The Big Book of STEM Classroom Activities:

125+ Challenges and Team Designs

by
Harry T. Roman

Author Harry Roman is a regular ITEEA contributor and author of the long-time "Classroom Challenge" feature in *Technology and Engineering Teacher*. As a retired engineer and inventor, Harry likes teaching teachers, students, and school leaders about STEM and its applicability.

To support the important work of ITEEA's Foundation, Harry is permitting this publication to be downloaded at no cost to all—but asks that anyone who downloads consider making a donation to the ITEEA Foundation.

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Introduction

While a research project manager for a Fortune 500 company for 37 years, I had the pleasure of working with teachers and students from all over my home state of New Jersey. After an early retirement, I continue to work with local teachers and students, write and publish classroom resource books, and publish numerous articles and journal-quality papers in a variety of educational forums. ITEEA is one of my most valuable venues to interact with teachers. I never get tired of designing activities for teachers and students. I guess it is in my DNA. My wife claims I was a teacher in a former life or will be one in my next. She may be right.

This publication follows and extends upon my recent ITEEA book, *100+ Activities to Bring STEM to Life for Classrooms and Student Project Teams*. It includes a special section on Thomas Edison and related activities for teachers to use.

Edison was my boyhood hero. I became an engineer and inventor after reading about him in the fourth grade. That hero worship fire still burns strong today, as I have the pleasure of lecturing regularly at the Thomas Edison National Historical Park [TENHP] site in West Orange, NJ and consult and advise at the Edison Innovation Foundation in Newark, NJ. The organization raises money and develops educational materials in support of TENHP. I have the dream job of showing teachers, students, and educators how Edison invented the modern world and created what we know today as STEM education.

Also, at the end of this book are five (5) big bonus team activities I have used many times in schools and discussed often in my articles and presentations. These bonus activities will take some prep time by the teacher but will yield fun results and keen insights to student creativity and problem solving.

Finally, I have included some math challenges to use in the classroom, as so many students today are math averse. The examples I have selected are very relevant to a STEM type of education—practical and relevant to the modern world.

Enjoy!

Harry Roman

Activities

In the following pages are a variety of classroom activities across a range of technical subject areas you can use to creatively engage your students. You are certainly free to embellish these suggested activities and make them as intense as your classroom dictates. Also, feel free to add more of your own activities from your readings, studies, and accumulated experiences.

Engineering

- Identify famous male and female engineers, inventors, and entrepreneurs who contributed significantly to the world. Briefly outline their accomplishments and how these changed the world.

- Compare and contrast the methods and techniques used by engineers and architects to solve problems. What things stand out in either profession?

- Materials science is crucial to engineering—how and why materials behave the way they do normally and under stress. How might nanotechnologies change the field of materials science? How about 3D printing?

- What kinds of concerns would engineers have when building Elon Musk's hyper train, specifically regarding:
  - Foundations/construction?
  - Vibration?
  - Power needs?
  - Retrieving stalled trains?
  - Passenger safety?
  - Other?

- Encourage your students to look around their homes and identify where engineers may have had a hand in designing common things found there. Make lists and discuss in class.

- Contact a nearby engineering college and invite some students to visit the class to discuss what is being learned by today's engineers, and why. If this is not geographically possible, perhaps it can be done via electronic means or through a webinar prepared by the college students.

- If possible, take a small group of students to an engineering school to see engineering labs and projects and learn more about what kinds of problems they are solving.

- Construct a timeline showing the great engineering achievements in our nation since its formal founding. Are there identifiable technologies that were massively applied at certain times in the nation's history?

- Identify the mechanical and stress points on large wind turbines. Identify such points on the:
  - o Blades
  - o Hub
  - o Gear box/nacelle
  - o Tower
  - o Foundation

  What types of engineering have gone into hardening these areas for long hours of operation in all kinds of weather? Discuss how wind turbine blades are derived from helicopter blade technology.

- What kinds of engineering concerns go into creating heavy-duty lubricants for use in engines? The field of lubrication is known as tribology. How did it progress from the original use of well-head-derived products to synthetic lubricants? Can plants be a source of lubricants?

- Study the science, technology, and engineering of soaps and cleaners. Examine how chemistry influences the performance of soaps and cleaners. What were the first cleaners and detergents? Can simple cleaners be made from plants and other natural products? How was soap originally discovered and used?

- Study the science, technology, and engineering of paints. When did paints first come into large-scale use for surfaces and selected items? How did the colors for the original paints come about? How are paints tested for their application and durability?

- If there are students in the class who have parents who are engineers, perhaps those parents might be able to visit the class to discuss what engineers do. Is there a teacher in the district who was previously an engineer who might be able to chat with the class?

- Engineers are already creating microminiature sensors, which some have termed "smart dust." These devices can be dispersed throughout materials or the environment to monitor and sense important parameters. Where do your students think this smart dust should be deployed and why? Are there precautions that should be taken to make sure this dust is not harmful now or in the future?

- Research some of the engineering societies that engineers join and participate in. What benefits do engineers obtain from belonging to professional societies? Can you contact some and examine their offerings—maybe through the internet, or even by snail mail? Do teachers have professional societies, too? What and how do they benefit from membership?

- What is the average annual salary for engineers in the U.S.? Look at some typical engineering categories like electrical engineer, mechanical engineer, nuclear engineer, etc. Compare this to other professions. What do engineers' salaries tell you?

- Take a look at the profession of engineering in the United States versus other countries or continents such as India, Europe, Japan, and others. Is the profession viewed similarly in all countries, or is it more esteemed in other countries? Why might this be so?

- Describe the similarities and differences between engineers and scientists and how they approach problem solving.

Entrepreneurship

- Try to identify 20 entrepreneurs in your state and discuss their accomplishments. Perhaps each student in class could identify one and write a short brief about their work. Perhaps one or more could be invited to class to discuss their experiences.

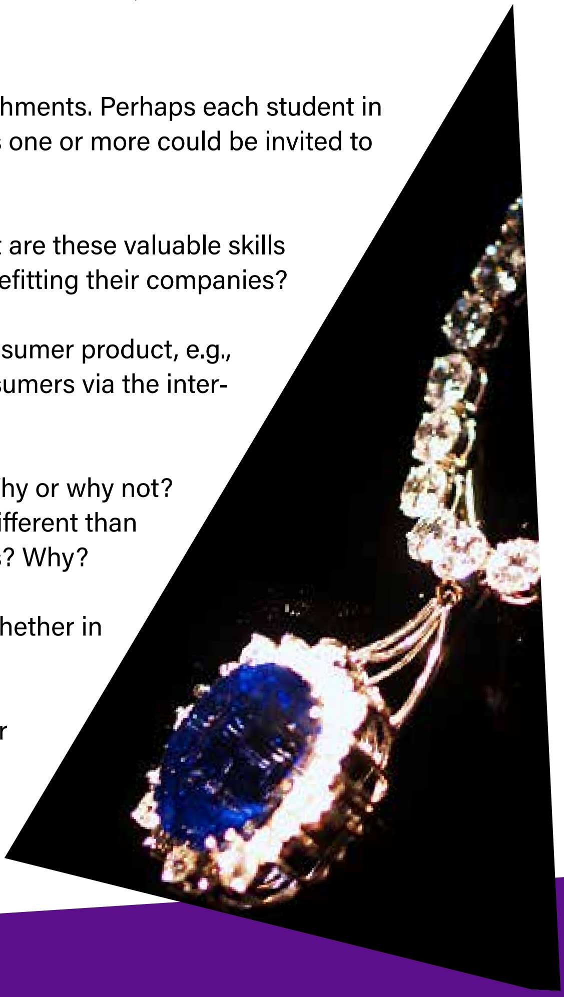
- Research why companies want to hire employees with STEM skills. What are these valuable skills that companies want and need? How do they see such skills greatly benefitting their companies?

- You have just started a new company that will make a certain kind of consumer product, e.g., jewelry. This company will make, display, and sell jewelry directly to consumers via the internet. What kinds of people with what skills will you seek to hire and why?

- Do companies favor employees who are creative or have high grades? Why or why not? How can companies tell the difference? Are new high-tech companies different than older companies and industries in what they look for in hiring employees? Why?

- Identify new products that could be developed to promote baby safety whether in the crib, while traveling, or playing.

- A project manager is typically in charge of bringing a project online, on or under budget, and within design constraints. In a technical company, should an engineer or someone without technical training be the project manager? Look at the panorama of issues to be dealt with and defend your comments. How do today's high-tech companies select project managers?



- Identify and list the characteristics of entrepreneurs. Look for typical characteristics like: learn from failure, persistent, etc. Lots of information is out there, so encourage students to forage far and wide on the internet.

- You are starting a new business involving "the smart house." In what different ways would you like to make a house smart?
  - o Use of electrical energy
  - o Use of heat
  - o Able to diagnose home malfunctions and call for help
  - o Safety of occupants [sensing carbon monoxide, toxins, etc.]
  - o Other?

  Which option(s) would you select and why? How would they affect cost? How difficult would they be to accomplish?

- Elon Musk is involved in building his hyperloop train system to move people and freight very quickly along dedicated rights-of-way. Could this right-of-way be used for other purposes as well?

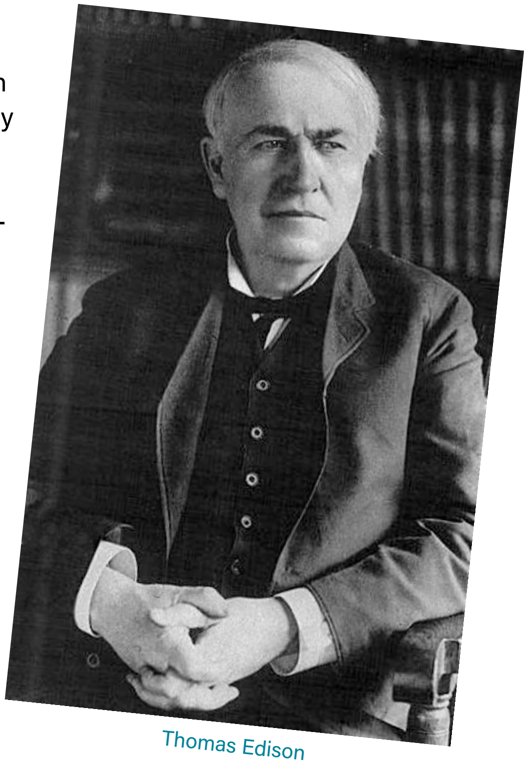
- On the popular TV show *Shark Tank*, contestants are often asked if they have a patent on their new products and ideas. Why do you think patents are important?

