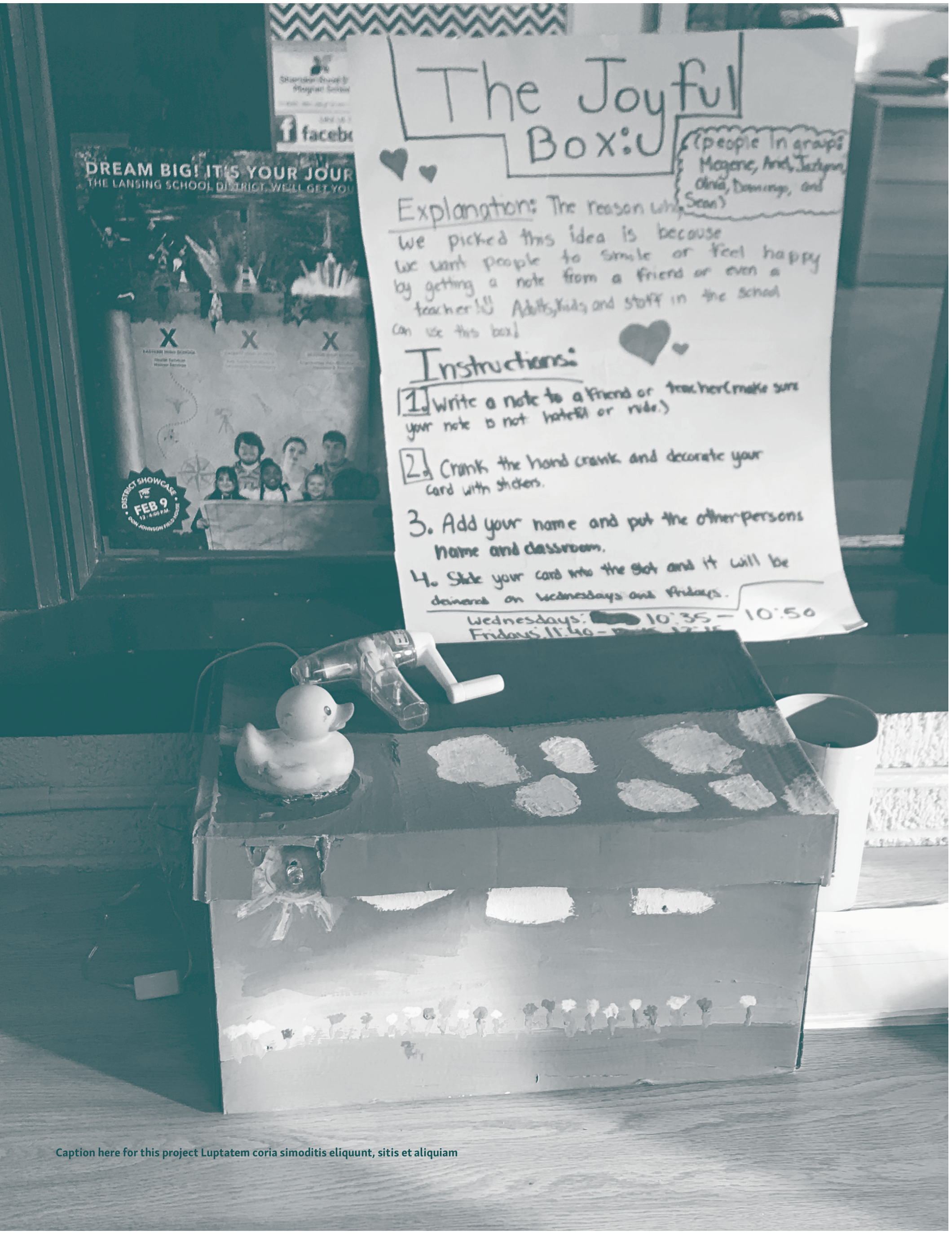
i-ENGINEERING

ENGINEERING for SUSTAINABLE COMMUNITIES

TOOLKIT

UNIVERSITY OF MICHIGAN

UNC GREENSBORO



Caption here for this project Luptatem coria simoditis eliquunt, sitis et aliquiam

CONTENTS

WHY TEACH ENGINEERING FOR SUSTAINABLE COMMUNITIES?

In alignment with the Next Generation Science Standards (NGSS) "to define problems more precisely, to conduct more thorough process of choosing the best solution, and to optimize the final design" (NGSS, 2013), an Engineering for Sustainable Communities (EfSC) approach recognizes the active role school community members can have during the engineering process. As students engage fully in the engineering design cycle, they do so in ways that are meaningful to science and engineering as well to their fellow students and communities.

Teaching EfSC requires teachers and students to consider both the technical challenge of design as well as how problems and solutions are defined, adapted, and optimized in response to community needs and concerns. This is done by incorporating the social dimensions of problems and solutions. The process of localizing engineering design through integrating technical and social dimensions, is one powerful way to support students in seeing themselves as welcome and able to use engineering to support their community. We want students to be able to say, "I can solve this problem collaboratively right here in my community, right now using what I know" rather than waiting to only use their STEM expertise in long-term future career goals.

Engineering for sustainable communities is a viable approach to supporting broadening participation in engineering in equitable and justice-centered ways. This domain expands what it means to be an engineer, and positively connects engineering to communities. Opportunities for ongoing reflection on interactions among technological and social dimensions deepen understanding of the design process and on what it means to be an engineer (NRC, 2010).

INTRODUCTION

OUR GOALS

Equity in Engineering

Promoting equity in engineering in K–12 education is critical. Many students choose to turn away from engineering because they view it as disconnected from their lives and pursuits (Tonso, 2007). Furthermore, society has foreclosed pathways to engineering for many people of color through limited access to high quality teaching, and promoting stereotypes about what engineering is, or who can and cannot do engineering. African Americans make up only 4% of the engineering workforce in the US (NCSES, 2017). This statistic has not budged in decades.

The inclusion of engineering in the Next Generation Science Standards encourages new forms of learning through the mobilization of students' everyday interests and practices in the context of authentic, project-based experiences. How the field conceptualizes and designs for learning engineering as a part of integrated science is important. If K–12 engineering is to reverse societal inequities, especially for youth growing up in non-dominant communities, it is essential to support engineering teaching that values students' cultural knowledge and practices through robust learning opportunities.

