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Inventing Tomorrow follows young scientists from Indonesia, Hawaii, India, and Mexico as they tackle some of the most complex environmental issues in their communities and prepare to present and defend their original research at ISEF, the Intel International Science and Engineering Fair. Considered the Olympics of high school science fairs, ISEF attracts approximately 1,800 finalists from more than 75 countries, regions, and territories every year. Each student spends hundreds of hours on their projects, guided in their scientific quest by dedicated mentors. Winning the competition may seem to be the students’ immediate goal, but the heart of the story is their desire to create innovative solutions to fix immediate environmental threats in their own backyards.

To support educators’ use of the documentary in the classroom and to further inspire students, the Teaching Inventing Tomorrow curriculum includes a unique set of four lessons to accompany existing courses in science, technology, engineering, and mathematics (STEM) in classrooms around the world. As Manu Prakash, professor of Bioengineering at Stanford University, said in his opening remarks at ISEF 2017:

“Over the last year or so I’ve been personally depressed. Climate change, biodiversity loss, denial of science, all these challenges sound very daunting. But when I think about these problems sprinkled everywhere, the solutions are also sprinkled everywhere. And that solution lies in the spark [in] eyes of people like you. We have to do everything we can to build an army of scientists around the world. That is our only hope.”

To learn more about the film, visit www.InventingTomorrowMovie.com. Additional resources will be posted on the website as they become available.

To learn more about science fair opportunities in your community, explore the Society for Science & the Public website at www.societyforscience.org.

Thank you for your interest in the film and accompanying educational materials.
OVERVIEW
OVERVIEW
The Teaching Curriculum for Inventing Tomorrow offers educators the opportunity to make science, technology, engineering, and math come alive by pairing screenings of the documentary with classroom learning. Each student story in the documentary lays the groundwork for one of the lessons in the curriculum. An individual lesson, or the complete curriculum, can easily be incorporated into existing coursework in middle school Science and high school Biology and Life Sciences, Chemistry, Marine Biology/Oceanography, Earth and Environmental Science, Geography, Geology or supplement units on Sustainability, Media Literacy, Global Studies, Current Events, and more.

Each lesson is at least two days in scope and includes:

- **A Lesson Overview:** Description of the lesson topic.
- **Lesson Objectives:** What students will learn by the end of the lesson.
- **Length and Materials:** Suggested duration of lesson and materials necessary for the lesson.
- **Lesson Activity:** An applied science lesson with a hands on lab based on the issue addressed and STEM content.
- **Extensions:** Suggestions and resources to extend student learning and research on the lesson topic.
- **Standards Addressed:** NextGen Standards are included that are specific to the content covered.

“With science, there’s really no value in just creating this data, and creating these inventions, and just sitting on them. You do need to actually have them make a difference in the world.”

– SAHITHI PINGALI, INVENTING TOMORROW
DESIGN PROCESS AND STANDARDS ADDRESSED

The lesson structure is guided by the Engineering Design Process. This step-by-step approach delves into the process of design thinking, learning from failure and deepening students’ capacity for empathy and connection with the people and communities who will benefit from their work and innovation.

The lessons also build upon the scientific method and the dynamic processes involved in scientific investigations. This can include experiments and observation, more testing, revision, failure, and the process can begin anew.

Teaching Inventing Tomorrow is also aligned to NextGen Standards and Performance Expectations for Engineering Design and for Human Sustainability:

Engineering and Design

**HS-ETS1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

**HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

**HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Human Sustainability

**HS-ET 1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

**HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

**HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

**HS-ETS1-4.** Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.
WHERE TO BEGIN
To maximize student learning, we highly recommend watching *Inventing Tomorrow* in its entirety before incorporating the curriculum into your classroom.

**Here are several ways you and your students can watch the film:**
1. Go to the film website’s [Educators section](#) to see if there are any upcoming field trip screenings in your community;
2. Purchase a license to stream the film in your school [here](#);
3. Purchase a DVD [here](#) to watch the film in your classroom or with the entire school;
4. Go to a theater showing *Inventing Tomorrow*.

To learn more about the film and access the film Screening Guide and other educational content, you can go to the film’s website, [www.InventingTomorrowMovie.com](http://www.InventingTomorrowMovie.com).

**INCORPORATE THE CURRICULUM**

The Teaching Curriculum for *Inventing Tomorrow* is designed as a set of flexible lessons to fit your specific learning objectives and could include:

- Integrating each lesson independently into studies on topics such as soil filtration, air pollution, ocean habitats, mining, biodiversity loss, water quality, and human impact on natural resources.

- Integrating the film and the four lessons using this sequence:
  - **Soil:** Understanding the Soil as a Filter
  - **Air:** Innovations to Clean Our Air
  - **Oceans:** Mitigating Industrial Pollution in our Oceans
  - **Water:** Citizen Scientist Efforts to Maintain Freshwater Bodies
LESSON OVERVIEW
The loss and destruction caused by natural disasters endures for generations. Families are displaced, homes and livelihoods are often destroyed, or left in need of lengthy rebuilding, and the natural environment is greatly altered. Often the media cover the immediate human toll on a community, but pay little attention to the long-term environmental consequences left in the disaster’s wake.