- Thomas Edison was both an inventor and entrepreneur, which is uncommon. In many cases the inventor and entrepreneur can be different persons, with widely different skill sets. How do your students feel about this dichotomy?

- In modern business, senior leaders draw important distinctions between "management" and "leadership." Can you articulate the difference between these two bedrock skills of the business world? Do teachers manage or lead the class?

- Research the internet and new business start-ups to determine the number of new businesses started by women, specifically:
  - o History of total women start-ups within the last five years.
  - o Percentage of women start-ups versus men start-ups.
  - o If possible, break figures down by state or region.
  - o Kinds of businesses women started.
  - o Other?

- Discuss entrepreneurs as agents of change, social disruptors, and how they reshape the social fabric. Quote technology-driven change in the last decade to support your viewpoints.



Thomas Edison

STEM

- Explain how STEM skills contribute to the nation's economy.

- Conduct a survey of students in your school. Who likes STEM courses and why; and who does not like STEM courses and why? Do you have any suggestions about making STEM more relevant to students?

- How are technology education and STEM courses similar, and perhaps different?

- Why is it important to include the “Arts” in STEM courses? Explain this in light of the process of turning raw ideas into practical products.

- Can you name great artists who were STEM-like in their thinking (e.g., Dante, da Vinci, etc.)?

- Should STEM courses include more detailed discussions about entrepreneurship and how to start a company? Explain.

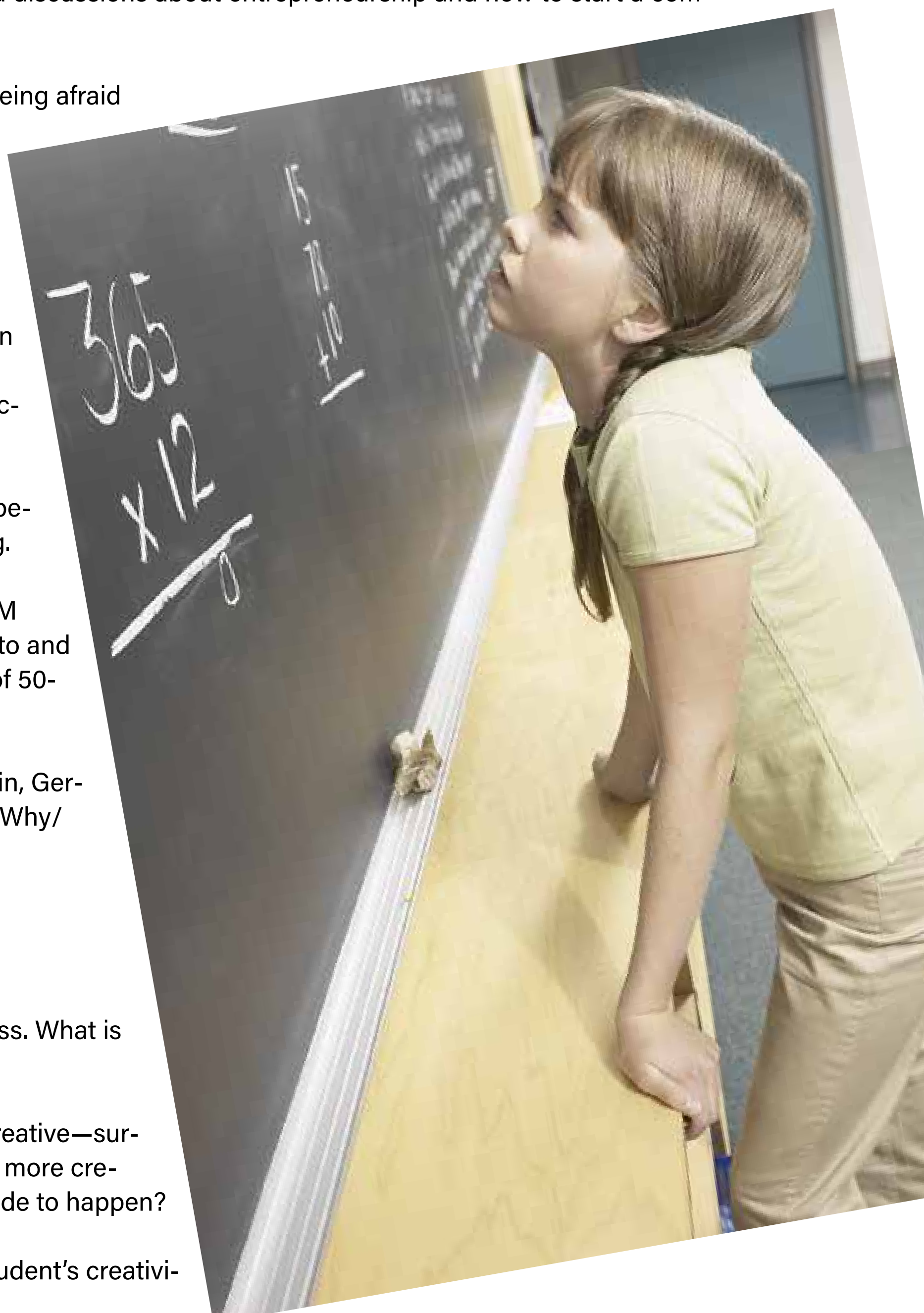
- Many students suffer from “math-phobia”: being afraid of, and intimidated by, math. But math is very important in understanding and solving problems and design challenges. How would students suggest “math-phobia” be addressed in the classroom?

- Identify the various infrastructures our nation makes use of and discuss why they are important to our society. What future infrastructures might we see?

- Describe the difference (and relationships) between science, technology, and engineering.

- Why is a “makerspace” so important in STEM classes? What makes makerspaces similar to and different from the old-school shop classes of 50-60 years ago?

- Is STEM taught the same way in Great Britain, Germany, Canada, Japan, and other countries? Why/why not?



Creativity

- Explore the subject of creativity with the class. What is it and why is it so important?

- How do students know what makes them creative—survey the class. Can students be made to feel more creative; and how do they think this can be made to happen?

- If there were a spot on a report card for a student’s creativity, how would this “grade” be determined?

- Have each student discuss and document their personal creativity in a log/diary:
  - o What things make them feel creative?
  - o How do they set a mood for creativity?
  - o What kills creativity or makes it hard to take advantage of it?
  - o What times of day are they most creative?

  Express the findings in graphic format like pie charts or another format.

- Discuss why questions are important to solving problems and in promoting creativity. Should students study how to ask questions?

- Have students start with their room at home as it is today and plan to upgrade or modify it. Students are to discuss this with their parents and develop a model or diorama of their expected result.

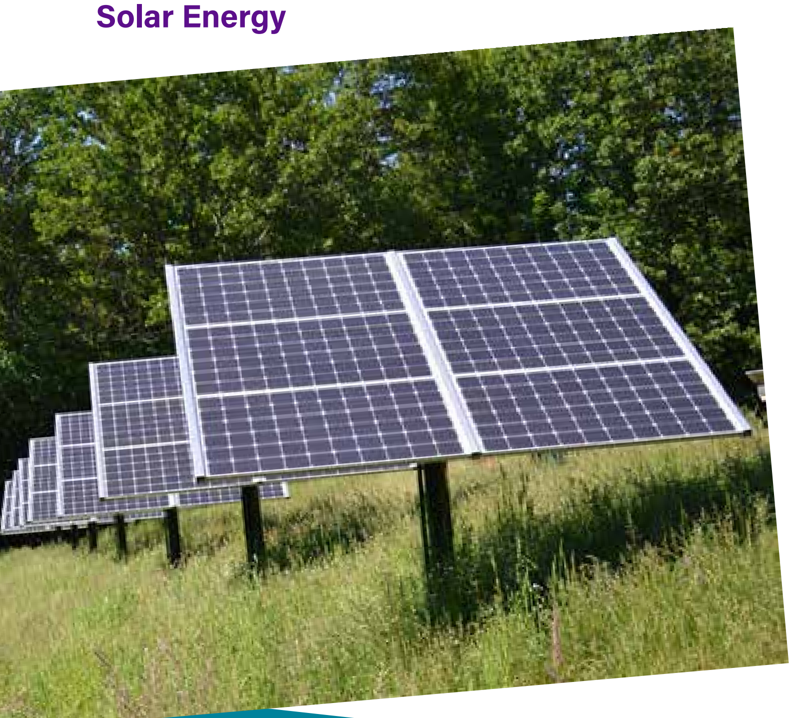
- When military members train, do soldiers promote creative thinking and behaviors? Why?

- Invite inventors into the classroom to explain how they use creativity techniques to develop solutions to problems. Either singly or in a panel discussion setting, allow students to learn firsthand from men and women who invent as a living or as a vital part of their jobs as engineers, technologists, scientists, etc.

- Discuss whether creativity is the province of the young or can occur at any age. What sources of evidence were students able to find and analyze about this?

- Are "gut instincts" and "hunches" valid when designing something or solving problems? How about "heuristics" that have been learned and gathered over time? How did the great cathedral builders create such huge structures without detailed math simulations and models?