A central aspect of engineering is how it solves problems that are socially consequential. One approach to teaching engineering in ways that value student lives is by supporting engineering design that centers authentic social needs of students. This Toolkit provides guidance for doing just that. We recognize that many educators lack the support they need to make sense of—let alone work with students to navigate—a wider range of experiences and ways of knowing that engineering practices entail. Further, whose experiences and ways of knowing matter, and how, in engineering and science education more broadly is highly contested, yet deeply significant in organizing for equity.

The Next Generation Science Standards (NGSS) have placed a new emphasis on students enacting science and engineering practices. Engineering for sustainable communities focuses on supporting teachers and students in engaging in the engineering practices of 1) defining problems and 2) designing solutions.

> **Teachers care, but they do not care about the community all of the time. We go outside on our time, and find places where we can go do science or engineering for our communities. School doesn't know how to do that. School doesn't know that we do that. We need to tell our teachers how we do it. We got to help them.**
>
> SAMUEL, 14 YEARS OLD

Taking a Justice Stance

Samuel's experiences are not unique. Many youth want to be legitimately welcomed in science and engineering as whole people with valuable knowledge, practices and experiences that matter in science and engineering. His quote calls us to consider why a focus on justice in science and engineering is necessary.

Engaging in science and engineering is deeply grounded in people's experiences in the world, including their families and communities' cultural practices. Students from historically non-dominant communities have powerful cultural knowledge and experience that are highly relevant to engaging with science and engineering. Yet, for many students, engaging in science and engineering can be constrained and limited. *The dominant discourse and practice of science and engineering reflect white, western and masculine ways of knowing and doing science.* The way that science and engineering are often taught and how students are expected to learn further projects these dominant cultural norms. Consequently not all students are encouraged or supported in leveraging *their* powerful cultural expertise towards meaningful learning or engagement in science and engineering. We can think about this as denying students a **Rightful Presence** in science learning.

INTRODUCTION

Rightful presence in a classroom community has two parts:

- Individuals are welcomed as legitimate, contributing, and fully human members of a learning community because of who they are, not who they should be.
- The community works to more fully value the cultural knowledge and practices of newcomers through equitably sharing power.

This kind of power sharing makes visible and present the whole of youths' lives, including both their individual and community strengths and the oppressions they experience. It also involves a collective disruption of what we currently understand as meaningful learning to support more expansive outcomes, such as identity work (such as who youth are and want to be), agency (such as What youth can do with science and engineering now in their lives) and social transformation (such as youths' imagined futures with/in STEM).

Engineering for Sustainable Communities

Youth and their families have a wealth of knowledge and wisdom that positively impact their communities. However, oftentimes their ideas and perspectives are not taken up in engineering design, even when the challenges addressed by engineers are grounded in the community. There are also a wide range of sustainability challenges facing young people and their communities today, such as poverty, racism, climate change, and affordable energy. People and communities need approaches to working together, and to drawing upon a diverse and distributed set of expertise, to understand and address these challenges at both the local and global level.

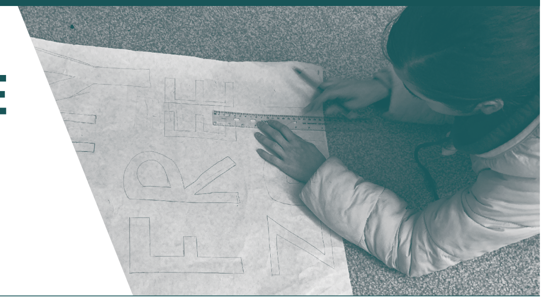
An Engineering for Sustainable Communities or EfSC approach supports these challenges by challenging and expanding what it means to be an engineer by connecting engineering practice to communities. Engineering for sustainable communities deals with problems and design solutions for the real world. Such design problems are often tied to human rights, economics, and oppression, and they have clear technological and social dimensions.

EfSC also supports community development. Engineering for sustainable communities requires the inclusion of 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). By focusing on the technical problem-solving dimensions of engineering, EfSC focuses on the needs and rights of communities. This not only enriches the engineering design process, but opens up equitable access to engineering by connecting it to student lives. As the United Nation reminds us, ending "poverty must go hand-in-hand with strategies that build economic growth and address a range of social needs including education, health, equality and job opportunities, while tackling climate change and working to preserve our ocean and forests."

Sum vel ea quidenderum, voluptata sundand ignimod qui voles eiciat lat niew niew more text can go here.

> **We want the kindergartners who walk down our hall to know that we, sixth graders, care about them . . . They will see these 'helping hands' and know. Their eyes will pop when the hands light up, and they will know that they can do STEM work when they are in sixth grade, too.**
>
> LOUISE, 6TH GRADE

ENGINEERING FOR SUSTAINABLE COMMUNITIES IN CLASSROOMS



The EfSC Approach

Engineering for sustainable communities is an approach to engineering that values learning and doing engineering with and for the community in support of building a healthier, happier and more just world.

The Engineering for Sustainable Communities (EfSC) approach supports students in engineering more healthy, happy and just communities in their classrooms, schools and neighborhoods. EfSC explicitly connects students and teachers to communities. Students learn to identify and balance community needs and rights with the technical problem solving of engineering.

The EfSC approach is undergirded by the engineering practices of: 1) defining problems and 2) designing solutions. These practices are the core of engineering design. These practices also support students in making sense of problems and solutions in careful, balanced ways. An EfSC approach also supports students in developing their engineering identities by supporting them in having opportunities to use what they know to make a difference in their communities, and to be recognized for it.

KEY IDEAS

Science & Engineering in Everyday Life Engineering design that builds on and contributes to students and communities' well-being.

Co-Learning The EfSC approach asks teachers to be co-learners with their students about the problems and solutions students will define with their community. While teachers may have the content expertise in engineering design, their students will be the experts of their communities. Together teachers and students co-learn how to apply engineering ideas to community problems.

Family & Community Funds of Knowledge Funds of knowledge are the various forms of expertise and practices youth develop over time in families and communities, and that can be strategically leveraged for learning and participation in school settings. Family and community (e.g. parents' work in and outside the home, travel, and environmental and health concerns); peers (e.g. formal and informal group activities); and popular culture (e.g. TV, music, print and social media) are some categories of funds of knowledge. Supporting students in using their funds of knowledge in engineering is an asset-based approach to supporting STEM learning, and provides opportunities to connect school and community.

Community By community, we refer to the people and places that students interact with on a regular basis.

