Video Project

- Create a video short: using the interview with Jim and other images you find online about microphones and new sound recording and transmission technologies, make a 1-minute video that would excite other students about science and technology. Decide whether it is for kids your age or for younger students.

Invention Challenge

Invent a way to distort sound.

- Explore It: Sound travels by vibrating the molecules it comes into contact with. Some sound technologies get used in ways their inventors never imagined. For example, Autotune was created to help singers stay on tune, but then some musicians used it to distort their voice.
- Create It: Using materials you can find around your house or classroom—such as a piece of paper or cardboard and tape—invent a way to amplify, distort, or muffle a sound.
    - Which did you choose to do: amplify, distort or muffle the sound?
    - How do the properties of the materials you selected make your invention work?

Invent an improvement to something that already exists that solves a problem in the way it works.

- Explore It: Seeing a chance to tweak an invention that already exists is a skill inventors practice every day. The ability to look at something you use, and think how you could make it better means you're looking at the world in a different way.
- Create It:
    - How did you choose the invention your innovation would be based on? Is it something in your life that frustrates you or you think could work better?
    - Does your innovation change the materials? Allow people to use it who couldn't before? Or let it solve more problems that it did before?

Appendix 1: Next Generation Science and Engineering Standards

The Inspiring STEM Pathways videos and accompanying classroom educational materials align with the Next Generational Science and Engineering Standards.

- Content standards (41 disciplinary-specific core themes covering Physical Science; Life Science; Earth and Space Science; Engineering, Technology and Applications of Science)
- Crosscutting Concepts (7)
  - Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
  - Cause and Effect—Mechanism and Explanation: Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
  - Scale, Proportion, and Quantity: In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.
  - Systems and System Models: Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering
  - Energy and Matter—Flows, Cycles, and Conservation: Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.
  - Structure and Function: The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.
  - Stability and Change: For natural and built systems, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.
- Science and Engineering Practices (8)
  - Asking questions (for science) and defining problems (for engineering)
  - Developing and using models
  - Planning and carrying out investigations
  - Analyzing and interpreting data
  - Using mathematics and computational thinking
  - Constructing explanations (for science) and designing solutions (for engineering)
  - Engaging in argument from evidence
  - Obtaining, evaluating, and communicating information

Appendix 2: Facilitation of Discussion Questions

The videos highlight inventors who work in different fields, bring different knowledge, interests, and characteristics to their work, and define the success they have achieved differently. But all of the inventive scientists, engineers, and designers featured also share core inventive traits, including curiosity, empathy, passion, creativity, resourcefulness, risk-taking, tolerance for ambiguity, and resilience. These are by no means limited to STEM careers. However, when aligned to traditional STEM content and integrated with the teaching of research and inquiry skills, inventiveness can underpin sustained STEM engagement beyond the short-term interest and enthusiasm of finding new solutions. In turn, comfort and confidence with STEM content can lower the bar for inventive playfulness and experimentation.

The discussion questions presented alongside each featured interviewee seek to draw out inventive identities (see table) in young people and give them additional tools to express their own interests and creativity aligned to STEM learning goals. Discussion questions specific to each video highlight each inventor's STEM or inventive identity and are These questions can be used as the basis for in-class discussion or as writing prompts to encourage students to consider their own interests and identities and how they converge with or diverge from that of the featured inventor.

We recommend beginning with a set of "pre-questions" prior to showing the video or assigning it for viewing.

1. What does an inventor look like?
2. What do inventors do?
3. Where do inventors work?

Students may struggle with these three questions, since the majority of the visual imagery of inventors (as with scientists and engineers) they have been exposed to is of white men, often in lab coats with wild hair, or based on black-and-white photographs of 19th century inventors who are long deceased. What inventors do is likewise poorly understood by the general public. Students may simply answer that "inventors invent." The instructor can expand on that by pointing out the need for inventions to be new—a new material, process, or service offering. An analogy to music will often make it more relatable to students; they may like older music, but a musician must create new songs to really make it big. Where inventors work opens up the opportunity to go beyond corporate labs (though these are important) to basements, garages, and other spaces. The point is to convey that inventors are men and women; of all nationalities, ethnicities, and races; and they sometimes work with a lot of equipment and resources, but sometimes also work out of their own homes or garages.