Solar Energy



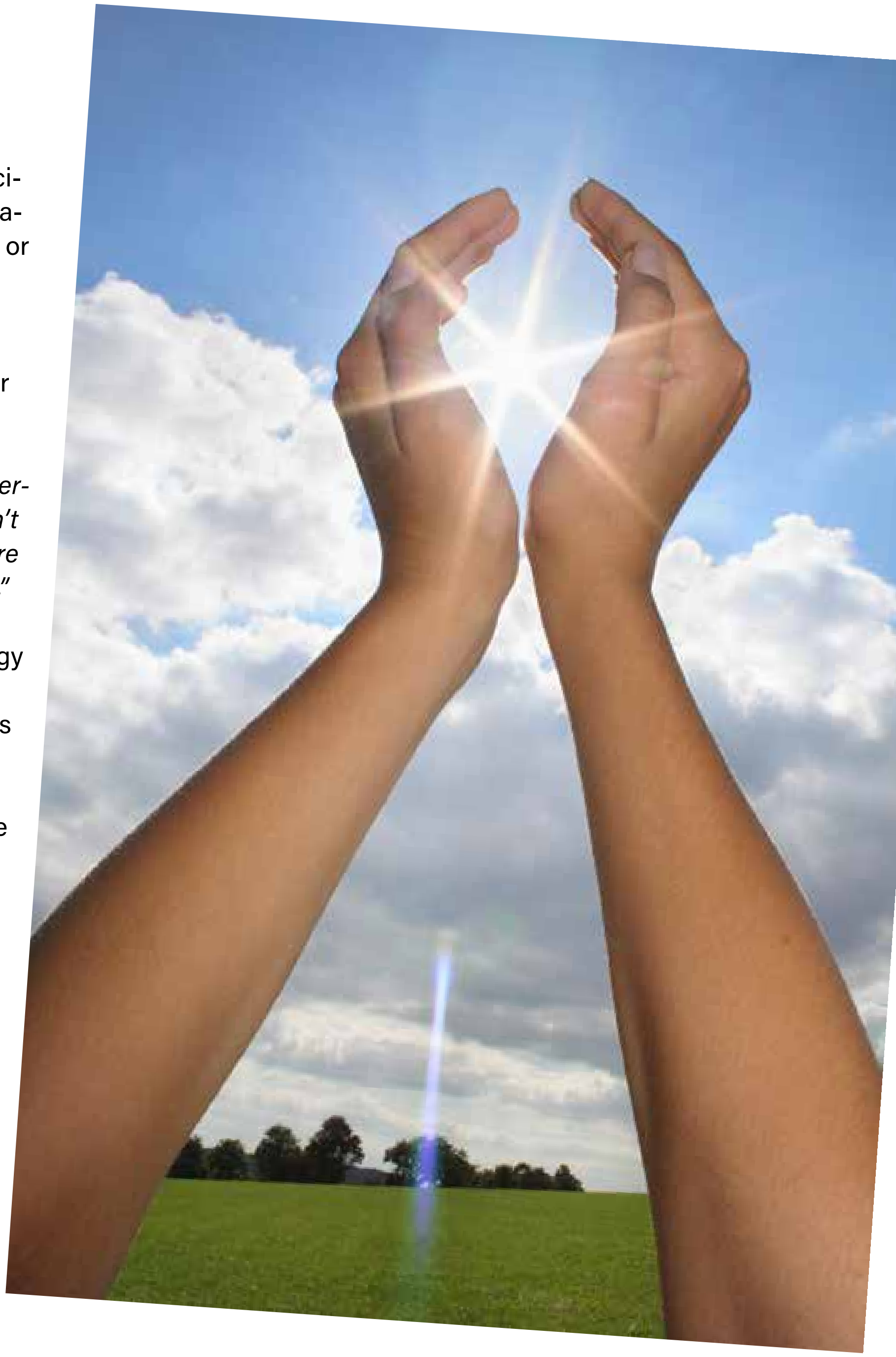
- What are the primary ways the sun's energy can be used here on earth? There are generally considered to be six (6) ways this can be accomplished—so please include a brief paragraph about each option.

- Solar electric applications are a prominent application that includes both solar cell panels and/or large wind machines. Research how these two applications might be used in your state or region.

- What is the concept of solar rights, and how can this become a problem in cities and congested building areas?

- Solar cells can often be made of exotic materials that contain heavy metals. During a building fire, solar cells on roofs can burn or heat and outgas these potentially dangerous materials. How could these concerns be mitigated?

- Many energy advocates today believe a solar-nuclear energy mix may be the best for the country. Discuss this in class and examine this option from the standpoints of:
  - o Cleanliness of the air.
  - o Climate change.
  - o Customer and grid reliability.
  - o Other?



- The major occupational safety concerns associated with wind machines and solar cell installations are accidental falls. Can this be reduced or eliminated? How?

- Here is an incredible quote from Thomas Edison circa 1910-1915 about the potential of solar energy,

  > *"I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that. I wish I had more years left."*

  Imagine what he was thinking about the energy sources available to him at that time, such as coal, oil, wood. What do you think his thoughts might have been?

- Have the students describe and conduct some simple experiments that could be used to show how one can capture the heat from the sun's light.

- What has been the timeline of the development of solar cells from 1954 at Bell Labs to present-day applications? Note key developments along the timeline and track the costs of the solar cells to the present time.

- Large offshore wind machines are gaining acceptance where wind speeds are greater than on land and big clusters of machines may be aggregated to produce larger amounts of power. Identify the environmental, safety, and installation concerns a wind power company might have in developing such a wind farm.

- Are solar cell systems more economic if placed on:
  - o Single-family home roofs?
  - o Large roof structures (like stores and warehouses)?
  - o On ground-mounted arrays?
  - o Floating structures?
  - o Other locations?

  Foster discussion among students to stimulate thinking. Could there be other ways to install solar cell panels (e.g., on walls? On window awnings? Other?)

- What if you coated large wind turbine blades with solar cells? How would this increase electricity production from the turbines? What potential engineering problems might arise from this?

- Try this calculation out. How much surface area is needed to generate 100 MW of power from solar cells or wind turbines? Try comparing this to the same 100 MW generated from coal, oil, natural gas, or nuclear fuel sources. Make it consistent and assume the surface areas are based on land areas needed to support each source. (Hint: this will require some internet researching and math.)

- Wind machines are spaced apart, so the operation of each does not interfere with that of others. What is the generally accepted spacing of large, on-land wind machines; and what factors govern this spacing of machines? Is the spacing of water-based wind machines similar or different?

- If you wish to build a solar concentrating system to achieve very high temperatures to melt and fuse metals and other activities, what concerns would solar engineers have regarding: ambient solar levels; location of the plant; and environmental conditions?

Electric Vehicles

- What are reasonable travel distances for electric vehicles, as compared to hybrid vehicles?

- How long will a vehicle battery pack last before needing replacement?

- What were the original attempts at electric vehicle design and builds? Who were the pioneers?

- Why did gasoline vehicles surge past electric vehicles back in the 1920s? What were the motivations and consumer wants that propelled this?

- How would electric vehicle batteries be recycled at end of life? What kinds of concerns would engineers have in this recycling process?

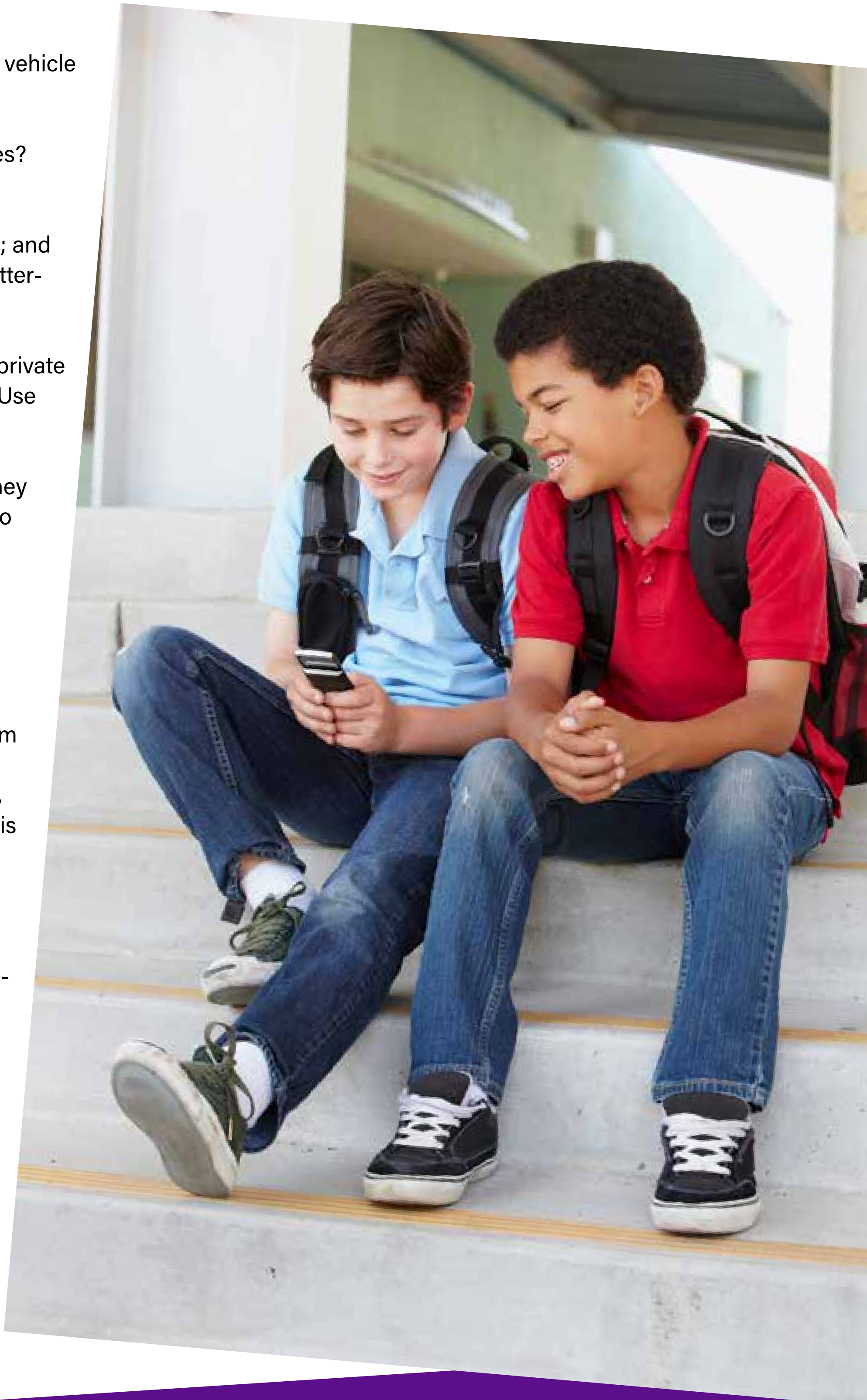
- What is the average cost of an electric vehicle versus a hybrid? Operating costs?

- How would you market electric vehicles? What benefits would you emphasize?

- What is the charging time for batteries; and how does quick charging affect the batteries?

- Who is likely to buy electric vehicles—private drivers or fleet vehicle owners? Why? Use existing data to support your position.

- In the early days of electric vehicles, they were known as "women's cars." Why do you think this was so?



School

- Design a museum about your school. What would you include in this museum and why? Who would you contact for ideas, and perhaps some memorabilia, to include? Where would you locate this museum and why?

