Invention Education Teacher Toolkit

INTRODUCTION

This sheet provides background information about invention education as well as suggestions for discussing inventing and invention education with your students. You will also find suggestions for support within your community.

INVENTION BACKGROUND

General information about inventing and inventors:

- Lemelson-MIT Invention Resources – Find profiles of inventors from past to present, invention activity books, cartoons, and videos from collegiate inventors.
- The Henry Ford's Innovation Nation – Showcases present-day change-makers from all over the world who are creating solutions to real needs.
- LiveScience's Inventions page – Read up on the latest invention news.
- Teenage Inventor Alexis Lewis Thinks That Kids Have the Solutions to the World's Problems – From *Smithsonian Magazine*.
- Inventing Green – The Science NetLinks collection of resources on invention education and impactful inventing.
- The Lemelson Foundation – The Inventor's Pathway – A video profiling how The Lemelson Foundation inspires, educates, and incubates the next generation of inventors.
- Inventors and Inventions - Learn about groundbreaking creations and the inventors and innovators who helped to shape the world as we know it in this collection of resources from Science NetLinks.
- Lemelson Center for the Study of Invention and Innovation – Located at the Smithsonian's National Museum of American History, the center explores the role of invention and innovation in the United States, particularly its historical context, and how that history relates to current events.

INVENTION EDUCATION

Invention education has at least two key differences from traditional classroom approaches:

- In the traditional classroom, the classroom is hierarchically flat. The teacher is part guide, project manager, coach, safety officer, and concierge. With an invention education approach, students take responsibility and initiative for organizing and progressing through iterative phases of discovery**,** planning, project initiation, completion, feedback, assessment, and review.

- Second, non-traditional sources of classroom knowledge and expertise are valued—perhaps even prioritized—over conventional texts, exercises, and problem sets. Inviting a practicing, problem-solving engineer into class to apply her or his knowledge and serve as a project mentor is one of the most potent forces of learning there is because it becomes rooted emotionally in a relationship with a person, categories of knowledge, habits of mind, and problem-solving techniques.

Here are some background resources for invention education:

- The Invented History of 'The Factory Model of Education' – Background on traditional education—a production model, not a problem-solving model
- Built to Peck – Compelling model of creative engineering problem-solving and multimedia exploration of a common health problem
- How to Break Free of Our 19th-Century Factory-Model Education System – Longform narrative on traditional education
- Issues over Invention Pedagogies – Pedagogical analysis of invention education
- Lemelson Foundation: U.S. Programs –Inspired by the belief that invention can solve many of the biggest economic and social challenges of our time, the Lemelson Foundation helps the next generation of inventors and invention-based businesses to flourish.
- Lemelson-MIT Program – The Lemelson-MIT Program celebrates outstanding inventors and inspires young people to pursue creative lives and careers through invention.

TEACHING A NEW WAY OF THINKING

Far too often in a traditional "factory model" of education, students are taught that failure is fatal. We inadvertently teach students that it is not okay to fail and that the opposite of success is failure. (If you don't believe that statement, just ask them.) History shows that failure is an important step in the process of becoming successful. The most successful people have more than likely failed more than those we would label as "failures." Not because they are lucky or talented, but because they learned from their mistakes and kept going.

"The world does not need more people who are good at math," said Gerald Aungst, supervisor of gifted and elementary mathematics in Pennsylvania's Cheltenhamn Township Schools. "What the world needs are more problem solvers and more innovators."

"We want people who are innovators, and don't assume that what people tell them is impossible is impossible," Aungst said during an edWeb leadership webinar. (https://globaldigitalcitizen.org/5-steps-to-a-problem-solving-classroom-culture)

Teaching invention education is an excellent way of conveying that idea to students. It's ok for an invention not to work the first time. Engineering is an iterative process that requires effort and perseverance. The skills taught in this way apply not only to inventing and engineering, but to almost every aspect of one's life.

Leadership expert Orrin Woodward teaches, in his best-selling book *Resolved: 13 Resolutions for Life,* the process to success he calls PDCA (Plan, Do, Check, Adjust). As a former engineer, Woodward knows this process works both in engineering/inventing and in life. Let's look at examples of both.

PDCA in Engineering/Inventing: Case Studies. (A student-friendly look at these case studies can be found here.)

Most school children have heard the famous story of Thomas Edison inventing the light bulb. Did you know that the common version of that story isn't entirely true? Edison did not invent the light bulb. He did make it commercially viable. Read the story of the light bulb with your students and discuss how Edison used the ideas of others as a starting point and went on to produce the first commercially viable electric lights.

The second case study involves an entrepreneur and programmer named Kevin Systrom, founder of Instagram. Systrom's "overnight" success was the result of a lot of hard work over a long period of time (as most overnight successes usually are).