In *Inventing Tomorrow*, we watch Jared Goodwin from Hilo, Hawaii research the patterns of arsenic contamination in the soil in response to the stories passed down to him from his grandparents about several local tsunamis, including one in 1960. Jared created a geographic model to track and measure the patterns of soil contamination resulting from natural disasters such as tsunamis. As city planners and state officials deliberate future zoning and expansion efforts in metropolitan areas, Jared sought to prove that his model could be an invaluable tracking tool to more accurately monitor and maintain the health and safety of the soil.

LESSON OBJECTIVES
In this lesson, students will use Jared’s story as a jumping-off point to conduct an introductory soil filtration lab and examine whether soil naturally can filter out impurities that result from events such as natural disasters. Students will:

- Learn what comprises healthy soil
- Analyze models that successfully filter contaminated soil
- Conduct an experiment to understand soil filtration
- Research models to restore contaminated soil

LENGTH
At least two, 50-minute class periods.

MATERIALS
This lesson is developed with the expectation that students will have access to the internet through a mobile device, laptop, or computer lab. If student access is limited, educators will need access to project video and links as well as print handouts linked throughout the lesson.
LESSON ACTIVITY

Step One: Connect to Hilo, Hawaii through Student Scientist Jared Goodwin
Introduce this lesson by reading this background sketch of student scientist Jared Goodwin’s ISEF Project.

“Jared passionately documents his love for his home of Hawaii through nature photography. His ISEF project studies the contamination of a local pond where arsenic was dumped by a company for nearly 30 years. Inspired by his family, who survived two major tsunamis in Hilo, he developed a new model to study tsunami debris patterns. The work is important to the community because the debris includes arsenic, and his model could potentially track arsenic disbursement into neighborhoods’ soil and water sources. He wants to use his project to motivate city and state officials to create more accurate safety measures for land use zoning.”

- Locate Hilo, Hawaii with students using Google Earth and discuss their geographic observations about Jared’s hometown.
- Jared passionately documents his love for his home of Hilo, Hawaii through nature photography. Project Jared’s photographs, several of which have been published online at National Geographic so students can get a sense of the local environment.
- Discuss what students observe about Jared’s home and his nature photographs. What observations can students offer about Jared’s relationship to his environment in Hawaii?

Step Two: Connect to Jared’s Project: Natural Disasters and Soil
1. Brainstorm with the class examples of natural disasters that have occurred in their community or that they have learned about recently. (e.g. flooding, tornadoes, ice storms, earthquakes, faulting, tsunamis, hurricanes, landslides, mudslides, wildfires, etc.)

2. After compiling a list, discuss the range of environmental issues that can arise in the wake of natural disasters. It may be helpful to offer recent examples to prompt students in their thinking.
   - The Fukushima Daiichi Nuclear Power Plant disaster was the result of the 9.1 magnitude Tohoku earthquake, which unleashed a tsunami on the coast of Japan in 2011. Nuclear contamination in the water and soil was extensive.
   - Hurricane Florence in North Carolina in 2018 caused flooding in large swaths of coastal areas along the North Carolina/South Carolina border. According to the firm Environmental Data Resources, Inc., (EDR), 236 unique sites that currently house hazardous waste or have been contaminated in the past were within the immediate path of Hurricane Florence. These include:
     - 156 Superfund/state cleanups Sites
     - 60 regulated facilities that store/treat hazardous waste
     - 24 facilities that use hazardous waste
     - 79 livestock facilities where floods potentially could release animal waste
     - 3 coal ash storage facilities
   - The 2018 wildfire season was higher in heat intensity and burn area than previous years were. The consequences of the high heat coupled with the number of fires continues to have multiple impacts on the environment including:
     - The release of higher concentrations of greenhouse gases, including carbon dioxide and other particulates into the air.
     - Charred land that is more prone to erosion and mudslides.
     - The release of particulates into nearby streams, impacting aquatic life.
With these examples in mind, ask students to think of other potential environmental consequences that can arise following a natural disaster. If students did not identify soil, introduce it as a natural filter and a central material in our ecosystem sustaining plants, animals, the natural environment, and food production. Emphasize that as the Earth’s population continues to rise, maintaining healthy soil is of paramount importance.

3. Another one of Jared’s long-term goals is to provide data for zoning officials, and communities at large, to easily identify areas where soil contamination occurred. With more accurate and concise data regarding the health of the soil, these officials can make more informed decisions at planning and zoning hearings and meetings. In this regard, Jared’s research can be applied as an environmental justice tool to prevent future development on contaminated land.

Ask students to define environmental justice using their background knowledge, and follow up by sharing the U.S. Environmental Protection Agency’s (EPA’s) definition. “Environmental justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations, and policies.”

Encourage students to explore how people in a variety of communities and nations advocate for environmental justice by exploring these websites:
- EPA: Learn About Environmental Justice
- United Nations Environment Programme and Strengthening environmental justice

Step Three: Connect to Science and Engineering Principles
Discuss in small groups these questions in relation to Jared’s journey to ISEF:
1. What questions did Jared’s project ask? What did he define as a problem?
2. In your own words, describe how Jared approached, developed, and designed his model.
3. What resources did Jared access in order to carry out his investigation?
4. What tools and resources did Jared use to evaluate and communicate his project?
5. Why are these important steps?