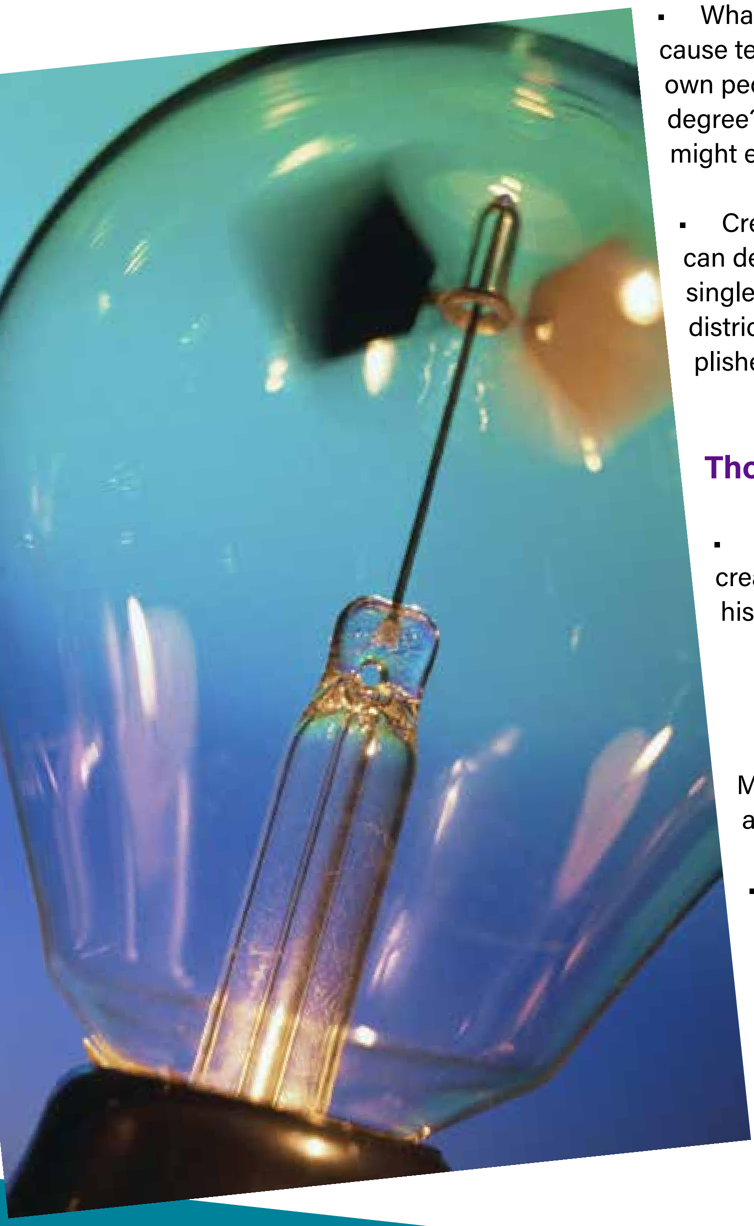
- If your school needed more space and could not build above ground nearby, can you envision an underground component of the school? What might this below-ground portion of the school look like, and what would you include in terms of classrooms, exhibits, learning labs, and other facilities?

- What if each day in school involved recitation in the morning (study of content) followed by afternoons where what was studied in the mornings was applied in real-world applications. What would be the pros and cons of this type of educational paradigm? Do you have another educational technique you think would be worthy of consideration? Defend your ideas!

- Design an archway for your school that captures the beauty and essence of your school's history, culture, and accomplishments.

- Design a school amphitheater for the showing of quality lectures, webinars, and educational events. What would the amphitheater contain besides seating capacity and 5G communications capability? Perhaps a cardboard model of the amphitheater should be made as well.

- Should schools reintroduce more hands-on learning like the wood shop and home economics classes of yesteryear? Why/why not?



- What might happen if it was no longer necessary to go to college because technology made it possible for private companies to educate their own people and grant some sort of nationally accepted and recognized degree? Examine the social, institutional, cultural, and other concerns this might engender.

- Create a school-wide invention contest where participating students can design new things and compete for prizes. Grow this idea from a single classroom event to a full-blown, school-wide event later. Invite district and government officials to see what the students have accomplished.

Thomas Edison

- Which was Edison's greatest invention? Study the many inventions created by Edison and engage in a debate about the pros and cons of his introduced technologies. How did his technologies impact the:
    - Economy?
    - Society?
    - Environment?
    - Progress?

  Make sure your students marshal their arguments as quantitatively as possible.

- What a great way to promote and practice communications—host a website newsletter! Have your students develop a website accessible to the entire school and perhaps other schools within your district. Students can write articles about how Edison changed the world and is influencing us still today. All things Edison can be explored and discussed, along with publicly available photos of the great inventor and his work.

- Contrast Edison and Elon Musk to determine how and why they solve problems and their insights into new technologies. Both men are/were heavily interested in rechargeable storage batteries and built large battery-manufacturing facilities. Why?

- Edison had a defined process for moving from raw ideas to commercial products for sale, which became very important to industry. Identify the steps in this process and how he accomplished it. Compare this process to the engineering design process students learn in STEM classes now.

- Why was Edison's West Orange Labs invention factory so seminal? Why was his creation of commercial R&D labs so important?

- Edison made tremendous strides in teaching the country and companies about the power of team-based problem solving. Have students team up to solve a problem or design challenge, and then evaluate the team experience, such as:
  - What they liked or disliked about working with others.
  - How it affected their creativity.
  - What they learned from others with different ideas and opinions.
  - Suggestions for future team activities.
  - Other?

- Edison filed the first electronic patent after discovering what would become known as the Edison Effect. This work later leads to the production of vacuum tubes, radio, and television. What follows after that? Use a timeline to depict the advances that today give us hand-held devices. This is a wonderful example of how 125 years of innovation can morph an original invention into something else.

- In the 13 years between 1876 and 1889, Edison made great discoveries that enabled new products and whole new industries. What were these, and how did they change the world?

- Examine how Edison's achievements are incorporated within a modern hand-held device like a mobile phone or tablet. How can your students realize and identify Edison's presence?

Edison Manufacturing Company phonograph at the Museum of American Heritage.
Credit: Daniel Penfield on Wikimedia Commons.


Edison telephone. *Credit: Wikimedia Commons, Runner1616. https://commons.wikimedia.org/wiki/File:Edison_telephone.JPG*

- Edison's greatest inventions involved telegraphy, telephony, recorded sound, motion pictures, electric utility systems and lighting, and R&D labs. How are most of these related? (Hint: Edison was profoundly hearing challenged.)

- Thomas Edison demonstrated the charging of electric vehicles in his home garage in 1908 (and possibly as early as 1905 in other buildings). Why did it take so long for Edison's championing of electric vehicles to really start to catch on?

- Edison had three great facilities, all in New Jersey: Newark, Menlo Park, and West Orange. What did he do and discover at each of these places; and why were the West Orange labs called "legendary?"

- How did Edison change Alexander Graham Bell's telephone—radically improving it and making it much more practical?

- Edison was famous for putting his corporate library inside his main office at West Orange. Why do you think he did that?

- Thomas Edison had 1093 U.S. Patents and several hundred more overseas. What are patents, and why are they so important? What is their impact on starting a new business or gaining and holding key market positions? What are the different kinds of patents, and who can obtain a patent?

- Two of Edison's inventions—the phonograph and motion pictures—had an incredible effect on the public, and still do to this day. What did Edison think the original uses of these inventions might be? Research this. What do you think his reasoning was, and why?

- Edison's first great foray into invention involved telegraphy. Examine some of his early patents after telegraphy to see if the influence of telegraphy can be seen in those patents.

- Compare and contrast Edison and Einstein: how they viewed the world, solved problems, and contributed to humanity.

- Why were Edison's laboratory notebooks so important to his operations?

Math Challenges

Here are five math challenges to get the students thinking about how relevant math is to everyday life. Try to work in some additional math challenges. It is very important for students to "become friends with math," as employers will expect their staff to be facile with math and its application to their business.

- How much rain water [in gallons] falls on a square mile of land? This is very important for hydraulic and water-supply engineers to know when planning how much drinking water a community will need and whether they will need storage or be able to purchase additional water from another source.
- What is the difference between electrical energy and power? Illustrate this by comparing two common appliances like a hair dryer and a TV set and how long they are operating. Compare energy and power to a hydroelectric dam.
- A water tower is 100 feet above ground level; and about 5 feet above ground level is a faucet. What is the pressure of the water in pounds per square inch (psi) at that point? What is the water pressure at a home located down a hill at an elevation of 25 feet below the ground level of the tower?
- In New York City the amount of daily solar radiation is 3.9 kWh/square meter/day. If you have a 300-squarefoot solar system on the roof that can convert 15% of the sunlight it receives into electricity, how much energy (kWh) will the system collect during a full year of operation?
- The water heater in your home heats the incoming cold water to a preset temperature for your comfort. If the incoming cold water is 70 degrees F, and you want to raise that to 110 degrees F, how much natural gas would you need to burn? (Hint: a typical water heater can be 80% efficient in burning natural gas.)

Team Activities

- What kinds of tracking devices can students develop for their safety and security while in school—especially during emergency situations like fire, armed intrusions, natural disasters, etc.? How would such devices, systems, networks operate? Do companies already have such systems, and could they be adapted to schools? Could there be social, legal, or governmental impacts associated with these systems? Do the same exercise for tracking devices for senior citizens in institutions where they are being cared for.

- Have a team of students design a miniature golf course with easy-to-assemble golf holes and hazards. Determine the best place to store this activity for use several times during the school year to raise money.

- Design a return mission to the moon to establish a manufacturing plant there that will ship finished products back to earth. Place special attention on:
  - What will be made there and why.
  - Time needed to build the facility.
  - Crew skills needed there.
  - Rotational time of workers.
  - Cost of moon base.
  - Social, legal, governmental impacts (and others) associated with the base.

- Design an underground aspect to an existing or new modern science museum. What would this aspect show or represent, and why? Museums have telescopes and planetariums, why not an underground exploration and educational venue?

