# TEACHING PRACTICES

THE CHALLENGE

## Engineering curricular resources lack a central focus on the local context.

Studies of K–12 engineering reveal that while there are resources available for teaching engineering design generally, there are few quality resources available for teaching how the design process is iteratively informed by analytically refining problem constraints and solution optimization within authentic community contexts. Equally as limited are resources for teaching about the *cultural, social, economic, and political dimensions of technology development* (NRC, 2009, p. 9).

**Teaching engineering for sustainable communities requires teachers and students to consider both the technical challenge of design as well as how problems and solutions defined, adapted, and optimized in response to community needs and concerns.**

OUR RESPONSE

## Engineering with, in and for Communities

Engineering for sustainable communities is an approach to engineering that values learning and doing engineering in participation with community. Four core principles guide this perspective:

- Uses Community Members' Ideas in Engineering
- Helps the Community Solve Their Problems through Engineering
- Cares about the Environment
- Designs Solutions for Now and in the Future

The principles help teachers to navigate from a topic (e.g. alternative energy) to a problem space where students can develop realistic and testable tools based upon current knowledge, empirical investigation of technical and social dimensions, operational constraints, and specifications (e.g. What devices, powered by alternative energy, can I build to get me to my friend's house when my parents cannot take me?).

Engineering for sustainable communities includes community-based forms of research as part of the design process. It requires engineers to ask, "Who is the project for? Whose knowledge counts? Who takes part in problem definition, data collection, and analysis? Who takes action?" (NRC, 2010, p. 8).

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Teaching engineering for sustainable communities requires teachers and students to consider both the technical challenge of design as well as how problems and solutions defined, adapted, and optimized in response to community needs and concerns. This requires an approach to engineering that moves beyond traditional STEM content and practice to incorporate the social dimensions of problems and solutions.

We focus on two engineering practices that help youth to integrate the technological with social ideas and concerns: defining problems and designing solutions.

These practices align with two core engineering practices identified in current reform initiatives as important to teach young people (NGSS, 2013). They also provide opportunities to bridge engineering work with empowering community engagement. How problems are defined, by whom, and for what purposes require engineering and community expertise). This approach provides opportunities to bridge engineering work with empowering community engagement.

**Table 1** provides questions to guide planning to support the integration of technical and social dimensions into the practices of defining problems and designing solutions. For example, when planning engineering design challenges teachers can focus on solving local, real-life challenges and support students in using their multiple knowledges and experiences as powerful resources for doing engineering. Teachers planning authentic design challenges should ask where, when and how the engineering design solutions

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can be used by the students and/or their community. Engineering designs that are authentic and get used within the community. Furthermore, through engaging students in multiple design iterations, teachers create sustained opportunities for students to deepen STEM understanding while integrating students' knowledge, experience and expertise. Through multiple design iterations, students have opportunities to bring new expertise into their engineering learning.

**Table 1: Practices in Engineering for Sustainable Communities**

| | Technical | Social | Interactions |
|---|---|---|---|
| DEFINING PROBLEMS | What problems can technology solve? What do I need to know about the technology to solve the problem? | How can I identify, seek out and incorporate multiple perspectives from relevant stakeholders? How can I translate my technical thinking into questions, ideas and concerns for outsiders? | **SETTING CRITERIA** What perspectives matter and why? How do different perspectives constrain problems differently and why does this matter? |
| DESIGNING SOLUTIONS | How do I decide on a design that best meets the criteria and constraints? What do I build and how do I test it? What do I need to know to optimize my design? | What perspectives should my design address and how do I test my design against these perspectives? How do I communicate ongoing design decisions to others who may not have the same knowledge as me? | **OPTIMIZING** Which criteria are most important? How do I balance conflicting factors? How do I maximize trade-offs? |

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AN EXAMPLE IN PRACTICE

## Planning a design challenge

We highlight an electric art engineering design challenge meant to support students' sense-making of a) core disciplinary ideas on energy systems (e.g. power requirements) and transformations (e.g. electrical to light energy) and the two engineering practices, defining a problem and designing a solution. Rather than only asking students to make and test different circuit types and draw model-based explanations for how and why the circuit types work, students leverage these insights towards making a light-up gift for a loved one, limited to the following materials: one 3-volt battery, up to two 5mm led lights, copper tape, cardstock and other common classroom craft supplies.