Step Four: Soil Filtration Lab
There are many existing lessons on soil filtration that echo the work of Jared Goodwin. Below are three recommended model lessons that can be adapted to grade level and background knowledge. It may also be instructive to review the Engineering Design Process with students to reinforce the process of STEM before undertaking either lesson.

United States Department of Agriculture: Filtration
TeachEngineering: Survive That Tsunami! Testing Model Villages in Big Waves
Scientific American: How Dirt Cleans Water
EXTENSIONS

1. Natural Disasters

Ask students to discuss why they think people continue to live in areas that are at high risk for natural disasters. Encourage students to consider the range of reasons including economic livelihood, community, climate, etc. After discussing, research the full range of natural disasters and the inventions created to mitigate their destruction. The International Red Cross and Red Crescent Association use the following terminology of natural hazards to describe the naturally occurring phenomena caused by either rapid environmental phenomena (like a tsunami), or a slow progression of events over time (like a drought).18

- Geophysical (earthquakes, landslides, tsunamis and volcanic activity)
- Hydrological (avalanches and floods)
- Climatological (extreme temperatures, drought and wildfires), meteorological (cyclones and storms/wave surges)
- Biological (disease epidemics and insect/animal plagues).19

As you imagine innovative solutions to help communities prepare for, mitigate, and respond to natural disasters, consider the following:

- What are sustainable practices that can be immediate responses to natural disasters?
- What are proactive approaches that individuals, communities, and nations can take to avoid using toxic materials altogether?
- What can be created as immediate responses to a natural disaster and what new ideas can decrease the magnitude of destruction?

2. Articles on Arsenic in Soil after Natural Disasters

Have students read one or more of these articles and write a one-page critique of the article to share in class the following day:


3. Incorporating Foldscope into your classroom

A Foldscope is a self-assembled microscope made mostly of paper developed by Manu Prakash and Jim Cybulski. Foldscopes expand access to science by offering students portable, low-cost equipment that enables them to explore the world around them. On the Microcosmos site, microcosmos.foldscope.com, students and other users from around the world can share their observations, ideas, and problems that emerge from using their Foldscopes!

Have students explore the microcosmos postings that align with Jared’s work in soil, including Arthropod Soil Biodiversity and Foldscope-DSLR Camera Hack.20
NEXTGEN STANDARDS:

HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.21

HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.22

HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.23
LESSON OVERVIEW
The issues of pollution and air contamination can be observed at local, regional, and global levels. Often, human activity and industrialization are the root causes of air pollution and produce both short-term and long-term effects on our health, the environment, and biodiversity. Consistent monitoring and accurate data collection alone do not lead to air quality improvements. Rather, air quality improvements are usually driven by policy and scientific innovations.

In Inventing Tomorrow, the team from Monterrey, Mexico observes that the pollution in their city was increasing rapidly as a result of the city’s growth. One member of the team, Jesús Alfonso Martínez Aranda, had a personal connection to this environmental issue as his uncle had died from a respiratory disease that was exacerbated by the poor air quality. And as a team Jesús, Fernando and José saw that deteriorating air quality in Monterrey was also a visible sign of climate change. With the help of Universidad Autónoma de Nuevo León, the team developed a paint that when painted on brick and activated by sunlight, is chemically designed to absorb air pollutants that contribute to climate change.

LESSON OBJECTIVES
In this lesson students will explore methods scientists and engineers employ to clean up and prevent air pollution, learn how to research air quality, and identify visible and invisible air pollutants to learn the correlation between air pollution and climate change. Students will use Jesús, Fernando and José’s story as a jumping off point to:

- Identify the main causes and sources of air pollution
- Investigate how everyday items can contribute to air quality
- Analyze real-time global Air Quality Index data
- Draw conclusions on how air quality affects human health and biodiversity

LENGTH
At least two 50-minute class periods.

MATERIALS
This lesson is developed with the expectation that students will have access the internet through a mobile device, laptop or computer lab. If student access is limited, educators will need access to project video and links as well as print handouts linked throughout the lesson.
LESSON ACTIVITY

Step One: Connect to Student Scientist Issue, Air Pollution 101

1. Have students create a K/W/L chart with the title “Air Pollution,” and complete the first two columns with the prompts, “What do you know about air pollution?” and “What do you want to know about air pollution?” At the end of this lesson, students will complete the final column as part of their assessment.

2. Have students watch this National Geographic video and read the brief overview on air pollution from their Climate 101 series and begin to add new information to their third column.

3. Have students read this background sketch of student scientists Fernando Miguel Sánchez Villalobos, Jesús Alfonso Martinez Aranda, and Jose’ Manuel Elizade Esparaza and their ISEF Project:

   “Fernando, Jesus, and José live in one of the most polluted cities in Latin America: Monterrey, Mexico. After a lifetime of riding diesel-powered public buses that exposed them to harmful pollutants, they decided to try and address local air quality as well as global warming. Several of the team members hold part-time jobs to support their families, and the whole team must ride a bus several hours to meet with their university mentor. They invented a photocatalytic paint that can remove two pollutants that contribute to global warming from the air: sulphur dioxide and titanium dioxide. The first in their families to attend university, the three friends were ecstatic to visit the United States for the first time when they attended ISEF.”