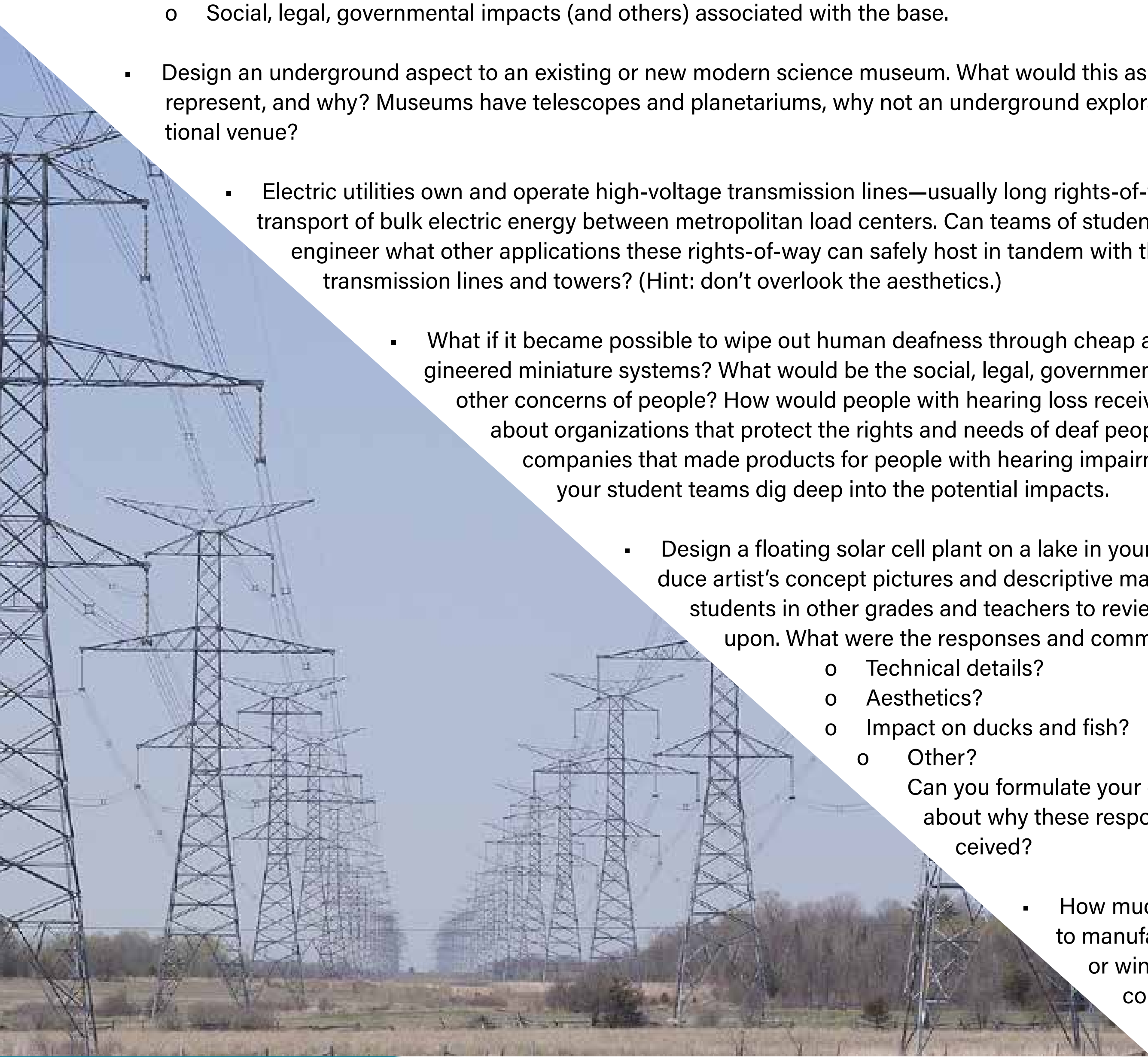
- Electric utilities own and operate high-voltage transmission lines—usually long rights-of-way for the transport of bulk electric energy between metropolitan load centers. Can teams of students imagine and engineer what other applications these rights-of-way can safely host in tandem with the high-voltage transmission lines and towers? (Hint: don't overlook the aesthetics.)

- What if it became possible to wipe out human deafness through cheap and effective engineered miniature systems? What would be the social, legal, governmental, cultural, and other concerns of people? How would people with hearing loss receive this? What about organizations that protect the rights and needs of deaf people? How about companies that made products for people with hearing impairments? Have your student teams dig deep into the potential impacts.

- Design a floating solar cell plant on a lake in your local park. Produce artist's concept pictures and descriptive materials for fellow students in other grades and teachers to review and comment upon. What were the responses and comments about:
  - Technical details?
  - Aesthetics?
  - Impact on ducks and fish?
  - Other?

  Can you formulate your own comments about why these responses were received?

- How much energy is used to manufacture solar cells or wind machines compared to the



energy they can capture (net energy analysis over their useful life)? This may require a bit of research and some math, so help the students through this exercise. Try this one out too—can solar cells be recycled? How? Put a team on this complex subject and see how they do!

- Design a robot that can move through a pipe and perform the following functions:
  - Videotape the inside.
  - Check for pipe corrosion and thinning.
  - Remove blockages.
  - Coat the inside with a protective liner.

- Design a swarm of drones that could be launched following severe storms or natural disasters and be used to establish a communications network to reach out to survivors and rescue teams.

- Design a car that contains instrumentation suites that can be used to detect various environmental and toxic parameters in the air. It could then coordinate that collected information with other such cars (a car network) and share to a central processing point so safety and emergency announcements can be issued if necessary.

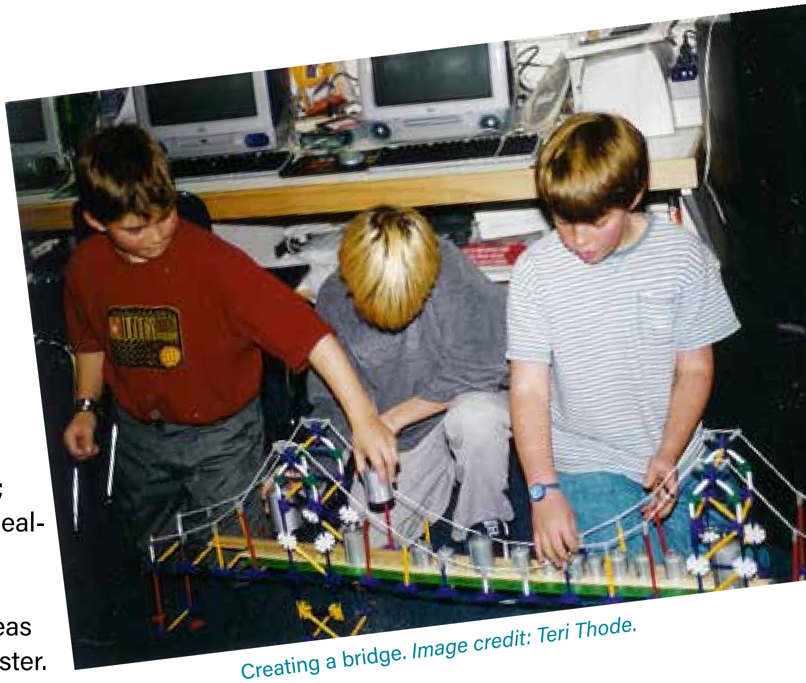
- Start with an abandoned building in town and have a team of students identify possible uses for it. Select the most promising application and develop a detailed plan for transforming the building. Involve your local town council or supervisors to comment on the work of the students.

- In your local town or county parks, host student teams to create bridges and/or spanning structures over portions of lakes, ponds, streams, or creeks to enhance the visitor experience and understanding of the environment.

- Write a children's book on:
  - Robots.
  - Solar energy.
  - Nuclear power.
  - Electric vehicles.

- Design classrooms made from old shipping containers; equip them with solar power and stack them in an appealing way to help promote learning.

- Design air-delivered emergency shelters for remote areas and underdeveloped countries following a natural disaster.



Creating a bridge. *Image credit: Teri Thode.*

- Design flood-proof homes and retrofit kits to existing homes.

Big Bonus Team Activities

#1. Super Robot Design Challenge With Role Playing

Introduction

Over the years I have found that role playing is a great source of creativity—as is the subject of robots. In this chapter, I use a favorite design challenge of mine, repeated at many schools in a wide variety of grades, including with teachers at in-service seminars. It never fails to create energy. Give it a try in your classroom. This challenge has appeared in a variety of my articles and books.

The Challenge

The subject of robots is powerfully interesting for students. I learned this early when students and teachers visited the robot lab in which I designed and built mobile robots. As a result of these visits, a favorite design challenge emerged. Students (and teachers) who have taken on this challenge have designed robots to:

- Assist handicapped individuals.
- Fight fires.
- Clean up hazardous wastes.
- Provide security.

The creativity I have seen displayed in such exercises is nothing short of incredible. I have successfully used this same basic exercise with students as young as Grade 3.

Let's have some robot fun and at the same time use this challenge to integrate the curriculum—showing the different real-world design constraints that come into play. This entire design challenge can be accomplished in two hours. First, arrange the students into teams of five (5). Let each team pick a team name and choose a captain.

Next, assign a design challenge to invent a robot to perform a certain task. You can choose from among those mentioned above or choose another. It is important that all teams use the same challenge so they can learn from each other.

During this design challenge, each member of the team assumes a specific role during the invention process:

1. The marketing person—whose job it is to represent the user of the robot. If the challenge is to design a robot to assist a person with a disability, then our marketing team member should act on behalf of the "customer," making sure their needs are being met by the invention/design.

2. The economist—whose job it is to be concerned with how much the robot will cost and how it can be made at the most reasonable price possible.

3. The engineer—whose job it is to look at the technical details of the robot design and the kinds of materials that can be used in its construction and production.

4. The activist—whose job it is to look after the legal, safety, and environmental impacts that such a design may present.

5. The team captain—whose job it is to make sure that the team members are communicating in a give-and-take manner and considering the different aspects of the challenge. The team captain will lead the oral presentation by the team at the end of the two-hour challenge.

At the conclusion of the challenge, each team will make an oral presentation, during which they can talk about:

- Their robot design.
- Why they chose to design it a particular way.
- What it will cost to build.
- Its special features and benefits.

The team captain will lead the oral presentation, and it is suggested that all team members have a chance to say a few things about the robot design. Each team should have 5-10 minutes for their presentation.