Engineering Practices Engineering practices as forms of sense-making in engineering—embodied forms of learning—that are culturally embedded. Engineering practices reflect the valued ways of doing in a STEM community of practice. They take shape through social interactions, discourses and tools. EfSC values many different engineering practices, but centers two practices in particular: 1) defining problems and 2) designing solutions.

- **Defining Problems** Students ask questions and gather information to determine specific challenges that need to be addressed through engineering. They gather and analyze information to define the dimensions of a problem. Students enacting this practice with an EfSC approach focus on both the technical and social dimensions of the challenges using multiple forms of data.

- **Designing Solutions** Students design solutions that address the multi-faceted dimensions of their defined problems. While students engage in designing solutions, they balance different constraints for their design. In this practice, students consider both the technical and social dimensions and optimizations of their engineering design solutions.

Authentic Solutions Designing real-world solutions to real-world problems that can be designed, built, refined and used by students in their classroom, schools and communities, in the here-and-now and towards hoped for futures.

Working Towards Justice Educators and youth working together to challenge and transform what participation in science and engineering can be, or what meaningful representations of learning look like, in ways that humanize participation and value youths as whole people. technical and social dimensions and optimizations of their engineering design solutions.

IN ACTION
Bank of Compliments

ANALEIGH
This is something that is going to help someone in the future.

MARY
We think about other people's feelings. Even though we failed a few times with our lights, we still don't give up.

In these quotes, Analeigh and Mary are describing their experiences designing a "Bank of Compliments," a light-up box filled with laminated cards that contained supportive compliments, such as "You're worth a million dollars" and "Your heart is filled with wonder." One could reach into the box to pull out a friendly motivational card while also enjoying the colorful bright lights as they turned a handcrank generator. The four LED lights were hand colored red, green, blue and pink to reflect the different emotions they and their peers felt during the day. The girls designed and built the Bank during a six-week STEM unit focused on engineering for sustainable communities. As they wrote in their final project write-up:

> *The Bank of Compliments solves the problem we identified by making our peers feel good with compliments. Students can reach into the top of the box and get a compliment. They light up the box if they like the compliment they have. If they don't like the compliment, they can grab another compliment. If they like that one, they can light up the box. We used a parallel circuit to power four lights. Our energy source is a handcrank. Students can light up the box by turning the handcrank, transferring energy to the LEDs.*

The two girls describe how they built the Bank in order to foster a happier and more just school community. They worried that school had "too much drama" and kids were often "mean" and "bullied" each other. Their analysis of their school-based observations, surveys and interviews of classmates and peers also indicated that school morale was low, which made it "too hard to learn." As the quotes indicate, the girls worked hard on their project, and were proud knowing their efforts would help to bring positive change.

When their project was completed, the girls, with their teacher's support, moved the Bank to the restorative justice room, a place where they had spent time in relation to bullying, and a place where they felt agitated. They believed their engineering design would be helpful in the room because it would provide the students with new and different ways to feel better.

The girls identified a **meaningful community problem**—low school morale, often caused by bullying—and applied their **knowledge and practices** related to energy transformations and environmental sustainability along with their **funds of knowledge** related to peer well-being and bullying to design the Bank of Compliments in response. The Bank was an **authentic solution** to a problem they and their peers faced in **everyday life**. And the bank was used by their teachers and peers everyday. In building the Bank, the girls responded to the technical dimensions of the task—build something that promotes sustainability, involves energy transformations, and uses ordinary classroom materials. However, in building this artifact they actively sought to change how people in their classroom, and later in the restorative justice room, felt about themselves and each other. As their quotes illustrated, the girls really cared about their classmates' feelings, both now and in the future. Their teacher, Mrs. L., too, commented on how exciting their project was as she co-learned with them about how they experienced the restorative justice room.

GUIDING PRINCIPLES

Our EfSC framework supports and expands NGSS' key engineering practices, defining problems and designing solutions, based on four key ideas central to the design process:

- Using community members' ideas in engineering
- Helping the community solve their problems through engineering
- Caring about the environment
- Designing solutions for now and in the future

These core design principles for EfSC support teachers in teaching engineering practices from this perspective. They help teachers to navigate from a disciplinary core idea (e.g. energy) to a problem space where students can develop realistic and testable designs based upon current knowledge, empirical investigation of technical and social dimensions, and 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 caregivers cannot take me?).

While the four core design principles for EfSC should be considered as a whole while working with students to engineering for sustainable communities, each principle is described in depth below with:

- An elaboration on the meaning of the principle
- Ideas on how to enact in classrooms
- Questions for students and teachers to consider
- A brief illustrative case

1 Using community members' ideas in engineering

Using an EfSC teaching approach supports students' in working alongside community members to improve the daily lives of people they know in their lives. Teachers can decide whether they want to focus on the local classroom and/or school community or expand to the neighborhood community. Throughout the engineering design process, students elicit multiple communities' perspectives about the problem they defined, their proposed solutions, and multiple design iterations/prototypes.

In an EfSC approach, students learn about the importance of community input about the problems affecting them, and community suggestions for possible solutions. They conduct and analyze surveys, interviews and observations to help them elicit ideas about the sustainability challenges that affect themselves and their communities directly and which ones most need to be solved. This way, community input on what problems needed to be solved, why and how, were integral to the design process.

Reflection Questions

- What problems affect our community and how do we know?
- What approaches could we use to help multiple stakeholders, including their peers, family and community members, teachers, and school staff, have roles in the process of defining a problem?
- What roles might community members play in defining a problem?

IN ACTION
Switcheroo

To better understand what problems were affecting their school community, Blake, Sasha, and Ruby (Switcheroo's engineers), surveyed their classmates and other school community members (e.g. caregivers) using an online survey they co-generated with their classmates and teacher. Ms. W asked the class how they might find out what problems the members of their classroom and school community cared about. The class co-generated questions such as "What challenges related to a happy and healthy community do you think are most important?". After analyzing responses, the students noted that 100% of respondents indicated that there was a need for a stronger sense of community. After further exploring the open-ended survey responses, they refined the problem to be the need to address the continuous interruptions they experienced in their classroom, from the other class, when it was time to change classrooms. For them, this was a problem because their classroom community was interrupted by other classes unintentionally entering the room unannounced. For example, while the teacher, Ms. W, was clarifying and answering questions the other class would come in without previous notification, interrupting the student's questions or the teacher's explanation. This was something they wanted to solve.

I get so upset when kids get bullied. Just because my friends don't speak English they don't count. When the survey showed everyone cares if we are inclusive, it was like what I was feeling. It was like we had to do something.