4. Identifying Greenhouse Gas Emissions (GHG)

   It is critical for students to understand that air pollution includes the output of carbon into our environment and comes from both our individual actions and our corporate and agricultural industrial system. For example, our current transportation system, how we generate electricity, heat our homes, and grow and transport our food are just a few examples of the leading contributors to the increased release of greenhouse gases into our atmosphere. The increase of greenhouse gases is affected by the behavior of individuals as well as corporations. We can modify our individual behavior, but we must rely on regulation to monitor the behavior of corporate actors. As we see in Monterrey, industrial pollution is part of the everyday lives of Fernando, Jesus, and José.

   To build important background knowledge on what constitutes air pollution, including the output of greenhouse gases, have students survey each of these websites to answer these questions:

   Questions
   - What are the primary greenhouse gases?
   - What are the primary sources of greenhouse gases?
   - What countries are the largest (and smallest) contributors of greenhouse gases?

   Websites
   - “Sources of Greenhouse Gases,” Environmental Protection Agency
   - Carbon Calculator, The Nature Conservancy
   - U.S. Energy Information Administration International Data
   - Fossil CO2 & GHG emissions of all world countries, 2017, Emissions Database for Global Atmospheric Research
   - “Agriculture’s greenhouse gases on the rise,” Food and Drug Administration of the United Nations
Step Two: Connect to the Community of Monterrey, Mexico

- Have students locate Monterrey, Mexico on Google Earth and discuss their geographic observations about Jesús, Fernando and José’s hometown.34
- Have students locate Monterrey, Mexico on the World Air Quality Index Map (AQI) and compare its air quality with the AQI from your location.35
- Have students read this brief history of Monterrey and discuss what they learned.36
- Encourage students to add new questions or information to their K/W/L chart.

Step Three: Connect to Science and Engineering Principles

Read this summary report from the Universidad Autónoma de Nuevo León on the problem of air pollution in Monterrey.37 This article is translated from Spanish so be aware of this as you read through the information. In small groups, have students discuss these questions in response to the article:

- What problems related to air pollution are identified in this article?
- What solutions are proposed in response to the air quality in Monterrey?
- What is your assessment of how this information is communicated to the public?38

Step Four: Lab on Air Pollution

There are many lessons that include labs for students to explore air pollution and examine the principles of photocatalytic paints, tiles, or lights, and highlight the kind of solution the student scientists from Monterrey were hoping to create.

Got Dirty Air? from TeachEngineering39 is a lesson that closely aligns with the work of Jesús, Fernando, and José. It is an introductory lab and builds foundational knowledge on visible air particles and their relationship to air quality.

EXTENSIONS

1. Exercises to Track Individual Carbon Footprint

Building awareness and knowledge about our individual roles in contributing to air pollution is an effective step towards prevention. Several organizations, including the Environmental Protection Agency, have created accessible tools that students can use to measure their own carbon footprint, or track how their individual everyday actions affect the environment. These organizations also offer tools for measuring the direct emissions of gases into the atmosphere.

- The Nature Conservancy Carbon Calculator40
- EPA Carbon Footprint Calculator41
- EPA FLIGHT Calculator (Facility Level Information on Greenhouse gases Tool)
- Climate Literacy & Energy Awareness Network: Calculating Your Family’s Carbon Footprint42

2. Innovations to Address Air Pollution

Students can continue to learn about innovative approaches to addressing air pollution. See this inspiring article from Harvard University’s Data-Smart City Solutions Initiative as a place to start. “How Cities are Using the Internet of Things to Map Air Quality.”43

3. Important Legal Ruling on Air Pollution:
Massachusetts v. Environmental Protection Agency

Alongside individual actions and industrial regulations, in the United States, legal rulings have also
played an important role. Have students review the 2007 United States Supreme Court ruling in *MA v. EPA*, which established which regulations the Environmental Protection Agency is required to implement.44

4. General Articles on Examining Air Pollution

United States National Library of Medicine, National Institutes of Health, "Effects of air pollution on human health and practical measures for prevention in Iran." [https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5122104/](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5122104/)


### NEXTGEN STANDARDS

- **HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

- **HS-LS2-7.** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.45

- **HS-ESS 3-4.** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.46

- **HS-ESS 2-6.** Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.47
o INSPIRED BY SHOFI LATIFA NUHA ANFARESI AND INTAN UTAMI PUTRI, BANGKA, INDONESIA.

o ISEF PROJECT: BANGKA’S TIN SEA SAND - FE3O4 AS A REMOVAL OF PB(II) IONS IN BY-PRODUCT OF TIN ORE PROCESSING (TAILING)

LESSON OVERVIEW
Tin is a relatively rare metal found in the Earth but is a crucial component of many products such as cell phones, solder, glue on circuit boards within electronics, and tin cans. Approximately one-third of all tin mined in the world comes from the islands of Bangka and neighboring Belitung. Traditionally, tin is mined underground in a way similar to iron and other ores and goes through a purification process to separate the tin from other compounds. As the demand for tin increases, more countries are resorting to ecologically devastating ways to mine the tin, such as seabed dredging which causes high levels of poisonous chemicals to be dumped back into the water, affecting all aquatic life and coral reefs.