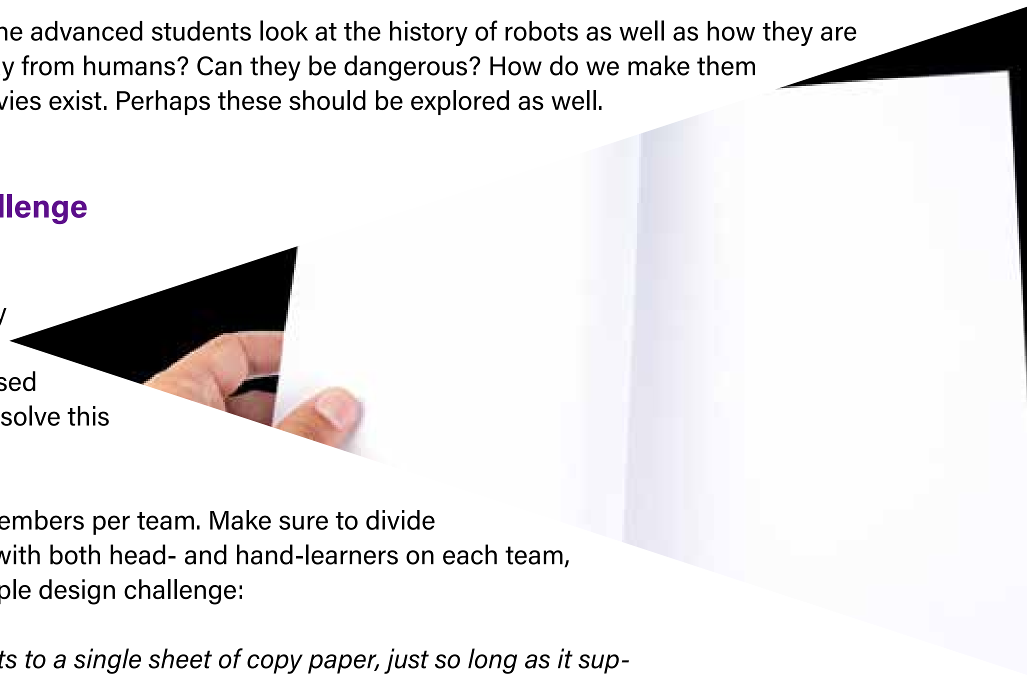
I have found it useful over the years to "prime the pump" for this exercise by showing a short video dealing with robots to get students thinking along this line. Perhaps provide something to read a day or two before the challenge that discusses robots and the many applications in which they are used. The challenge can also be the conclusion to several lesson plans that have discussed robots.

For older, more advanced students, this exercise can be expanded to include a written team report component and team interactions that span as much as a week's time. During this expanded effort, each team member can write a section of the team report, with the team captain organizing the report and introducing it as well as writing a conclusions section.

This design challenge is a microcosm of the workplace, where team efforts are common. This is basically the new product design process in industry, with experts from around the company lending their knowledge and expertise to the effort. This makes the role-playing component especially important.

Something as complex as building a robot requires many different job skills and disciplines. Time should be allotted to discussion of this topic, letting the students identify the skills.

A related aspect of this exercise is to have the advanced students look at the history of robots as well as how they are viewed by society. Will robots take jobs away from humans? Can they be dangerous? How do we make them safe? Many very good robot stories and movies exist. Perhaps these should be explored as well.



#2. The Single Sheet of Paper Challenge

Background

I have used this wonderfully creative activity countless times—having given it to both students and teachers. Each time I'm surprised by how different teams of students see and solve this problem.

This team activity is best served with 4-5 members per team. Make sure to divide your students into equally balanced teams with both head- and hand-learners on each team, so they can learn from each other. It's a simple design challenge:

> *"Each team may do whatever it wants to a single sheet of copy paper, just so long as it supports their history book one (1) inch off the table."*

Have some scissors, a little tape, and things like rulers, pencils, etc. available. It will be OK for them to use a little tape, but not excessive amounts. The key is to get the paper to do the work (no taping of the book-supporting structure to the table!).

The Fun Begins

Teams usually begin by trying to manipulate the paper to increase its strength. There is not a great deal of deductive reasoning at this point, as most teams are anxious to crumple, fold, twist, and bend paper to get the challenge underway. The teams tend to first run on instinct and fly by the seat of their pants. In almost all cases, students ignore the "1-inch" criteria—but for now that is okay.

Generally, students end up crumpling the paper and trying to see if that will let them support the book. Walk around with a ruler doling out the bad news about that pesky "1-inch" request. Most students are more concerned with simply supporting the book, rather than meeting the "1-inch" constraint. Students also often fold the paper into a long strip, taping it into a cylindrical form, and then attempt to balance the book on this shell of paper. Again, our trusty ruler reveals a continued lack of respect for the "1-inch" criteria. Some students at this stage will try to add more books to their paper foundation to see how many books they can support. The urge to compete is great—but keep pushing them to meet that "1-inch" criteria.

A team or two may, just by luck, hold a book off the table at 1 inch or maybe a bit more. They may also become adept at balancing about 4-8 books on a shell of paper. Here is where they resort to the tape to make the paper immune to crumpling. Eventually they fail at maybe 10-12 books. At this point, call a breather and inject some tips about thinking the problem through:

> *"All teams—listen up: that 1-inch request is important. You need to address it. Many of you are having trouble balancing the books on your single-paper support. Think about how you can make that book more stable. How are things supported in the real world? What makes a table so strong?"*

Trying Harder

At this point some lights go on and students realize they can cut the single sheet of paper to make supports for the corners of their book. Some teams also choose a triad design as well, using three supports instead of four.

Away we go again with the urge to pile books up. Alas, the "1-inch" request still gets little serious play. Teams are back to crumpling and folding paper more furiously. Now they might, again by luck, get 12-18 books off the table, but they are far from the "1-inch" criteria. Frustration starts to set in, as teams bend the rules, trying to force a solution. Lots of tape will be used in a vain effort to make the paper very strong. Some students will try using more than 1 sheet of paper.

It's now time for a little talk on engineering and a common material all around us. By tearing a piece of cardboard, students see why the cardboard is so strong. The inside is a rolled and glued column-like structure. Discuss how this type of construction provides great strength—emphasizing that the columns of paper that run through the sheets of cardboard perform the same function as columns in a building.

> *"Engineers have built cardboard structures so strong, they can hold up battle tanks. Surely, this class can design some paper structure that can hold up some books ... 1 inch off the table."*

Now focus hard on the "1-inch" criteria. This is where engineers start—with the specifications about exactly what is needed. The "1 inch" is what gets the planning process started, because planning comes before building anything. In fact, more than 50% of any project is analysis and planning. The rest is straightforward. But here in class, it seems to be all building and no planning.

Soon the teams are experimenting with columns and eventually they begin constructing columns from 1-inch strips of paper they measure and cut from a single sheet of paper. As they learn how to make the columns nice and tight and seal them with a little tape, the number of books they can support radically increases—while they meet the 1-inch criteria!

Flushed with success, the kids now scramble for books and, if they don't get over-anxious and load them up carefully, there is the potential for something like 25+ books nicely piled up and still exactly 1 inch off the table.

Use the floor at this point for the column test as it is much easier to stack the books that way. Desks can wobble under the weight of the books.

I have seen piles over 40 books in height and one as large as 52. With each history book estimated at 5 pounds, this is an estimated 200 pounds supported on paper columns!

Some Final Words

This exercise drives the following points home:

1. The key to success is in the details and the specifications given about what the solution must satisfy.
2. Those specification details drive the design challenge, and hence the analysis and planning for a successful project.
3. We all want to "do" the challenge and get caught up in the excitement. The right thing is to step back and first understand the problem.
4. Jumping around, trying one thing and then another, just wastes time and creates frustration.
5. Real creativity starts with understanding exactly what the specifications are and innovating around them.

This is an exercise where hand-learners can often shine, able to see solutions before their book-learner counterparts. Have fun with this activity and remember that the key is in the details and that 1-inch specification—and have plenty of books on hand!

In one class, we ran out of books, and team members resorted to placing students on top of the book piles they had already created—and the little columns of paper took the weight! Be prepared, as this challenge generates all sorts of enthusiasm and competition.

#3 What's a Red Brick?

A Team Challenge

Here is an interesting challenge I like to give to classes of all ages, including college students. I once gave it to 40 teachers in an in-service seminar class on invention. It's really all about structured idea generation and about getting teams of students to think before they start trying to solve a problem challenge.

"Okay class, I want you to break into teams of 4-5 people. Our challenge today is a simple one. I need you to generate ideas for how we can use red bricks. I have a friend whose red-brick-making factory has made too many red bricks, and he needs some new markets for his oversupply. Your challenge in the next 15-20 minutes is to generate some new application ideas for my friend to think about. Let's begin to list our raw ideas now!"

Students will undoubtedly start massively dumping raw ideas to paper and make lists of how they would use red bricks. Over the years I have seen lots of interesting ideas, some of which include:

- Decorative walls.
- Driveway pavers.
- Planters.
- Toilet tank volume reducers (to save water).
- Hull ballast for ships.
- Artillery projectiles.
- Artificial reefs.

This is a very brief list of the many applications I typically see, but it simply boils down to capturing what happens to pop into the minds of team members while they are engaged in generating ideas. The students generally are not structuring their thinking, because if they did, they would generate even more ideas.