VALIA, *on why she addressed bullying through her design*

2 Helping the community solve their problems through engineering

By helping the community solve their problem, students learn and experience how all community members have the right and the responsibility to contribute to defining problems and designing *authentic solutions* to *work towards justice.* This way, community members are treated more justly, and design solutions work towards improving community for everyone. Furthermore, there exists a wide range of expertise in any community that can be helpful to students working on engineering for sustainable community designs:

In an EfSC approach, students solicit input from community members throughout the design cycle. Such input can happen in face-to-face ways through interviews and community feedback sessions, or in asynchronous ways, such as through electronic surveys.

- Students can solicit input from community members through surveys and interviews as they define and refine a problem they wish to solve.
- Community members, including technical experts, can offer feedback on students' design ideas before they move towards building and prototyping. In their sketch-up, students include how their design solution would look and what materials they needed, along with both technical and social specifications.
- As students build their designs they can test them with different people and at different times to determine how well they work towards solving the problems they set out to address.

Through this process students learn to optimize their designs through integrating both technical and social (e.g. community) input, and become experts of their communities.

Reflection Questions

- What problems affect our community and how do we know?
- How can we use science and other expertise to design solutions that benefit our community?

IN ACTION
Switcheroo

The Switcheroo group decided to address the challenge of classroom interruptions. This design consisted of a parallel circuit connected to a hand-crank as the renewable energy source, with three LED lights. In their sketch-up they included how the Switcheroo would look and how it would work by using the materials provided. During the community feedback session, they explained that the handcrank would be inside the classroom, connected to the copper tape which was attached to the wall all the way out of the door in a parallel circuit connected at the other end to a cardboard with the three LED lights. The Switcheroo would signal to the incoming group when the teacher was ready to welcome them, once a student cranks the handcrank from inside the classroom, lighting the light on the outside to the awaiting students. This way, the incoming group would not barge in and interrupt the lesson, maintaining a respectful environment in the community. After presenting their sketch-up, students considered the community feedback and ended up including a box to hold the hand crank, which they made from recycled cardboard, based on that feedback.

> **You know how kids, or anybody, does good things and they don't feel accomplished? This way they can feel accomplished and anybody can know what they did.**
>
> **ISSA,** *on the purpose of the "All the Way Up" Light-up Accomplishment Board*

3 Cares about the environment

Engineering for Sustainable Communities involves designing solutions that minimize the impact to the environment, or even help to improve the environment. Minimizing impact on the environment can mean:

- Maximizing materials already available in classrooms/communities
- Using renewable resources, such as cardboard boxes
- Supporting renewable energy sources for projects requiring power (e.g. small 3V solar panels)
- Building projects that last

Students are encouraged to look at how their designs work, what their designs are made of, and how durable their designs are as some ways to think about how their design may minimize impact on their environment. For example, students can ask: How does the way my design works help the environment? How do the materials I am using to build my design help the environment? Will my project last for the school year?

All of these approaches push against engineering design challenges that support students in creating prototypes that are quickly recycled or destroyed.

Reflection Questions

- What materials are absolutely necessary for the design?
- What changes can be made to the design to make sure it lasts?
- What materials can be repurposed for the design to work well?
- What impacts does this design have on the environment? Can you reduce any of the negative effects?

> **I liked that we used recycled stuff, instead of buying a lot, and I liked that it was for the community.**
>
> **GABRIEL,** *on his impression of i-Engineering (His class thought recycling was a significantly important issue on their community survey.)*

> **It encourages kids to use renewables and recyclable materials to do projects.**
>
> **WILL,** *expanding upon Gabriel's comment.*

IN ACTION
Tablón de Positivo

A group of sixth grade engineers decided to design a bulletin board with cardboard, recycled paper, LED lights, and a hand-crank generator so that students could post notes with positive messages for all to see. The purpose of the bulletin board, which they named "Tablón de Positivo," was to persuade their peers to stop writing "bad" things on the bathroom walls. This was becoming a problem for their class and for the other classrooms too, because every time new writings on the wall appeared, the bathroom was closed to student use. If students needed the bathroom, they then had to walk all the way to the front of the building to use the office bathroom. The Tablón de Positivo, which included a complex parallel circuit allowing a single 12V hand crank to power the string of 12 lights, brightly displayed the students' positive messages. By using a renewable energy source and using the reusable materials, they intentionally made a design that cared for the environment.

EfSC IN CLASSROOMS

4 Designs solutions for now and in the future

Learning to balance trade-offs equitably among environmental, social, and technical effects of designs is an important challenge for engineers. However, learning to make trade-offs in the process of refining and optimizing solutions is an important part of engineering design. In an EfSC approach, students learn to gather and evaluate multiple but different forms of evidence. This process can be reciprocal and help students to engage more deeply in the often challenging technical side of their designs.

For example, analyzing community perspectives can help students further consider the technical dimensions of their projects, such as figuring out how to design for the higher power requirements of multiple lights, when community feedback indicated a sign should be brighter to capture more attention. The involvement of relevant perspectives in both engineering and local communities (e.g. parents, teachers, engineering experts, etc.) and evaluating the degree of their impact in the design process, help to maintain the balance of perspectives in this process.

Reflection Questions

- What design features are most important if I want my design to work for the whole school year?
- How do my design decisions impact the people most likely to use my design?
- What design features are "a must" and what features are "optional" for my design to work in a way that solves the problem I identified with my community?

> **It's solving how some kids feel like when they do good things they don't get rewarded. We have that board and they can get rewarded . . . because more kids need to get rewarded; it makes them feel good.**
>
> ISSA, *on the purpose of his group's engineering design*

> **Because if [students are] not having fun, they're going to be bored and they'll want to have fun, so they're going to get it out while they're learning, and when they're doing that they're not learning real stuff.**
>
> CORY, *on school needs to be fun*