Shofi Anfaresi and Intan Putri from Bangka, Indonesia understand the central role tin plays in the economic sustainability of their island. They also make a connection between the decrease in plankton, fish, and coral in their local waters and the legal and illegal tin mining barges off the coast. By harnessing their powers of observation and conducting personal interviews with tin miners, Shofi and Intan developed a simple but effective prototype to separate tin from the lead ions in an environmentally safe way. Knowing that tin mining is a primary source of income for members of their community, their proposed design attempted to balance environmental protection with economic sustainability.

LESSON OBJECTIVES
In this lesson, students will learn the scope of ocean mining and gain deeper knowledge on current global policy and laws regulating mining in the ocean, like the practices observed by Shofi and Intan. Students will use Shofii and Intan’s story as a jumping off point to:

- Construct an explanation of how mining from the ocean works and create an experiment that models extraction over time.
- Research the different types of mining on land and in the ocean, and compare and contrast these methods in terms of their effects on biodiversity, humans, and the environment.

LENGTH
At least two, 50-minute class periods.

MATERIALS
All handouts and supplemental content necessary for the lesson.
LESSON ACTIVITY

Step One: Connect to the Community of Bangka, Indonesia
Introduce the lesson by reading this background sketch of student scientists Shofi Anfaresi and Intan Putri ISEF Project:

“Shofi and Intan live on an island in Indonesia called Bangka, which is the world’s second-largest source of tin ore. The young women have seen legal and illegal tin mining expand to the point where the previously bright blue waters around their home have faded to brown, and they have observed the local fish and coral reefs dying. They realize that both legal and illegal mining are key to the economy of their island, but they also realize how both types of mining are contributing to the ecological degradation of the ocean which surrounds them. They develop a prototype that would filter the effluents from the dredging process, especially lead, to protect the fragile oceanic ecosystem of their island, allowing the local fish supply to flourish again.”

- Have students locate Bangka, Indonesia using Google Earth and discuss their geographic observations about Shofi’s and Intan’s hometown.
- Have students read this historical overview of the island of Bangka and discuss what they learned about the island.
- Have students share new findings and/or questions that have arisen.

Step Two: Connect to Student Scientists’ Issue, Tin Mining
Shofi and Intan are very aware of the history and the sensitive nature of their research on tin mining on land and in the oceans within their island community. “When the Dutch colonized Indonesia in the early 18th century, one of the first things they set up were the mines to exploit cassiterite, the main mineral in tin ore. Today Bangka’s economy relies almost entirely on this nonrenewable resource.” Over the decades, the detrimental effects of tin mining on the environment and on human populations has continued to grow. For example, for tin miners working the mines on land, the threats of landslides and mines collapsing have increased as the surrounding forests are cleared and the land becomes less stable. In the ocean, disposing the waste material from tin mining activities back into the water not only pollutes and compromises the water quality, but kills the surrounding coral reefs and fish populations.

Before distributing these readings, spend a moment sharing and discussing this photo-essay on tin mining in Bangka and ask students for their thoughts and observations using these prompts:

- What words describe what you see in these pictures?
- Who is doing the mining?
- What questions do you have about the tin mining process?

Organize the students into groups of four. Distribute these articles to read and discuss the questions in Step Three of the lesson.

2. EDP Sciences, ”The impact of tin mining in Bangka Belitung and its reclamation studies.” (Have students read sections 1 – 3, Introduction, Methods, Socio-economic impacts, and section 7, Conclusions.
3. The Guardian, ”Death metal: tin mining in Indonesia.”
4. Reuters, ”Indonesia’s tin islands: blessed or cursed?”
Step Three: Connect to Science and Engineering Principles
Have students cite the evidence they gather from the articles they read in Step Two to discuss the following questions:

1. What problems exist with deep sea mining, specifically with deep sea tin mining in Bangka?
2. What models, if any, have been proposed to solve the problems associated with tin mining both from an environmental and economic perspective?
3. Some of the tin mining is done by government owned companies. Does that make it less harmful? Who is holding tin mining companies accountable? Are the regulations sufficient?
4. According to a report in *The Guardian*, “Tin mining is a lucrative but destructive trade that has scarred the island’s landscape, bulldozed its farms and forests, killed off its fish stocks and coral reefs, and dented tourism to its pretty palm-lined beaches.” When an economy is so reliant on one industry such as tin mining, what solutions are possible? Or in other words, what can be done differently?
5. Is the information on tin mining in Bangka reliable? Why or why not? How do we know the reporting is accurate?

After analyzing the socio-economic and environmental issues associated with tin mining in Bangka, view the photo-essay "The Tin Mines of Bangka Island." Have students choose one image that stands out to them and share their visual analysis observations in pairs. If helpful, students can use these prompts:
- What do you see in the image?
- What questions do you have about the image?
- Using your background knowledge, what interpretations can you offer about the image?

Step Four: Lab on Mining and Extraction
Transition from this visual analysis exercise focused on tin mining in Bangka to having students learn through a simulated lab exercise about the environmental impact of human reliance on nonrenewable resources. See "Fossil Fuels: Mining for Chocolate."

After discussing the Wrap-Up questions at the end of the lab, ask students to reflect upon the connection to this simulation and to tin mining in Bangka.