Students engaged in two iterative, electric art design cycles. Students decided for whom they were making their electric art, and how to design it both socially (artistically) and technically (circuit-wise) to celebrate that person. They accomplished this through two cycles of prototyping. In the first cycle, students modeled three types of circuits (simple, parallel and series), analyzing and developing evidenced-based explanations for the different advantages and constraints of each circuit type in terms of power requirements.

The students then used this expertise in a way that mattered to them as they designed their own electric art. During this second prototyping cycle, students leveraged personal, family and community resources, in personalizing their electric art. Students were positioned as experts as they helped peers make their cards. Their hybrid-expertise involved helping peers troubleshoot how to make their circuits and switches work within their desired social specifications of their designs, or to modify their specifications as they moved through multiple iterations.

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## Impacts on Student Learning

Layla created a 3-dimensional, light-up paper lantern-style mug as a gift for her mother during an engineering unit focused on energy systems. To light her mug, Layla designed and built a parallel circuit using two LED lights, copper tape and a coin cell battery. The switch, a movable flap between the battery and copper tape, was decorated with a bow.

Layla drew upon many personal and cultural resources, including her passion for making and crafting. She explored pictures of 3-dimensional lanterns and cards on Google Images and drew from her prior positive experiences making 3-dimensional and tech-centric projects like a working robot with her brother. In addition to drawing on resources to successfully engineer circuits in a 3-dimensional way, the electric art templates provided in the engineering unit informed her circuit design. Decorations to increase "coziness" were carefully added, including gluing flowers on the mug's base so "it can look like it's just a wonderful imaginary world of yours" and a curling pipe cleaner to represent a steaming beverage. Her initial design with only one LED was not "cozy" enough. So even though "it took a long time to do the circuit" she added a second light, requiring her to switch from a simple to a parallel circuit.

Layla felt proud as she shared, "I feel like I can teach, and if someone asks me about LED lights, series circuits, simple circuits or parallel circuits, I can help them." She predicted that her mom would "think that I am very creative, very smart, and very thoughtful that I did this for her. And she's going to think I'm successful."

Layla went through many iterations before having a working, 3-dimensional light-up mug. Each iteration was prompted by challenges that advanced her sense-making. When she thought her mug needed to be more "cozy" she added a second LED light, prompting further circuitry explorations, plus additional crafting features, such as the curling pipe cleaner to represent the steaming hot beverage. These iterations invited Layla to use multiple types of her social and technical knowledge. To evaluate Layla's various design iterations, Mrs. L asked her to explain the process she undertook making the electric art and then asked her how each change she made deepened her expertise using the post-electric art interview rubric.

Through an iterative process involving cycles of feedback, Layla engineered a light-up mug that met multiple needs—a process which Layla experienced as deeply meaningful and empowering.

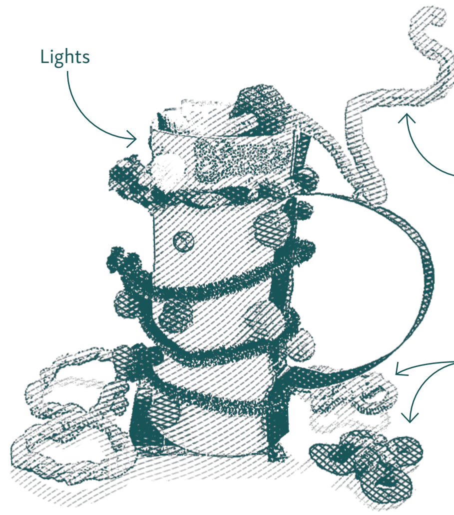


**Table 2: Layla's process of integrating social and technical data**

| Layla's 3D Light-up Mug |
|---|
| 1 Used knowledge developed in her relationships with mom and brother; love for 3D and robotics; big DIY-er; loves art projects; savvy internet browser |
| 2 Changed from one light (simple) to two lights (parallel); added decorations to make the mug cozier; added pipe cleaners to represent steam; kept working on it after class finished lesson; helped others make switches and circuits after getting help with her own switch; offered feedback to others |
| 3 Designed an imaginative, glittery, light-up mug for her mom inspired by previous experiences making paper lanterns |

> **I feel like I can teach, and if someone asks me about LED lights, series circuits, simple circuits or parallel circuits, I can help them.** LAYLA

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