When facilitating discussion about scientists, engineers, and inventors, it is empowering for students to hear their ideas reframed in relation to core STEM skills as expressed in the table below. The instructor can productively point out when students have invoked one of the core trains and then ask for examples either from the videos or from other places students have observed this behaviors being used.

Inventive Identity & STEM Learning			
CURIOSITY • Identifies problems, opportunities, and challenges • Pays attention to small practicalities while aware of large-scale systems	**EMPATHY** • Seeks out ways to understand needs and wishes of others • Welcomes feedback and input from multiple points of view	**PASSION** • Cares deeply about the problem • Personally invested in the process and the outcome	**CREATIVITY** • Generates many new ideas, both practical and out-of-the-box • Brings together disparate ideas and unexpected combinations
RESOURCEFULNESS • Solves problems using the resources at hand • Uses arts, design, and materials in new and novel ways	**CALCULATED RISK-TAKING** • Explores new possibilities, including wild or unproven solutions • Feels comfortable taking chances	**TOLERANT OF AMBIGUITY** • Accepts not knowing the answers • Embraces multiple facets of a problem while trying to solve it	**RESILIENCE** • Embraces failure as a learning experience • Remains open to feedback • Continues to innovate despite setbacks

Appendix 3: Facilitation of Invention Challenges

Materials: For a quick idea, or to get started, students may choose to sketch their invention. Often, though, building is a lot of fun and engages them in thinking about their invention ideas in different ways. An easy and flexible way to make prototypes is to use consumable materials: craft supplies, cardboard and cartons from recycling, etc. You may ask students to bring in supplies and pool them, or use what they have at home and see how inventions differ based on what was available. Thinking about alternative and unexpected uses for items is a skill inventors develop, and you can encourage this in students as they identify materials they can use (with parent/guardian approval, of course).

Here are some ways to think about a mix of materials:

- Something to build on: cardboard in all shapes and sizes; paper like newspaper, packing paper, or construction paper; recyclable (cleaned) plastic containers
- Ways to join two things together: tape works great, but you can also try string, wire, or brads
- Ways to make a structure or frame: straws of lots of different sizes, chenille stems, and craft sticks all work really well
- Ways to add color: Making your invention look good is important, too! Add color with markers, magazine pages, or construction paper; or used colored straws, chenille stems, or craft sticks

Facilitation Questions: As a facilitator, use inquiry-based learning to draw out the stories behind your students' prototypes as they build. In addition to the questions listed alongside each invention challenge, here are some general questions you can ask.

- Getting Started
    - Is your idea based off of something to help at home? In your community? Or to help people living somewhere else?
    - What materials do you have to use? How do they inspire you?

- Creative Problem-solving
    - Why did you choose this method to solve this problem?
    - Is it based on the materials you had?
    - A personal experience or something you learned about?

- Materials Use
    - What are the different parts of your invention?
    - What does this material represent?
    - What would you use to build your invention in real life and why?

- Invention Process
    - How have other people solved this problem in the past, and how will your invention be different?
    - How has your idea changed as you built it?
    - Did you have to tweak your prototype after you built and tested it?
    - Did you make changes to improve how your invention worked, or to change what it did, as you learned more about the problem?

Additional resources for invention challenges and activities can be found here:

- US Patent and Trademark Office: https://www.uspto.gov/kids/
- Smithsonian Institution: https://invention.si.edu/try/encouraging-innovative-thinking

Appendix 4: About the Smithsonian Institution's Lemelson Center for the Study of Invention and Innovation

The Lemelson Center for the Study of Invention and Innovation is a research and program team located within the Smithsonian Institution's National Museum of American History. Its mission is to engage, educate, and empower the public to participate in technological, economic, and social change for good. The team undertakes historical research, develops educational initiatives, creates exhibitions, and hosts public programming to advance new perspectives on invention and innovation and to foster interactions between the public and inventors. The *STEM Pathways* project aligns strongly to the Center's longstanding attention to inventor diversity and to its educational goals of developing inventive identities in all young people so that they can realize their full potential.

The *STEM Pathways* project seeks to inspire young people by connecting the work of relevant role models to subject matter of middle and high school courses. Pre-teens and teens will expand their understanding of inventors and invention (*who gets to be an inventor, what an inventor looks like, what kinds of problems inventors solve*) and more importantly, of themselves (*I can invent*, *I can solve problems*, *I can change the future*). Research shows that for girls and minority youth in the United States, affinity for and confidence in STEM drop significantly during middle and high school years. This project showcases diverse role models, emphasizes the real-world applicability of what is being taught in math, science, and other classes in middle and high school, and aspires to motivate young people to pursue further education and careers in technical industries poised for growth through innovation.