EXTENSIONS
1. Tin as a “Conflict Mineral”
To add a further dimension to this lab, there are numerous studies on tin as a “conflict mineral,” and the exploitation of people working to mine tin. Offering students an opportunity to discuss the political, economic, and social challenges of mining nonrenewable resources and the politics of the supply chain can bring another dimension to the issue. See "Mining for smartphones: the true cost of tin."

2. Analyzing Data on Tin Mining
NEXTGEN STANDARDS

**HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

**HS-ESS3-1.** Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

**HS-ETS1-4.** Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.
LESSON OVERVIEW
Bangalore is the capital of the Indian state of Karnataka in the southern central part of India. Bangalore is also landlocked, yet at one time it was known as the city of 1,000 lakes. Today Bangalore, renamed Bengaluru in 2006, is most often referred to as “the Silicon Valley” of India. With a population of 12.476 million, Bengaluru is a megacity confronting many environmental challenges because of this density.

On February 17, 2017 a center spot in Bellandur Lake, the largest lake in Bengaluru, caught fire and burned for 12 hours. This was not the first time the lake caught fire, but it was a turning point for student scientist Sahithi Pingali. Sahithi knew that data can play an influential role in shifting perspectives and changing policy and soon discovered that very little data existed on the water quality of Bellandur Lake. In response, Sahithi created an app enabling anyone to take water samples, upload the data, and open-source the information for all to access, with the goal of influencing public officials to remediate the pollution.

LESSON OBJECTIVES
In this lesson students will use Sahithi’s example of a student citizen scientist to practice the full scope and sequence of the Scientific Method and the Engineering Design Process with an environmental problem in their own community. Students will:

- Reflect upon the importance of STEM in their lives
- Explore the definition and role of a student scientist
- Identify an environmental problem in their community to solve
- Research the problem
- Propose possible solutions to the problem
- Select one solution and outline a plan in writing

If time allows in class or when students show initiative, these objectives are recommended:

- Create and build a prototype
- Test and evaluate the prototype with peer and/or mentor review. The mentor could be their teacher, or as we saw in the film, mentors were research scientists.
- Redesign the prototype and enter it into a local science fair
LENGTH
Two, 50-minute class periods to begin the prototype process. This lesson can also serve as the spark for a full semester or year-long STEM project.

MATERIALS
All handouts and supplemental content necessary for the lesson.

LESSON ACTIVITY

Step One: Connect to STEM
Before beginning this lesson, have students reflect in writing on the role of science, technology, engineering, and math in their everyday lives. For example, what types of technology do they use every day? How does it help? When do they use any aspect of science in their lives? What inventions or innovations save them time? Are there inventions that they imagine creating? Why?

Take a moment for students to share their reflections in pairs, small groups, or as a class.

Step Two: Connect to the Community of Bangalore/Bengaluru, India
Transition to students reading this description of Sahithi Pingali's ISEF project as background.

“After seeing the lake behind her home burst into flames, Sahithi decided to combine her love for science and social activist skills to create an innovative method for citizens to gather and share data about the severe water pollution in Bangalore. In order to protect her local lakes, she is developing technological solutions to amplify citizen voices in an effort to stop the dumping of raw sewage into the watershed.”

- Have students locate Bengaluru, India on Google Earth and have them discuss their observations about Sahithi’s hometown.
- Read this historical overview of Bengaluru and discuss what information from this reading is relevant to Sahithi’s research.

Step Three: Connect to Student Scientist Issue and Science and Engineering Principles
Share with students these facts excerpted from the UNESCO International Initiative on Water Quality Water Quality Report.

Water Quality Facts:
- One in nine people worldwide uses drinking water from unimproved and unsafe sources.
- 2.4 billion people live without access to improved sanitation facilities.
- Lack of sanitation is one of the most significant forms of water pollution.
- 90% of sewage in developing countries is discharged untreated directly into water bodies.
- Every day 2 million tonnes of sewage and other effluents drain into the world’s water.
- Industry discharges an estimated 300-400 megatonnes of waste into water bodies every year.
Non-point source pollution from agriculture and urban areas often greatly increases the total pollutant load together with industrial point source pollution.

A reduction of about one-third of global biodiversity is estimated to be a consequence of the degradation of freshwater ecosystems mainly due to pollution of water resources and aquatic ecosystems.

Re-use of wastewater in agriculture is important for livelihoods but is associated with serious health risks.

Have students do a close reading of this article: "City of burning lakes: experts fear Bangalore will be uninhabitable by 2025" and discuss these questions as a class or in small groups:

- What are the key environmental problems in Bangalore/Bengaluru?
- What problems with the lakes have developed over time, and what are the causes of those problems?
- What solutions have been proposed?
- What policies or programs have been implemented to improve the conditions of the lakes?
- How do scientists and citizens know that these programs are effective?

Step Four: Solving Environmental Issues in Your Community

Explain to students that, like Sahithi, they also will be identifying an environmental issue in their community that they wish to solve. They should not be intimidated by the scope or scale of the issue as this assignment will be about imagining how STEM can be applied to solve pressing environmental issues.

1. Begin by watching the introductory video on the Engineering Design Process website and clarifying any of the students questions.

2. Transition to discussing the core steps to begin a STEM project using the TeachEngineering model found on their website. We have also excerpted the steps and included them in Appendix I.

