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Tinkering in Makerspaces: Developing Skills for a Changing Technological Future

If one thing is certain about the job needs of the future workforce, it is that they are uncertain. Technology has been a source of global upheaval, requiring today's students to be diversely skilled, adaptable, technologically savvy, and computational thinkers (ISTE, 2016).

To prepare students for work and life in an ever-evolving future, the International Society for Technology in Education (ISTE)—an organization that serves educators interested in using technology in the classroom—updated its Standards for Students in 2016 to "emphasize ways that technology can be used to transform learning and teaching." Additionally, the US Department of Education's National EducationTechnology Plan recognizes technology as a powerful tool through which educators can reimagine learning, expanding growth possibilities and learning equity for students (US Department of Education, 2017).

Makerspaces—the collaborative, hands-on work spaces where students can create, tinker, problem-solve, and explore to understand a phenomenon—are ideally suited to blend technology, science, and engineering design to help students develop the skills they need to adapt to a future of discovery. Their learner-driven approach supports ISTE's emphasis on student empowerment and on providing a framework to progress as students build mental and emotional "muscle" as well as the science and engineering practices of the Next Generation Science Standards* (NGSS). While students work to design solutions, fail or succeed, redesign, and test, they also develop skills considered necessary for success: communication, creativity, and collaboration.

> "**Goal:** All learners will have engaging and empowering learning experiences in both formal and informal settings that prepare them to be active, creative, knowledgeable, and ethical participants in our globally connected society."
>
> *—Office of Educational Technology, US Department of Education*

The STEM Alliance

In teaching and learning in the classroom, how do ISTE initiatives mesh with the NGSS and other similar standards based on three-dimensional learning? The ISTE clearly states that its standards are not meant to supersede other educational initiatives but "rather work alongside them, amplifying and transforming learning through technology" (ISTE, 2016). And in developing the framework that is the basis of the NGSS, the National Research Council (NRC) acknowledged the importance of engineering and technology as a context for testing and developing scientific knowledge, ultimately enhancing students' understanding and interest in science (NRC, 2012). Through makerspaces, students have an opportunity to apply science and engineering practices as technology and science learning goals converge in key learning domains.

> **Science:** The traditional natural sciences—physics; chemistry; biology; and earth, space, and environmental sciences
>
> **Engineering:** Any engagement in a systematic practice of design to achieve solutions to particular human problems
>
> **Technology:** All types of human-made systems and processes
>
> *—National Research Council*

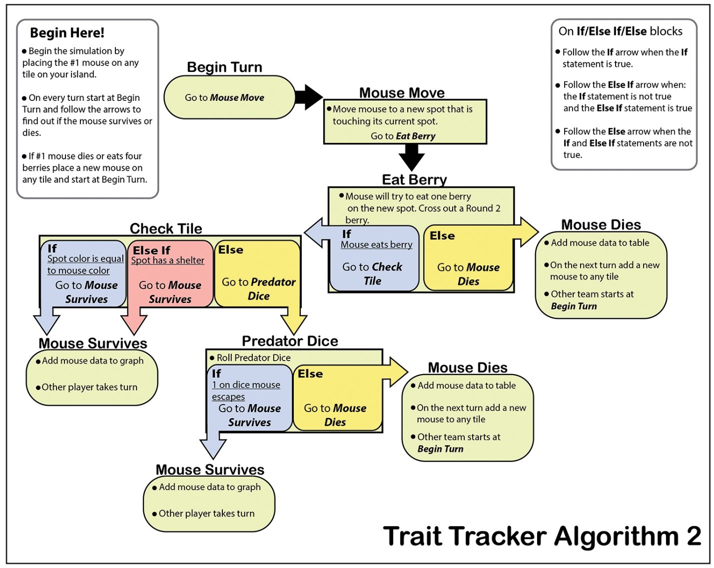
- **Both ISTE standards and NGSS seek to improve a learner's ability to have experience in solving real-world problems through the engineering design process.** For ISTE initiatives, design-related challenges include a hands-on approach to problem-solving, where students refine prototypes to generate a solution to a problem. Similarly, the NGSS science and engineering practices have students develop and compare possible solutions to address real-world problems.

Credit: Smithsonian Science Education Center

In Smithsonian Science for Makerspaces "Wilderness Watch!" engineering design challenge, students use a 3D-printed camera trap to gather data to make connections between resources and animal populations.

- **Both ISTE and NGSS feature computational thinking as a means to confront real-world problems.** Considered the highest order of problem-solving, computational thinking (CT) emulates the process computers use to address problems and sort through pertinent information, guiding students to apply scientific and engineering design principles as they reinterpret complex phenomena into smaller algorithmic steps.