IN ACTION

Switcheroo

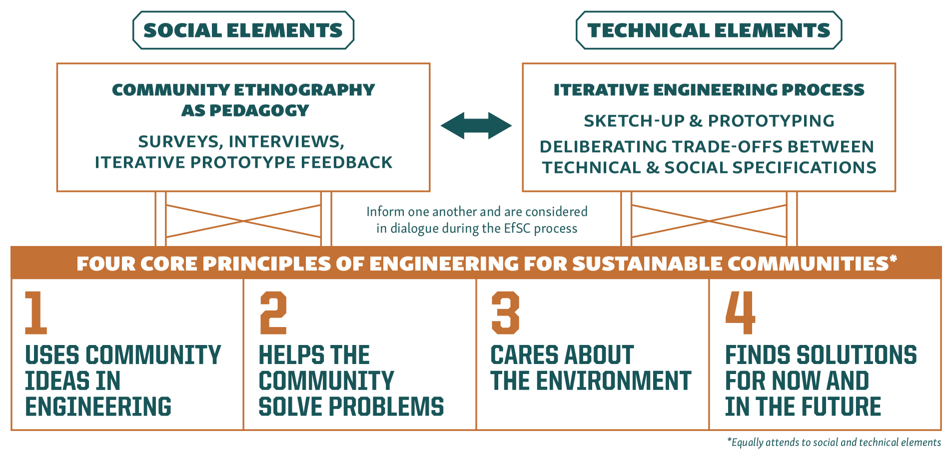
The young engineers in charge of the Switcheroo shared their prototype with the school community. During the STEM school night showcase, they had the opportunity to show caregivers, school staff, and other community members how to use the Switcheroo. They also had the opportunity to show and explain their project to kindergartners during a mentor day at their school. In preparation for the school night showcase, Ruby, Sasha and Blake made sure to refine their prototype by adding a pocket-box to hold the hand crank, so it could be ready for presentation. They learned that they needed to put the pocket lower and make it more durable so that the younger children could reach it and not accidentally break it.

TEACHING APPROACH

Social and Technical Elements of Design

The EfSC teaching approach is underpinned in a stance of consequential learning. Consequential learning involves opportunities to develop deep and meaningful disciplinary understandings and practices—in this case, science and engineering. However, consequential learning also focuses on how learning happens in ways that disrupt and transform traditional forms of power in science and engineering. It supports students in developing as "community science experts" for example, where their knowledge and practices from their communities matter in what they know and do in engineering.

This stance on consequential learning thus values forms of participation that extend beyond "studenting", broadening the *who* and *what* areas of expertise to help all students gain a rightful presence in school science. With this consequential learning stance, *who* students are in their everyday lives, *what* and *who* they care about and *why* they care, are fundamental to the engineering process. We think of these questions as resources for the **social elements** of the engineering design, to be considered in dialogue with the **technical elements**, which would be the NGSS standards, relevant disciplinary core ideas, engineering knowledge and practices.



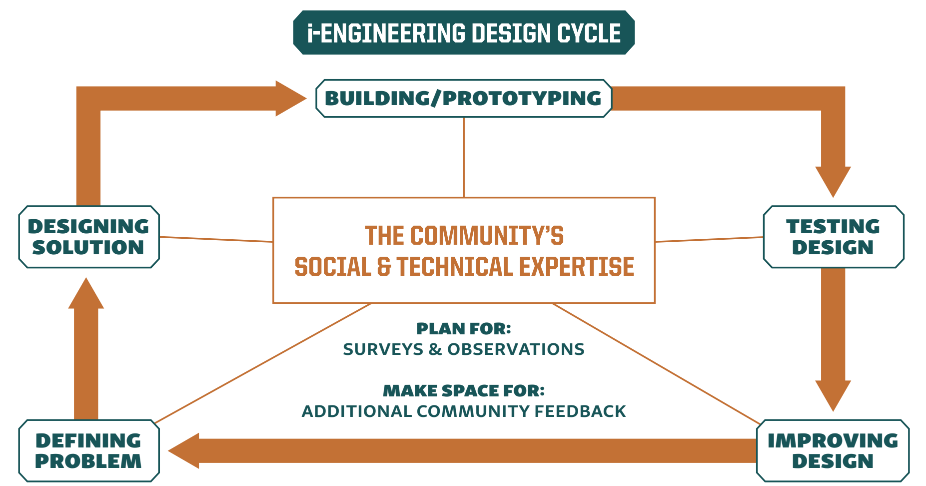


Figure 3.1: Pedagogies of community ethnography in engineering design

The EfSC Design Cycle

The EfSC design cycle guides students through iteratively eliciting and leveraging community perspectives as they engage in the practices of defining problems and designing solutions as they engineer for sustainable communities.

The core principles for EfSC are also present in the EfSC design cycle. The elements related to communities' perspective and sustainability make the EfSC design cycle distinctive from other design cycles. The EfSC design cycle also serves as guidelines for the youth engineers while they engage in the design process.

As students engage in engineering design challenges, move through the EfSC design cycle in a non-linear way. Sometimes this means students will need a better understanding of the community problem when they are trying to initially design a solution so they then can return to the defining the problem step. In another example, students might realize while testing their designs that their engineering design will not last long into the future so they have to return to the build stage to make it more durable. In your classroom, display the engineering for sustainable community's design cycle. You can also incorporate it into your slideshows. You can access the image to be printed in multiple sizes **here.**

Figure 3.1 illustrates the integral role of pedagogies of community ethnography in engineering design. Teachers can **plan** to have students use surveys, participant observations throughout the whole engineering design cycle. Teachers **can make space** for students to decide when they need more community perspectives and leverage additional surveys, observations or interviews. Below we highlight each community ethnography tool and provide ideas for teachers to both plan for their use and make space for students to determine and gather community perspectives as needed.

Pedagogies of Community Ethnography

Community ethnography is using research methods like observations, interviews and surveys to learn more about one's community members, their wants and needs. Students using community ethnography can leverage multiple forms of expertise as they engage in defining problems and designing solutions that transform their community to be a more just place. Integrating community ethnography supports more equity-oriented science teaching by supporting students in learning with and for their community. To effectively engage in these practices, students ask questions and gather information to determine specific challenges that need to be addressed. In this process, they gather and analyze information to properly define the dimensions of a problem. While students engage in designing solutions, they determine and balance different constraints for their science and engineering design. Community ethnography supports students in optimizing their solutions to be responsive to community wants and needs.