3. As you explain and discuss these steps, remind students that this will be the process that each of them will be following as they identify an environmental issue in their own community.

4. After explaining and discussing the design process, organize students into small groups to begin brainstorming the environmental issue they would like to solve.
EXTENSIONS

1. Have students explore models and activities to inspire their own citizen scientist project.
   - Common Sense Media
   - Scientific American

2. Have students read different approaches to monitoring water quality.
   - Great Lakes Restoration and Great Lakes Initiative
   - National Oceanic and Atmospheric Administration, "Ocean Pollution"
   - UNESCO Resources: "International Initiative on Water Quality" and "The Global Water Challenge"
   - Blog: "All Water is Connected: Citizen Scientists Monitor Virginia Water Quality"

3. Encourage students to work with Google Tour Builder and connect Sahithi to the three other communities: Hilo, Hawaii; Monterrey, Mexico; and Bangka, Indonesia. After building the tour, have students discuss in small groups the shared physical, environmental, and geographic connections they see between each place, along with the noticeable differences. Are these connections important? Why or why not?

4. Incorporating Foldscope into your classroom
   A Foldscope is a self-assembled microscope made mostly of paper developed by Manu Prakash and Jim Cybulski. Foldscopes expand access to science by offering students portable, low-cost equipment that enables them to explore the world around them. On the Microcosmos site, www.microcosmos.foldscope.com, students and other users from around the world can share their observations, ideas, and problems that emerge from using their Foldscopes!

   Have students explore the microcosmos postings that align with Sahithi’s work in freshwater bodies, including:
   - Visit to Ropar Wetlands
   - #IRTC - Public Awareness Programme on Quality Drinking Water Using Foldscope

NEXTGEN STANDARDS

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.
NEXT STEPS
I will start this letter by being honest. Previous generations, including mine, have not left the world in great condition for you. You are growing up during an unprecedented moment in history, facing a range of environmental issues that threaten the precious and fragile biosphere of planet Earth. That’s the bad news. The good news is that there ARE solutions to halt and even reverse this phenomenon, and young people are coming up with some of the best approaches.

My goal in making *Inventing Tomorrow* was to tell a story about what it’s like to grow up on Earth today, from the perspective of teenagers who are asking the right questions about environmental issues they face in their own backyard. It’s natural after becoming educated on these problems to start to feel overwhelmed or paralyzed, which can lead to apathy or just denying reality. The students in our film feel like they can’t accept doing nothing, so they decide to take action using STEM. Some are creating science projects to gather adequate data on the problem to encourage local officials to get involved. Some are devising solutions to actually stop or reverse the problem, and some are combining their scientific work with activism to increase public pressure on local authorities. What connects all the students is their courage to look at the world around them, be honest about what they see, and commit to action in order to create change.

When I first attended the International Science and Engineering Fair in 2016, I was most inspired by the students I met who had a personal investment in their research, and that became the guiding principle for who I cast in the film. I didn’t care who won or lost at the science fair, that isn’t the point of the story. I was more interested in why the students were doing their research, and how they were going about it. You’ll notice that all the students in the film have a bigger goal than winning a prize—they want their science projects to save the land where they live and the communities who live there. Exemplifying all the qualities we look for in leaders, they have vision and purpose, and they’re focused on something bigger than themselves. At the same time, they’re still just teenagers, confronted with all the insecurities and challenges teens face in the real world.

Recently I was showing the film to a theater filled with students along with one of the subjects in the film, Sahithi Pingali. One of the students asked her, “What if I don’t care about the environment?” Sahithi answered, “That’s ok, maybe you don’t care. But you might care about your own health. And if you want to drink clean water, or breathe clean air then you need to know that’s connected to the environment. If you want to be healthy, you need the environment to be healthy too.”

It’s my hope after watching the film that you can brainstorm with other students, your teachers and your families about how you can live on our planet in a way that supports a healthy environment. If the youth scientists in the movie inspire you, think about how you can contribute to creating a healthy planet, in whatever way suits you. That could be a science project where you gather data or test a solution, supporting conservation efforts, starting a club at school, or writing about an issue where you live. The point is doing something because if we all are engaged and active that’s how we create change. Based on what I’ve seen, I have deep faith that your generation will do a better job of mine at valuing the fragile ecosystem that we call home.
Blueshift is a team of education specialists with backgrounds in social impact work. The team recognizes and builds on the power of documentary film in reaching broad audiences to spark energy for deep and lasting social change. The team works with filmmakers, photographers and writers to develop innovative educational strategies, experiences, tools and resources that bring stories off the screen and into viewers’ lives.

We would like to thank Sarah Rivera, Science/STEM Teacher/Tech Coach, and Perry High School in Ohio, for their advice and support in creating this curriculum.

Learn more at www.BlueshiftEducation.com
RESOURCES FOR FURTHER LEARNING

It is exciting to imagine all the creative and innovative solutions *Inventing Tomorrow* will inspire in classrooms around the world. But don’t stop with the film and the lessons. That is just the beginning!

Here are some amazing resources and organizations listed on the [Student Science: A Resource of the Society for Science & the Public](http://www.societyforscience.org) website that are great places to learn more.