Although students can use digital tools to, for example, assist data analysis and develop abstract models, CT exercises don't always require high levels of technology and can be used in low-resource, or "unplugged," environments while still addressing technological learning through human-made processes. This promotes equitable access of this problem-solving skill to all students regardless of the level of resources available.



Credit: Smithsonian Science Education Center

Students use a paper algorithm chart from the Smithsonian Science for Makerspaces "Trait Tracker" to uncover patterns related to how characteristics can influence an animal's success in an environment.

Making the Most of Makerspaces

Activities at makerspaces are closely tied to the engineering design process—a process that encourages students "to develop 21st century cognitive competencies, engage in authentic engineering practices, and integrate science and math concepts" (Grubbs, 2015) as they support student-driven, hands-on learning. In makerspaces, students have the freedom to make and learn from mistakes as they figure out solutions through designing prototypes.

Research shows that "As STEM learning allows for a cross-curricular training in unique skillsets, so too does the marrying of STEM and makerspaces for learning those skills" (Daughrity et al, 2019). Additionally, makerspaces have been recognized as a means to improve collaboration and diversity in STEM and are often seen as a positive environment to teach STEM-related concepts to groups that have been marginalized in more traditional science learning experiences (Sheffield, 2017).

To enhance students' STEM learning opportunities, the classroom makerspace can serve as a bridge that extends formal science education through weekly or monthly engineering design challenges that investigate phenomena. These engineering design challenges can:

- Support educators as an activity that elaborates on a lesson of an established NGSS-aligned curriculum
- Be used as a stand-alone experience that engages students but is not necessarily tied to an overarching curriculum goal

Teachers' responsibilities include providing supplies and mentoring students in makerspace initiatives, but they also can maximize student learning by providing challenges that advance curriculum objectives (Duhaney, 2019). In these hands-on, creative environments, educators are empowered to adapt their strategies as they improve their own self-efficacy in challenges that integrate technology. To support teachers in planning and implementing makerspace activities, free resources that boost the science curriculum, such as the Smithsonian Science for Makerspaces challenges that are inspired by the Smithsonian Science for the Classroom curriculum for grades 1–5, are valuable teaching and learning tools.

Through makerspace challenges, teachers can engage students with emerging technologies that make real-world connections, nurturing students' curiosity and helping them develop confidence to adapt and achieve in a STEM-driven world.

Science and Engineering Practices	Makerspace Applications and Examples*
Asking Questions and Defining Problems	Ask questions based on observations about a phenomenon. *How do stringed instruments create sounds through vibrations?*
Developing and Using Models	Use materials to create models to predict and explain phenomena. *Use an algorithmic model to uncover patterns of how differences in environmental characteristics affect an animal's chance of survival.*
Planning and Carrying Out Investigations	Plan and carry out procedures for collecting data to test explanations. *Students make weather predictions for a trip to two cities and design weather widgets to find "actual" travel weather conditions.*
Analyzing and Interpreting Data	Analyze and interpret data to explain or provide evidence for phenomena; compare results of tests for different design solutions. *Students investigate how well each of four materials absorbs or channels water.*
Using Mathematics and Computational Thinking	Use digital tools or human-made processes to analyze and interpret data to provide evidence for phenomena. *Students consider patterns in data to reveal relationships between magnetic force and motion.*
Constructing Explanations and Designing Solutions	Apply scientific ideas and evidence to construct an explanation; develop and optimize solutions to problems. *After using a camera trap to study animals, students consider what resources make an area an attractive place for animals.*
Engaging in Argument from Evidence	Determine and refine the best explanation; select and optimize the best solution. *Students compare designs to realize that there may be more than one solution to a problem.*
Obtaining, Evaluating, and Communicating Information	Evaluate relevancy and quality of sources; communicate ideas to others. *Combine student groups for a class discussion to share their answers to the Test It! questions.*

***Examples are from Smithsonian Science for Makerspaces resources.**

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The Smithsonian Science for Makerspaces Approach

Smithsonian Science for Makerspaces resources were developed by the Smithsonian Science Education Center with support from Johnson & Johnson to create an educational environment that embraces technology and computational thinking to assist the learning process. Inspired by the Smithsonian Science for the Classroom curriculum, these resources help learners solve real-world problems through a hands-on approach, using skills and concepts supported by technology, as they observe, make, design, and test solutions to a problem. The free Makerspaces activities are applicable in both low-resource and high-resource schools and informal learning environments and encourage a diverse student population to engage in STEAM learning.

Get the resources at ssec.si.edu/makerspaces.

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ScienceEducation.si.edu