You can use these questions to begin a discussion with your students:

- How many people have used Instagram?
- What is the coolest feature of it?
- How is Systrom's story similar to Edison's?

PDCA in Life

It is important to help students understand that the lessons learned through the scientific method and the iterative nature of the design process applies to a lot more than science and technology. The PDCA process that Orrin Woodward teaches can be applied to every aspect of one's life where they want to improve and strive for excellence. Whether it's in sports, music, business, or academics, there's a scoreboard. To improve, one must "keep score" and determine if they are winning. If their results are not what they want, then it is time to adjust one's plan and try again, NOT time to quit. Anything worth doing is worth doing poorly until you get good.

Here are some discussion questions you might consider bringing up with your students:

- What is the opposite of success? (Most will say failure. That is not true: The opposite of success is quitting. Failure is a necessary step on the way to success.)
- Would you have the tenacity, courage, and conviction to "fail" thousands of times as Thomas Edison did to reach a dream or goal that you have? (Talk about Edison's quote of finding thousands of ways that it doesn't work.)
- What is one area of your life where you have a dream or goal? What is it?

Discuss with students how the PDCA process could be used in a variety of activities. Here's an example for academics. Have students write down things that apply to their stated goal as you discuss this example.

"P": Plan. Many students do not consciously plan for improving academically. They think that performance on tests is a matter of intelligence rather than hard work and planning. If they don't have a plan, then the plan is to not make a plan.

- If you want to improve in a class, what actions can you take, at home and in class, to improve your performance?
    - Pay attention in class,
    - Take better notes
    - Study a little bit each night
    - Ask questions when you don't understand,
    - Etc.

"D": Do. Talk about the idea that the best laid plans are useless without action. They aren't going to improve if they make a plan, and then ignore it. Binge-watching NetFlix won't cut it if their plan was to study a bit each night.

- Make a commitment right now to carry out the plan.
- Set aside time specifically for the plan.
- Make a game out of parts of the plan

- *Maybe a game of flashcards with your friends.*
- *Text someone a definition to see if they can give you the term.*

"C": Check. The check in academics is the score that they get on a test or project. If they don't like the results, then it's time for the next step.

- Did you get the results you were looking for?
- Could you have done better?

"A": Adjust. If the results in the check step were less than ideal, then it's time to adjust the plan.

- Did you follow your plan?
- Did you do the things you said you were going to do?
- Did you do them well?
- Did you do them often?
- What can you do better next time?

You can go through this type of thought process with other examples.

FAILURE

Failure is a scary word for students (and for educators, too!). No one likes to fail at things, particularly in school, where the stigma of failure is tremendous. However, failure is an integral part of the process of innovation. In his autobiography, automotive titan Henry Ford wrote, "**Failure is only the opportunity more intelligently to begin again.** There is no disgrace in honest failure; there is disgrace in fearing to fail." Students may need to be reminded regularly that failure within the constraints of invention is merely another opportunity to learn and improve.

- The Benefits of Failure – In this blog post at Education Week, the author suggests that discussing failure and rejection is something we ought to do with our students to better prepare them for life.
- Failure Is Essential to Learning – At Edutopia, a project-based learning expert asks educators to create schools where "students are friends with failure…[to] truly prepare students for transformative success, in college and beyond."
- How to Help Kids Overcome Fear of Failure – From Greater Good Science Center, this article suggests ways to encourage kids to embrace failure.
- How to Give Your Child the Gift of Failure – An interview with Jessica Lahey, author of *The Gift of Failure*. Includes links to research on this topic.
- What if the Secret to Success Is Failure? – A *New York Times Magazine* article talking about the character traits of those who get ahead, and how the ability to deal with failure is key amongst them.
- Teacher: The Important Conversations We Are Too 'Scared' to Have – A *Washington Post* column discussing how we need teachers to model failure for our students.
- Teacher: In My Class, Failure Is Not an Option. It Is a Requirement. – A Washington Post column sharing the importance of productive struggle in education.

ENVIRONMENTAL IMPACTS OF INVENTIONS

While it is possible to invent a process or product without taking into account its impact on the environment in the manufacturing, usage, and disposal periods of its lifespan, it is not a responsible way to be a citizen of the 21st-century world. Here are some resources that help address taking these issues into account during the invention process:

- Redefining Innovation: Eco-Innovation Research and the Contribution from Ecological Economics (pdf) – A 1999 journal article by Klauss Rennings from *Ecological Economics*. One of the first papers on this topic.
- GCSE Bitesize: Design & Technology: Electronics: Environmental and Social Issues – An archived article from the BBC, this discusses how a designer must consider not only the function of the product, but also broader environmental and social issues, when developing a product.
- Designing Sustainable Products – An Australian resource for things to consider when designing, sourcing, and creating environmentally sound products.
- Technology & the Environment – Walks inventors through creating green products, including creating an Environmental Development sheet
- Embedding Environmental Sustainability in Product Design (pdf) – This piece from the Product Sustainability Forum offers professional research and design departments guidance for initiating and embedding sustainability in product designs and R&D programs.