**Where to Begin:**

*Environmental Stewardship and Conservation Organizations*
- CLEANET: Climate Literacy & Energy Awareness Network
- Environmental Defense Fund
- Jane Goodall’s Roots & Shoots
- National Wildlife Federation’s Eco-Schools
- Natural Resources Defense Council
- Sierra Club
- The Climate Reality Project
- The Edible Schoolyard Project
- The Nature Conservancy
- Union of Concerned Scientists

*Science Fair Projects*
- Great Science Projects
- Internet Public Library – Science Fair Project Guide - A resource guide providing a variety of excellent web resources.
- Intel ISEF Resources - Useful resources not only for Intel ISEF but for all science fairs.
- Mosaic - An online archive of articles published in the National Science Foundation’s flagship magazine from 1970 to 1992. A background resource for students, teachers, and others in need of a reliable reference for current research.
- Sparticl - A new web and mobile service for teens that collects the best internet resources in STEM. Sparticl was created by National Productions division of Twin Cities Public Television.

**Additional Interesting Science-Focused Educational Resources**
- The Archimedes Initiative - An effort formed to promote science literacy and increase the number of scientists and engineers in the United States.
- Computer Science Online: Educational Resources, Degrees, and Career Tracks
- Intel Education Page - Intel’s listing of education resources for students and teachers.
- The National Science Digital Library - An online library for those interested in education and research in science, technology, engineering, and mathematics.
- USA Science & Engineering Festival - An official partner of the inaugural USA Science & Engineering Festival held in Washington, D.C. in 2010 and the most recent Festival in 2014, which more than 325,000 attended.
- Zooniverse: Participate in citizen science projects where anyone can be part of a larger project and learn to collect data.
Engineering Design Process, Excerpted from TeachEngineering

The overarching themes of the engineering design process are teamwork and design. Encourage students to work together to brainstorm new ideas, apply science and math concepts, test prototypes and analyze data—and aim for creativity and practicality in their solutions. The design process applies to problems big and small—global, local and personal.

Ask: Identify the Need and Constraints
Engineers ask critical questions about what they want to create, whether it be a skyscraper, amusement park ride, bicycle or smartphone. These questions include:

- What is the problem to solve?
- What do we want to design?
- Who is it for?
- What do we want to accomplish?
- What are the project requirements?
- What is our budget?
- What are the limitations?
- What is our goal?

Research the Problem
This includes talking to people from many different backgrounds and specialties to assist with researching what products or solutions already exist, or what technologies might be adaptable to your needs.

Imagine: Develop Possible Solutions
You work with a team to brainstorm ideas and develop as many solutions as possible. This is the time to encourage wild ideas and defer judgment! Build on the ideas of others! Stay focused on the topic, and have one conversation at a time! Remember: good design is all about teamwork! Help students understand the brainstorming guidelines by using the TE handout and two sizes of classroom posters.

Plan: Select a Promising Solution
For many teams this is the hardest step! Revisit the needs, constraints and research from the earlier steps, compare your best ideas, select one solution and make a plan to move forward with it.

Create: Build a Prototype
Building a prototype makes your ideas real! These early versions of the design solution help your team verify whether the design meets the original challenge objectives. Push yourself for creativity, imagination and excellence in design.

Test and Evaluate Prototype
Does it work? Does it solve the need? Communicate the results and get feedback. Analyze and talk about what works, what doesn’t and what could be improved.

Improve: Redesign as Needed
Discuss how you could improve your solution. Make revisions. Draw new designs. Revise and re-do your design to make your product the best it can be. And then, REPEAT!
The majority of life on Earth is dependent upon six critical elements: hydrogen (H), carbon (C), nitrogen (N), phosphorus (P), oxygen (O), and sulfur (S) that pass through, and are transformed by, soil organisms (the soil biota). The process of biogeochemical cycling is defined as the transformation and cycling of elements between non-living (abiotic) and living (biotic) matter across land, air, and water interfaces (Madsen 2008). Biogeochemical processes are dependent upon the biota in the soil or pedosphere, the outermost layer of the Earth that is composed of soil and subject to soil formation processes. It exists at the interface of the lithosphere (rock), atmosphere (air), hydrosphere (water), and biosphere (living matter).”

Today Monterrey is the third largest metropolitan area in Mexico, with over 4 million people.
71. https://www.google.com/earth/
72. https://www.britannica.com/place/Bangalore-India
77. https://www.teachengineering.org/k12engineering/designprocess
81. https://www.noaa.gov/resource-collections/ocean-pollution
82. https://en.unesco.org/waterquality-IIWQ/activities-projects
86. https://www.nextgenscience.org/pe/hs-ets1-3-engineering-design
Fishbowl Films is a full service entertainment company whose primary focus is on developing and producing projects for film and television. The company’s mission is to deliver the highest quality of entertainment to the marketplace in order to find each project’s maximum audience, engaging them in the fullest possible sense, whether it be a daring, thought-provoking independent feature film, a richly told one-hour television drama, a laugh-out-loud comedy, or a consciousness-Shifting documentary film. With over 30 combined years of hard work and experience in the entertainment and new media industries, we believe our solid foundation of production, development, and marketing experience coupled with Fishbowl Films’ talent for discovering new voices establish us as a powerful player in the entertainment world.

Screening Guide developed and written by Blueshift Education.