Structured Thinking

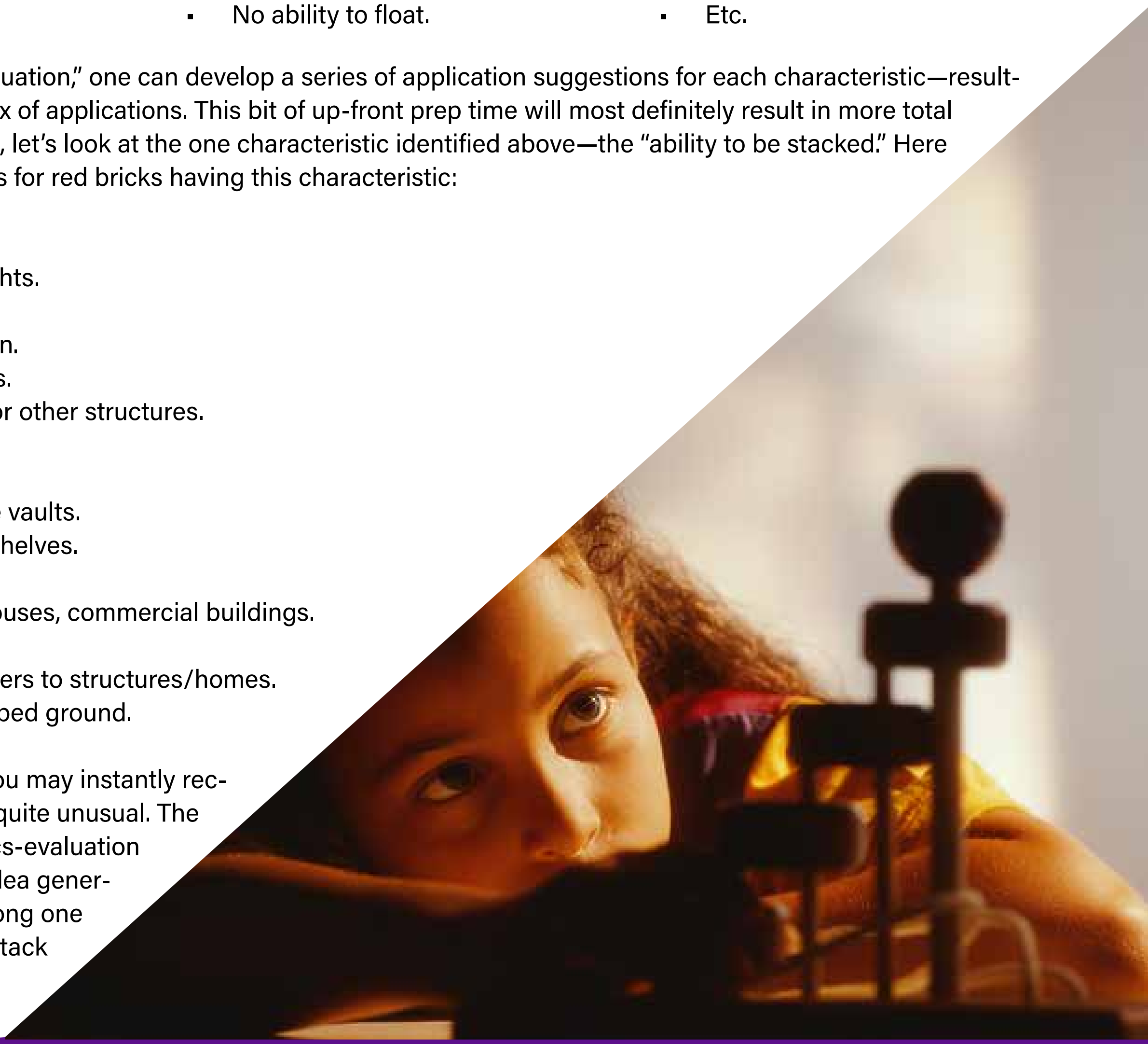
By structured thinking, I mean don't worry so much about what you can dream up for how to use red bricks—first determine the characteristics of the red brick. If we do that, we find that red bricks have:

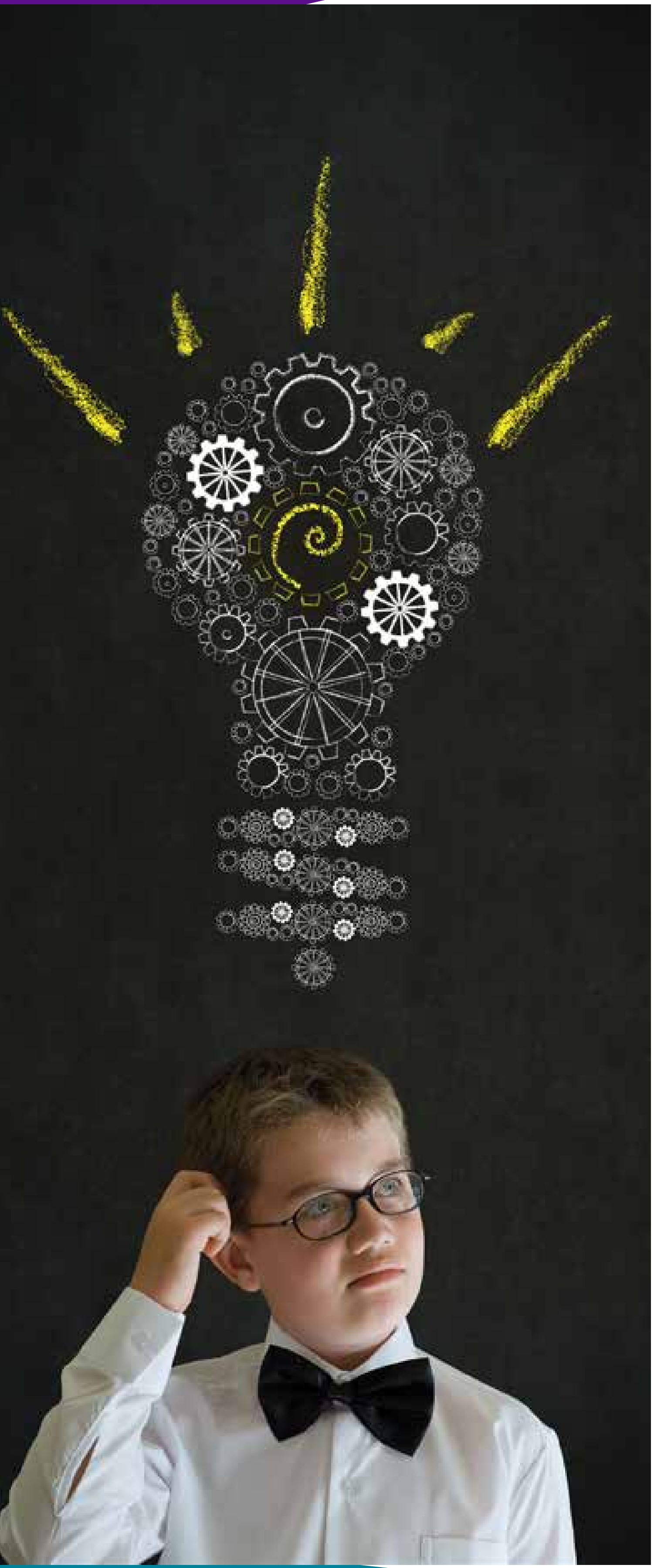
- Uniform shape.
- Uniform size.
- Color.
- Known density.
- Known weight.
- Known volume.
- Ability to be stacked.
- Survivability underwater—will not melt or dissolve.
- No ability to float.
- Resistance to fire damage.
- Impact resistance.
- High durability and long life.
- Huge compressive strength.
- Etc.

After this "characteristics evaluation," one can develop a series of application suggestions for each characteristic—resulting in a broad and deep matrix of applications. This bit of up-front prep time will most definitely result in more total ideas generated. For instance, let's look at the one characteristic identified above—the "ability to be stacked." Here are some specific applications for red bricks having this characteristic:

- Building walls.
- Building foundations.
- Elevator counterweights.
- Planters-potters.
- Pillars for construction.
- Raised amphitheaters.
- Steps into buildings or other structures.
- Pools for fountains.
- Swimming pools.
- Underground storage vaults.
- Free-standing book shelves.
- Ballast for ships.
- Room partitions in houses, commercial buildings.
- Privacy barriers.
- Wind protection barriers to structures/homes.
- Soil stabilizers on sloped ground.

Some of these applications you may instantly recognize, and some may seem quite unusual. The point is that the characteristics-evaluation orders thinking so that new idea generation can be focused deep along one line of reasoning—"ability to stack the bricks." This kind of idea





generation can be duplicated for each identified characteristic and will result in many more ideas generated by your students—a broad and deep compilation of ideas.

Putting it Into Perspective

This example is illustrative of how we as humans think. Think about what happens in kindergarten when young children are allowed to play with wooden blocks, that old standard activity we all remember. The first thing energetic children do is build something with the blocks. Their young minds "apply" the blocks, gaining satisfaction with making something.

They do not necessarily theorize about the blocks or organize them by characteristics. This kind of logical analysis comes later via their teachers. First, they are encouraged to explore and be creative. Our minds are always looking first to create, even as adults. By the way, this exercise is exactly what the legendary Dick and Jane readers did. They used a see-and-say method to engage the natural enthusiasm of children, allowing them to have quick success at reading. The teachers then filled in the gaps with word pronunciation, meaning, spelling, and, when done right, with phonics as well. The theory and formalized process of reading came after the empirical success. The characteristics-evaluation of the red bricks is no different. We naturally resort to "application" at the outset when confronted with something new. It is a basic human reaction. By applying the red brick, we gain familiarity and success with it. Organization and structured thinking take us the rest of the way, by hypercharging our thinking and creativity as well. Is all this not reminiscent of that wonderful story *Rocket Boys*, later made into the movie, *October Sky*?

In the business world of project managers and supervisors, 70-80% of any project challenge is spent in planning and analysis. Here we bound the problem, ask critical questions, and fully understand what it is we are trying to accomplish. After that, the rest is execution. Planning and organization skills are very important. One cannot afford to waste time and resources.

Here is another example of something I do with students and teachers that reinforces this type of thinking. I throw a ping-pong ball down a long tube and allow students to use anything they want to get the ball out—except turning the tube upside down. Many students try tape and even gum on the end of long sticks or use two sticks to wedge the ball out. Some have even tried to vacuum the ball out. The real answer is to think about the characteristics of the ball, and when one realizes that it floats, simply pour water into the tube to bring it to the top.

When you do the red-brick challenge with your classes, look for students who try to reshape the paradigm. These creative individuals may launch into out-of-the-box thinking to bypass restrictions in order to increase application potential. They might say:

- Why does the brick have to be red?
- Can it be another color?
- Can it be made of something other than stone/cement?
- Can't we change its size—make bigger and smaller versions?

These young and gifted iconoclasts are valuable paradigm smashers, redefining the world to gain advantage. Very often, the best inventions result from twisting conventions and looking at the problem from a new perspective. That's how Post It® Notes were created. The weak glue that holds the notes was really a failed glue that was supposed to be much stronger. The failure was turned into a huge market success.

Successful inventions and new businesses don't have to incorporate wholly new materials or sophisticated concepts. They can be a redefinition of what already exists. Creative teens do this all the time when they find new ways to wear clothes—men's ties for belts or headbands; multiple layers of colored pullover shirts; torn pants legs on jeans; a florescent choker necklace. It's all about looking at the characteristics of something and exploiting those traits that offer the best opportunities.