Pedagogies of Community Ethnography as a part of Engineering Teaching and Learning involves:

- A **stance** that community knowledge is a valuable part of disciplinary knowing and necessary for effectively engaging in the practices of defining problems and designing solutions. This is the starting motivation for supporting students using community ethnography.
- **Instructional moves** which support students, teachers and community members in interacting in different ways and in different spaces. These moves also help teachers to notice, value and respond to students' cultural and community knowledge and practice as important in learning and doing engineering.
- **Tools** which position students and teachers as co-learners of community concerns and their intersections with disciplinary knowing and classroom activity. The main EfSC tools include: making participant observations, administering surveys, and conducting interviews. These tools support students in defining problems by soliciting information from their community, and designing and optimizing their designs by gathering more community feedback. Teachers and students can collaboratively decide which community members' perspectives matter most their investigation, and focus using their ethnographic tools with those people

Integrating community ethnography into engineering design can support students in balancing technical and social concerns as they work to use science and engineering practices in meaningful ways. Planning to use one of these tools into a lesson is a strong step to connecting students' science learning to their community.

> **When she told me to start off small and finish big, it gave me a great mindset, and it made me think more about what I was gonna do . . . A lot of the kids had good feedback, and when you hear other people's feedback, it makes you think like, 'Maybe I should do this different, or maybe I should fix this and stuff like that.'**
>
> **JASMINE,** *on feedback she received from a younger student and why feedback matters when engineering for sustainable communities*

HOW TO GET STARTED

Pedagogies of community ethnography can be used throughout any design challenge to incorporate youths' and community's ideas into engineering design. *Note: Pedagogies of community ethnography can be applied to any K–12 science content foci, not just engineering.* Consider the following steps:

1 **Identify K–12 Science Content/Curricular Area (e.g. Engineering, 6th grade)** How does the curricular approach connect or not to the needs, perspectives, and experiences of youths' and communities' as identified in a sustainable communities approach?

2 **Co-identify with youth who might be community stakeholders with expertise and experiences relevant to this content area**

3 **Solicit community data**
On-going throughout design cycle/investigation

4 **Analyze community data**
On-going throughout design cycle/investigation

5 **Leverage insights from community data to support design and continued iteration around its technical/social aspects**

TEACHING APPROACH

STEP 1

Identify Content/Curricular Area and Connections to Community

How does the curricular approach connect or not to the needs, perspectives and experiences of youths' and communities' as identified in a sustainable communities approach? To begin to answer this question reflect on the disciplinary core ideas, practices and funds of knowledge present in the unit.

Step 1: Identify Content/Curricular Area and Connections to Community	
What disciplinary core ideas are emphasized in this engineering design challenge?	
What engineering and science practices are connected to this engineering design challenge?	
What youth and community funds of knowledge are connected to the science design challenge/science investigation?	

STEP 2

Co-identify with Community Stakeholders with Relevant Expertise

Now that you have a sense of how the unit connects with youths and communities or not, consider whose expertise and experiences can support youth in deep sense-making of the content area.

Step 2: Co-identify with youth who might be community stakeholders with expertise and experiences relevant to this content area.	
What community experts within your school can support the EFSC design/science practice challenge planning?	
What community experts beyond your school can support the EFSC design challenge planning?	
What community, physical and environmental resources are connected to this engineering design challenge, students' lives and the disciplinary core ideas and practices	

STEPS 3–5

Solicit, Analyze and Leverage Community Data (Integrated)

As you think about integrating the ideas and perspectives of the people and identified above, consider:
1) What approaches you can take to solicit perspectives 2) When in the curricular experience these perspectives make the most sense for students to engage in dialogue with community members

TEACHING APPROACH

Participant Observations

Students can make participant observations to support their efforts throughout an engineering design challenge. Participant observations pay attention to the culture, norms/practices and people in a space as well as show they interact within a space.

1 Making participant observations: Making participant observations can be both a formal and informal process. As students are defining a problem or designing a solution, teachers could support students in deciding which communities matter in their investigation, and why. From these insights, teachers could then encourage students to consider what they would like to observe in their desired community, and how they might do so.

2 Analyzing participant observations and building explanations: Students should be supported in analyzing their participant observations as a way to justify their design choices. This can occur in whole group conversation and through group work. Teachers should have students consider how their participant observations inform their efforts to define problems or design solutions through group discussions and using graphic organizers.

IN ACTION

The "Knock No More" group created a system that utilized a hand crank generator, copper tape and LED lights to design a green-energy powered system that would allow for visitors to alert the class community that they were there, without making a loud noise. The Knock No More students made technical participant observations about how the direction that the door opened would impact where their circuit could go, and social participant observations about how to teach visitors to turn the hand crank in a clockwise direction for the lights to illuminate inside the classroom. As an informal assessment, Mrs. B asked the students to justify their design choices with evidence from their observations.

Another group, "The QA" group, similarly made participant observations that motivated their designs. They observed that not every student contributed to whole class conversations. One reason they discovered was that some students who were shy were hesitant to raise their hands. Therefore, they designed a green-energy powered system to alert the teachers and fellow students when they had either questions or answers to share with the whole class.

The "Knock No More" allows visitors to alert the class without making a loud noise.

TEACHING APPROACH

Surveys

Students can administer surveys to define problems that they want to solve with their community. Surveys need to be designed, administered, and analyzed.

1 **Designing Surveys** Teachers and students can collaboratively design surveys. Teachers could ask students what type of questions they want to ask as they work to understand the technical and social aspects of a problem. This conversation can happen in whole class and small group conversations. Additionally, surveys can be used to gather community members' ideas about what some possible solutions are for defined problems as well as highlight community assets that can be used when designing the solution. Students, with their teachers, could design a survey with both free-response questions and multiple-choice questions. Surveys can be designed using paper and pencil or electronic forms. Survey Monkey and Google Forms provide free options for surveys that support students in collecting and analyzing data. Teachers should support students in making sure they understand and can explain the questions to survey responders when they administer the surveys. Teachers can ask students to explain the survey questions in their own words. This facilitates smoother survey analysis as well as supporting the students in better understanding the problems they are defining.

2 **Administering Surveys** Students should be supported in thinking about who should be surveyed. Teachers can ask students: What community members' perspectives are we most interested in and why? Which community members' ideas matter most to our investigation? Who is most affected by the problems and solutions being designed? Students can first administer the surveys to each other before they reach out beyond their classroom community. Students can administer surveys in school and at home. Teachers can organize survey sessions or have students make plans to administer the surveys outside of class time. Students should only administer the survey to people they know or under supervision from an adult. Additionally, their teacher can share their survey through social media or email in order to gather responses from people if the students think that matters.