The *STEM Pathways* project is currently in a pilot phase (winter-spring 2023). We value your feedback! To provide input and help us improve this project for the future, contact: LemCen@si.edu.

Appendix 5: Answers to Real World Application Problems

Nathan Brooks

- Satellites relay information using radio waves, which, like all electromagnetic radiation, travel at the speed of light: 186,000 miles per second (in ideal conditions). By knowing how long a signal takes to reach the GPS receiver in your phone, you can figure out how far away the satellite is. If a signal takes 0.06 seconds to reach the receiver, how far away is the satellite?

  [**Answer: 11,160 miles**]

- Knowing the distance to a single satellite isn't enough to define your position, since you could be anywhere on a sphere with a radius of that distance. Trilateration requires a minimum of three satellite signals to define an exact position on Earth's surface. Why are three signals needed? Why not just two?

  [Answer: The intersection of two spheres will define a circle, not a point. A third sphere reduces the possible locations to two, but since we defined the location as being on the Earth's surface, the second point can be eliminated. If we didn't fix the location on the surface, then it could take FOUR inputs to specify an exact location.]

Jessica Matthews

- Jessica's invention, Soccket, converts kinetic energy to stored (potential) energy. After an hour of active play, Soccket could power an 8-watt LED lamp for 3 hours. If you and your friends played with the Soccket soccer ball for two hours instead of one, how long could it power a 12-watt lamp?

  [Answer: 4 hours]

- Fully charged, the Soccket can provide 72 hours of power for its LED light. That's about 0.4 kilowatt-hour. (The energy equivalent of a ¾-cup serving of premium ice cream.) If the average home uses about 30 kilowatt-hours per day, how many fully charged Soccket balls would it take to power an average home for a week?

  [Answer: 525 fully charged balls]

Tahira Reid

- In Double Dutch jump rope, two people twirl two ropes between them in opposite directions, and a third person jumps as each rope passes underneath. If the ropes are 180-degrees out of phase (one rope is extended upward when the other is extended downward), and the rope turners take 2 seconds for a full rotation of each rope, how many times would the jumper jump in 1 minute?

  [Answer: 60]

- Imagine it were possible for the two Double Dutch rope turners to turn the ropes at different speeds. If they reduced the rotational frequency of <u>one</u> of the ropes by 50%, now how many times would the jumper jump each minute?

[Answer: 40. Note: one rope hits the ground every 2 seconds, so 30/min; the other rope hits the ground every 3 seconds (50% slower), so 20/min… but every 6^{th} time (at 6, 12, 18, 24 seconds, etc.) the two ropes coincide, so 30 + 20 = 50, and 50 - 10 = 40 jumps / minute.]

Anthony Ruto

- Tony talks about filling a stadium with virtual characters for a movie like *The Gladiator*. Suppose you had 4 hairstyles, 4 face variations, 3 skin colors, and 5 body shapes to work with. How many different characters could you make?

  [Answer: 240]

- If your stadium is showing 18,000 people in a scene, what is the minimum number of times the same character would repeat?

  [Answer: 75]

- If you had a cylinder that was 5 foot tall and had a radius of 1 foot and then draped fabric on every surface except the bottom, how much material would you need?

  [Answer: 34.5 square feet. Note: Total surface area of cylinder: $2\pi rh+2\pi r^2$. Area without bottom circle = $2\pi rh+ \pi r^2$.]

<u>**Jim West**</u>

- Sound waves are a type of energy. The amplitude of a sound wave determines how loud it sounds, its volume. The overall energy of a sound wave is proportional to the square of its amplitude. If sound wave one has an amplitude that is 4 times the amplitude of sound wave two, how much more energy does the first wave have?

  [Answer: 16x more energy]

- In electret condenser microphones, acoustical signals, which are longitudinal “pressure” waves, vibrate a thin foil diaphragm. These movements continuously change the amount of energy stored (capacitance) inside the microphone, while a special material provides an embedded “permanent” charge to power the microphone. The resultant electrical signals match the audio input. What would happen to the output signal if the space between the diaphragm and the rest of the microphone was increased?

  [Answer: Capacitance will drop and the output signal will be reduced.]