MAKER SPACES

Maker spaces/faires, Fab Labs, and other creative spaces can be a great resource for both inspiration and materials and technology for the modeling phase of inventing. Here are some suggestions for making the best use of these spaces in your community or for creating them if they do not yet exist:

- Libraries & Maker Culture: A Resource Guide – Created by a learning technologies librarian, this serves as a resource guide on the subject of maker spaces, maker culture, and 3D printing in libraries.
- How to Make a School Maker Faire – Steps, guidelines, and resources for school organizers.
- Maker Faire – Find local maker faires, share experiences and resources, including project ideas, videos, and articles on related topics.
- Maker Education Initiative – An organization dedicated to supporting and empowering educators and communities as they create opportunities for students through making.

MENTORING AND STUDENT SAFETY

Be sure to incorporate your school and school district rules for student contact with outside volunteers into the suggestions below. If you are having students reach out on their own to strangers asking for mentorship, review with them student safety protocols, such as cc'ing you on all correspondence; only meeting mentors in public, supervised spaces, such as at school or the public library; and reporting any interactions that make them uncomfortable. You may find more useful suggestions in this mentoring guide from The Hamilton Fish Institute on School and Community Violence & The National Mentoring Center at Northwest Regional Educational Laboratory.

MENTORING RESOURCES

Developing and connecting with a mentor is an important part of learning to network to advance and test ideas and benefit from a broadly engaged community. Mentors can help across the innovation continuum, from early concepts, to builds and revisions, to suggestions for how to broadly distribute the message and encourage diverse buy-in and community support. A student-friendly assignment for creating a mentoring database can be found here.

Who?	How?
Iridescent online science and engineering mentoring organization. Its tagline is: "IRIDESCENT CONNECTS SCIENTISTS, ENGINEERS AND CHILDREN SO THEY CAN CREATE TOGETHER." They offer mentoring training, and it is worth contacting them to find those they've trained in your community—or will train.	1. Go to Iridescent Online Mentoring to find links to resources that can help you find or train mentors for your students. They discuss training and qualifications of mentors on their Online Community Mentor Builder page. 2. Review the Iridescent Mentoring Philosophy outlining their mentoring philosophy, including colorful informational graphics highlighting the usefulness of divergent and convergent questions, predictions, critical thinking, and defending a position while listening to others.
Local and national environmental journalists who cover your issue with authority and respect for an evidence base.	1. Monitor valid science newsfeeds and publications and note authors' names who write about water access issues. 2. Keep a list of bylines—the authors' names—and article titles that you find beneficial. Use that article as the reason to contact them, and ask for their help in inspiring or guiding your students' research on the topic—or the solution. Perhaps they know organizations doing exactly what your students are and can introduce you. 3. Contact the journalists. Don't give up. Use FaceBook, Twitter, Email, phone, or write a paper letter, in multiple contact rounds and ask them to suggest mentors, or if they would serve as mentors. 4. Maybe they will become your Communication Partners and publish your final work! Think big!
Local college and university professors—don't forget Emeritus…often they conducted foundational work and in retirement have fewer demands, more time to	1. Search department Web pages and faculty directories for professors with relevant expertise to your project. 2. Contact them AND also email or telephone the relevant college or university department to explain your project and ask the department secretary for names of people who might help, or have a history of entering into mentoring relationships.

mentor.	3. Contact your local university news bureau and ask for the person responsible for covering Environmental Science and Engineering news. Tell them you are looking for professors or graduate students who embody innovative problem solving, and might be interested in mentoring. Ask them whom they would recommend, and obtain the potential mentor's contact information from the news bureau—it's more likely to be correct!
College student groups involved in the environment, engineering for social justice and change	1. Search within college and university Web pages and directories for student groups who share your interest—Engineers Without Borders is a good start. Check their FaceBook pages for contact info, follow them on Twitter, Instagram, and other social media until you reach them and can meet in person to explore a possible mentoring session or relationship. 2. Reach out to groups known to have an evidence-based water rights and access improvement agenda, such as Engineers Without Borders or YourExpedition: Access Water, a group of women adventurers who are investigating the access problem. 3. Begin with general contacts and refine contacts until you reach a local email, then a voice, then a person.
Librarians and archivists	Both public and private libraries—such as small private colleges—are student oriented, knowledgeable, and want to help. Go meet in person the librarians and archivists. Explain to them that you are searching for a mentor experienced in innovative, green problem-solving of environmental problems, and particularly water access problems. Ask them for help in developing a list of project metadata—water access, green, innovation, global shortages—to help librarians understand your project. Ask them for suggestions on helpful data bases they have access to that might be useful, and for search strategies in using them.