3 **Analyzing surveys** After administering the surveys, students analyze their data. This is an important aspect of the obtaining, evaluating, and communicating information practice. Teachers could project the survey results on a slideshow or print out the survey results. It is also helpful to separate out the responses from different community members (e.g. students, adults) in order to support students in understanding patterns in different groups' views. Students should use graphic organizers to analyze the data. The graphic organizers should have students analyze how many people chose each response, patterns in who selected/shared what, and support students in predicting why the responses were what they were and how to apply insights from the responses to their engineering work.

Here is an example of one Defining the Problem Survey:

EXAMPLE

School/Classroom Sustainability

We are working to make an engineering design to make our school community more sustainable. Do you have any questions before we start?

1. Which category best describes you?

- ❒ School Staff
- ❒ Student
- ❒ Parent or other adults in the community

2. What challenges related to a healthy and happy school/class community do you think are most important? (select 2 or 3)

- ❒ Wasting natural resources
- ❒ Need more sense of community
- ❒ Need to do more things as a class to make a difference
- ❒ Need to feel safer
- ❒ More opportunities to celebrate accomplishments
- ❒ Needs to be more fun
- ❒ Needs to be more happy and positive
- ❒ Needs to be more fair
- ❒ Need more chances to do something important

3. What other challenges related to happy and healthy communities do you think are important?

TEACHING APPROACH

Graphic Organizers

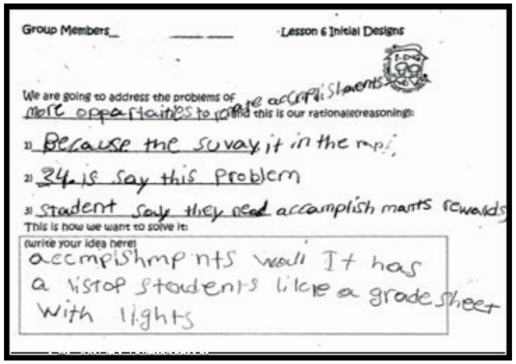
1. Kids Results

What are the top 3 problems kids identified?	What percentage of kids cared about this problem?	Why do you think this is a problem?

2. Adult Results

What are the top 3 problems adults identified?	What percentage of adults cared about this problem?	Why do you think this is a problem?

TEACHING APPROACH


Group Members___ Lesson 6 Initial Designs

We are going to address the problems of more oppartaites to get accplishments and this is our rationale/reasoning:

1) Because the suvay it in the mpi;

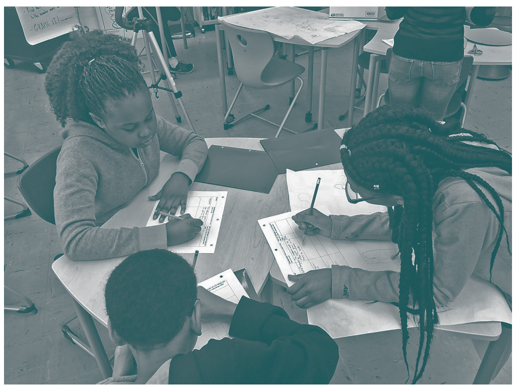
2) 34 is say this problem

3) Student say they need accomplish mants rewards

This is how we want to solve it:

(write your idea here)

accmpishmpnts wall It has a listof students like a grade sheet with lights



IN ACTION

Mrs. B went over a survey they were going to administer to better understand the sustainability issues that mattered most to their community. Mrs. B purposefully had students contribute to the survey design because their expertise as community members mattered. The students added and deleted questions. Then as a class, they decided systematically who they should interview based on who was most affected by their design and who had expertise that would support their efforts. They chose to interview a fifth grade class because they were impacted by similar issues as the sixth graders themselves. The sixth graders administered the survey to each other and then to the fifth graders. The students answered both open-ended and multiple-choice questions about their sustainability concerns and ideas.

After surveying the fifth graders, different sixth graders administered the survey to other community members, including Mrs. B, the school custodian, the administrative assistant and the students' services officer. The students decided that they would be impacted by their design efforts so their input mattered, too. Mrs. B actively encouraged students to seek out more survey participants because she valued the students' discretions on whose input mattered.

Next, Mrs. B supported students in analyzing what problems mattered most to different community member groups. The students also analyzed the qualitative data by looking for patterns in proposed solutions to sustainability challenges impacting their school community. The students then decided on what problems they wanted to address with their energy engineering designs. See the image at left for an example of student work.

TEACHING APPROACH

Interviews

Students can use interviews to better understand the technical and social dimensions of the engineering practices of defining problems and designing solutions. Teachers can support students in designing, conducting and analyzing interviews to improve the technical and social dimensions of their designs.

1 **Designing Interviews** Interviews can be utilized at any stage of a unit. First, teachers with students can determine a goal for the interview, such as defining a problem or optimizing a design solution. Then, students should write 3-5 questions. They should write a mixture of technical and social questions because science and engineering require this approach to be responsive to communities. Students should then identify who should be interviewed based on who is impacted by the issue they are studying.

2 **Conducting Interviews** Students in groups should take turns asking and recording the responses of interviewees. Have students take notes during the interview. Students can interview multiple people using the same interview protocol.

3 **Analyzing Interview Feedback** After interviews, students should systematically analyze the responses that they received. Ask students to discuss and record: What did they learn? How will it impact their plans?

> **I think it's gonna solve a problem for the future too because I'm gonna be gone soon, so when the next fourth-graders and fifth-graders come – when they see that sign, maybe they'll think, 'Oh, I like that sign. I wanna do that when I get in that grade.'**
>
> **JASMINE**, *on how her design would motivate future students*

IN ACTION

Mrs. B's class conducted interviews after they sketched-up their initial design solutions to make their classroom community more sustainable. The students' sketch-ups were designed to address the problems they defined, based on their previous survey and participant observations. The sketch-ups had each part of their engineering design labeled, with short descriptions of how it worked. Mrs. B had a conversation with students about how to design an interview that would elicit both technical and social feedback because both types of information supported the students in designing solutions that were effective. Each group generated technical and social questions that they wanted feedback on, for their designs. They also determined that they wanted community experts and engineering experts because they wanted feedback on both the technical and social aspects of their design solutions.

The students wrote their questions in groups, took turn asking them and writing notes on their feedback. Each group interviewed three community members. Mrs. B then supported them in reading through their feedback and revising their sketch-ups before they began building them. These revisions helped the students in optimizing their design as well as providing formal assessment information for Mrs. B to analyze how students were able to leverage interview data.

These interviews occurred during a planned feedback cycle event that allowed for every group to get feedback from many community members from both within and beyond the school community. The students engaged in another feedback cycle when they shared their built designs with the fifth grade students that they surveyed. Based on the students' feedback, the groups were able to optimize their design a final time.