Turn students loose and have fun. Try the red-brick exercise.

#4 Design an Educational Math Card Game

Objective:
Middle school students will design an educational math card game for use by lower grades.

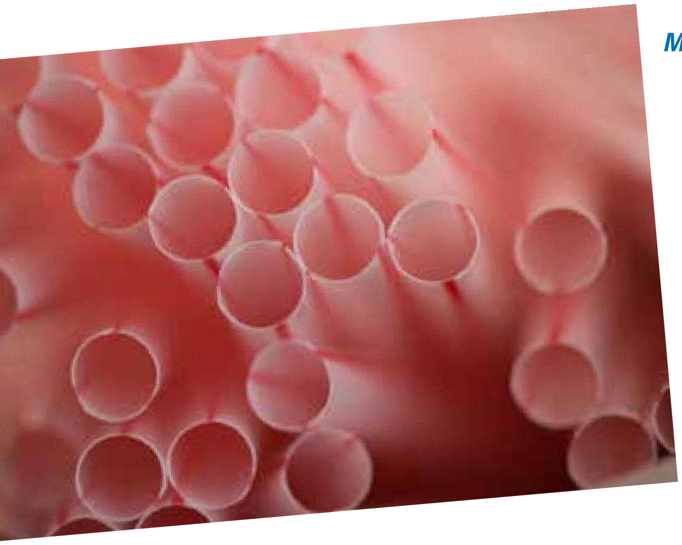
Planning:
Determine what math concepts the teams will design based on what seems to be needed for the lower grades, e.g., fractions, multiplication, geometry, etc. Why design this type of educational math card game? Survey lower-grade students and teachers for ideas and justifications. Consult other sources for guidance.

Process:

- Check to make sure the game being considered is not like something already on the market.
- Develop the strategies the games will employ.
- What kinds of cards will be used?
- Will dice be used to instill a chance component?
- Will special playing cards also be used as a chance element of the game?
- Design the game, cards, and other components.
- Write the rules for play, with diagrams and drawings.
- Can a teacher use all or part of the card game in the classroom, so all students can play?
- Give the game a catchy title or slogan!

#5 Straw Tower Build Project

The goal here is to engage student teams to construct straw towers as tall as they can, and to support a golf ball near the top for at least 10 seconds. This is a high-energy activity. Teachers should be prepared for intense team competition!



Materials Needed

Soda straws – preferably not the ones with a bendable tip, as the straws will be used to support weight (if that is all that is available, you can cut off that part). Each team will get an initial complement of 25 straws but may draw an additional 25 straws if needed during their build.

Pipe cleaners – each team gets a total allocation of 25 pipe cleaners.

Scissors – as some teams may want to cut their straws.

Masking tape – each team gets a yard or so of tape—but may draw some additional amounts later.

Paper clips – each team gets 20 but may draw more if needed.

The instructor will need a meter stick to measure straw tower heights.

Towers may not be taped to a table or other surface, nor supported by human hands or other objects.

Suggested Reading

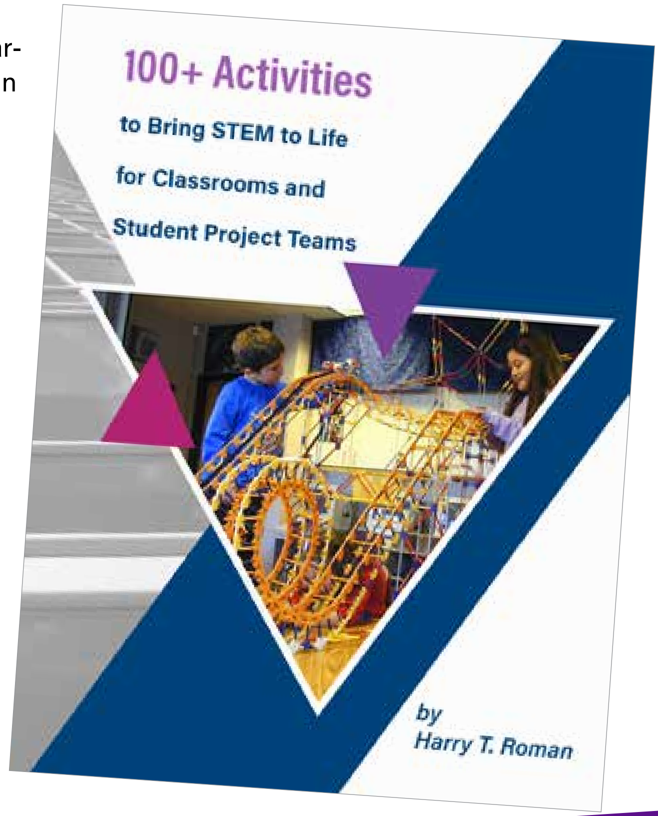
In addition to his extensive article writing for ITEEA, here are the books Harry Roman has published under the ITEEA imprint. These books also contain classroom activities.

100+ Activities to Bring STEM to Life for Classrooms and Student Project Teams
International Technology and Engineering Educators Association (ITEEA e-book), 2019.

Engineers and Engineering: A Review
International Technology and Engineering Educators Association (ITEEA e-book), 2014.

Classroom Challenges: Environment, Energy, Invention, and Safety
International Technology and Engineering Educators Association (ITEEA e-book), 2012.

Classroom Challenges: Problem-Solving and Design
International Technology and Engineering Educators Association (ITEEA e-book), 2012.



***Alternate Energy Technology Design Challenges** – Design Challenges for Tomorrow's Green Energy Engineers.*
International Technology and Engineering Educators Association (ITEEA e-book), 2010.

About the Author

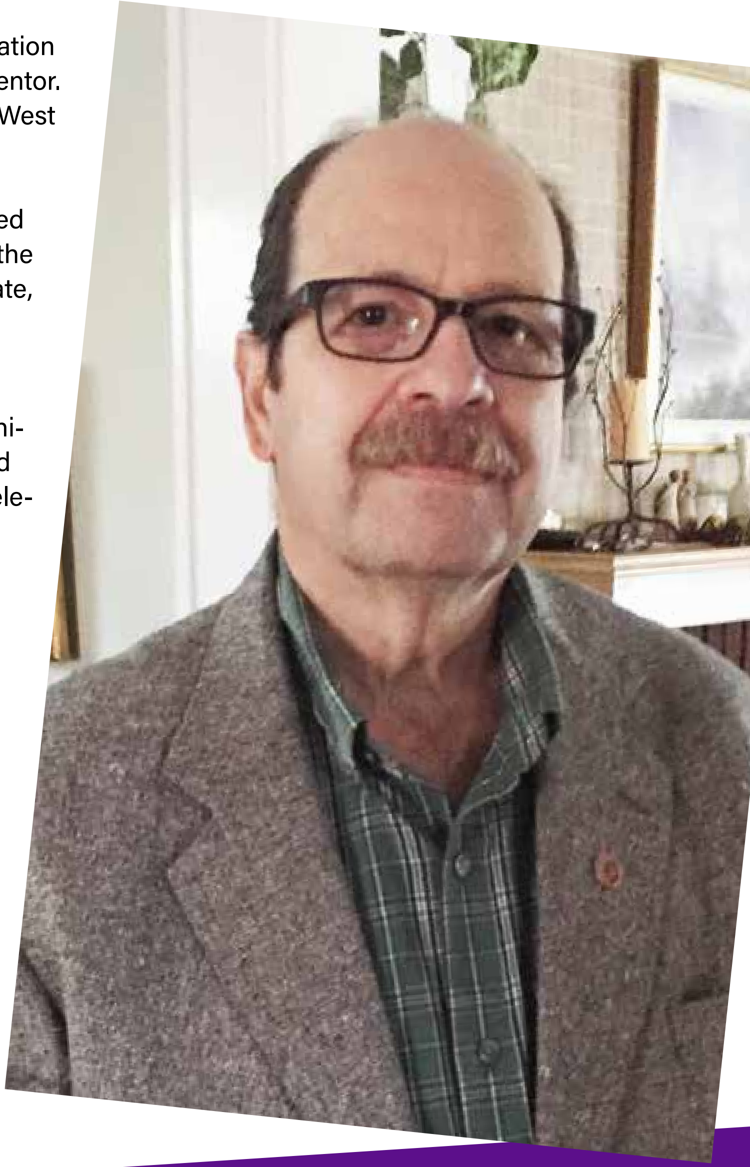
Harry T. Roman has been an ITEEA book and article author for about 20 years; and for the last 13 years has been the author of the "Classroom Challenge" feature that appears in every issue of the *Technology and Engineering Teacher* (TET) journal.

As a retired engineer and inventor, Harry likes teaching teachers, students, and school leaders about STEM and its applicability. Between 2012 and 2016, he created and co-taught graduate courses in iSTEM at Montclair State University's teaching college.

Harry also is an educational author and advisor to the Edison Innovation Foundation and writes many articles and books about the great inventor. Often, he lectures at the Thomas Edison National Historical Park in West Orange, NJ.

Prior to being involved in modern STEM activities, Harry was involved in the launching of Technology Education in New Jersey schools in the 1980s and is considered a leader in technology education in that state, accumulating many awards and top honors during his 30+ years of service.

He has received numerous industry awards and professional recognition during his 37-year engineering, invention, and patent career and was instrumental in establishing the NJ Inventors Hall of Fame to celebrate the state's many inventors. Harry holds 12 U.S. Patents.



Author Harry Roman is a regular ITEEA contributor and author of the long-time "Classroom Challenge" feature in *Technology and Engineering Teacher*. As a retired engineer and inventor, Harry likes teaching teachers, students, and school leaders about STEM and its applicability.

To support the important work of ITEEA's Foundation, Harry is permitting this publication to be downloaded at no cost to all—but asks that anyone who downloads consider making a donation to the ITEEA Foundation.

The ITEEA Foundation is in the middle of a Capital Campaign, with a goal of raising $250,000, which will allow it to continue providing much-needed support to current and future educators, as well as to those in our communities who are in need of assistance. Without the continued support of generous donors like you, these needs will regrettably go unmet.

ITEEA's Foundation is depending on your assistance and generosity. Please enjoy these activities and donate today to pledge your support. Be assured that your contribution will be put to good use to support tomorrow's problem solvers today!

MAKE A DONATION TODAY AT: www.iteea.org/capital_campaign.aspx

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