TEACHING APPROACH

Authentic Engineering Design

Engineering for sustainable communities emphasizes designing solutions for now and in the future. This requires planning before, during and after a design challenge. When defining a problem, students need to be supported in understanding the technical and social dimensions of the problem. When designing solutions, students need to leverage the expertise of community members who will be impacted most by the design and students need to not just make the engineering design, but negotiate with all stakeholders to determine when and how the design should be used. After the engineering design challenge, students should be supported in gathering data on how their engineering design is working, analyze that data and then optimize their engineering design. Below are examples of templates students can use to A) determine success criteria and B) develop a plan to analyze and optimize their engineering designs impact:

DETERMINE SUCCESS CRITERIA

Engineering Design:____________________

Name(s):____________________

Our prototype's goal is:____________________

	1. How can you tell if your engineering design is meeting your goal?	2. How can you collect data to evaluate this criterion?
Who is using the prototype? Who should be using the engineering design?		
How often should the engineering design be used?		
What changes should happen if your design is successful?		
How will you know if your design is sustainable (e.g. not making waste, working for a long time)?		
List any other criteria for evaluating if the engineering design is reaching your goals for it.		

TEACHING APPROACH

ANALYZE & OPTIMIZE

Planning

1. What tool(s) will you use to evaluate your engineering design success criteria? Surveys, observations, interviews, other ideas?

____

2. Why this tool?

____

____

3. Whose expertise and experiences will you gather?

____

____

4. What are three specific questions you will seek answers to?

I.

II.

III.

5. Share your plan with another group or your class and get one of your classmates' initial's here after you get feedback: __________

6. Update your plan based on their feedback.

7. Share your plan with your teacher and get their initial's here: __________

Invite students to discuss when and how often they think they should gather more community perspectives to optimize their design.

IN ACTION

Authentic Engineering Design

Mrs. B's class completed the engineering design challenge of making their classroom community more sustainable using a green energy source, copper tape, LED lights and classroom materials. One small group decided they wanted to support students who were feeling anxious, sad or upset. They initially created a light-up calm down corner, but they realized that their design was not being used enough. Therefore, they created a new solution: the Joyful box. The students talked with their teacher, classmates and school secretary as they sketched their solution. Then they built their prototype: a handcrank generator-powered light up box with a slot for students to write encouraging notes to peers and teachers. They put the box in the front office of the school. They wrote directions about how to use it, and revised those questions based on the school secretary's feedback. They posted those directions next to the box at the front office and shared them with all of the teachers in the school as a way to inform all of the students about how to use the box. They then kept track of how many notes were written and delivered each week and talked to teachers and students in the classes not writing many encouraging notes.

SUPPORTING POWERFUL OUTCOMES

Powerful Learning

The EfSC approach supports three dimensions of powerful learning:

STEM Knowledge & Practice An engineering for sustainable communities approach focuses on supporting students in developing deep knowledge of and abilities to use and iterate with engineering practices. The approach also emphasizes how such practices are always tied to both content and context. Emphasized are disciplinary core ideas of energy transformations, sources, and systems, green energy and the environment.

STEM Identities An engineering for sustainable communities approach supports students in seeing themselves as powerful experts in science and engineering—with the technical and social know-how to solve issues that matter to them and their communities. Who one is, in the past, present and possible futures, is tied to the opportunities one has to learn and enact new practices and activity with others. If a young person does not have the opportunity to learn the content and practices of engineering, it would be difficult for them to enact 'being an engineer' in ways that will be recognized by others. At the same time, if one cannot identify with engineering by does not see oneself as an important part of an engineering learning community, there will be barriers to learning new ideas.

STEM Agency An engineering for sustainable communities approach focuses on supporting students in feeling capable, able and welcome to use science and engineering and other expertise in ways that matter. Learning involves so much more than understanding. It involves doing in real and authentic ways. This approach supports students in taking action with and in science and engineering towards solving authentic problems they care about.

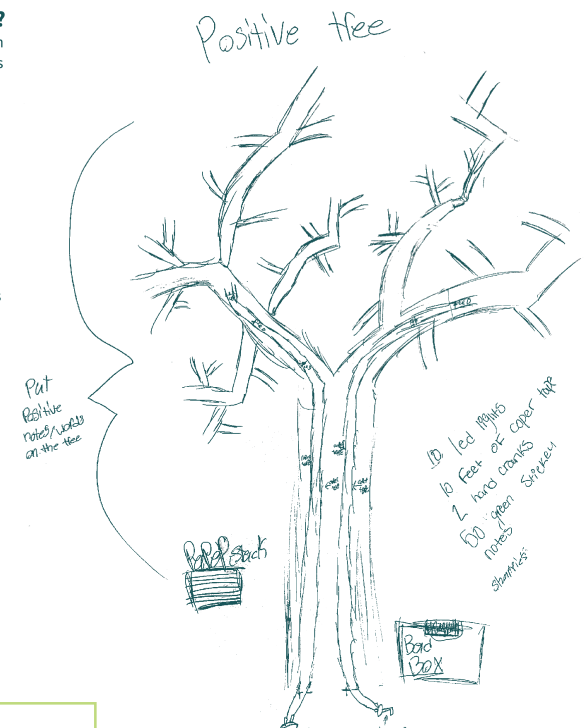
> **We actually collaborated with each other and used everyone's ideas, not just one person's. Not one person only worked on it; it was all three of us.**
>
> JASON, *on his team's light-up birthday board*

SUPPORTING POWERFUL OUTCOMES

How are these three outcomes supported?

An engineering for sustainable communities approach can support powerful and more just learning outcomes in science classrooms by:

- **Expanding whose expertise matters.** Enacting engineering for sustainable communities requires students to leverage the expertise of multiple communities. This challenges the way that science education has often positioned scientists and engineers as the only experts.
- **Expanding what expertise matters.** A successful engineering for sustainable communities engineering design requires a wide range of social and technical expertise. This approach recognizes and values students and their communities' broad expertise from multiple areas of their lives.
- **Positioning students and teachers as co-learners.** An engineering for sustainable communities approach supports teachers in distributing authority to decide both what and how students want to use engineering to help their community. This is a shift from teachers determining the problem space and design solution in engineering.
- **Design challenges that address justice.** The design solutions students create often challenge oppressive norms and create powerful new opportunities for students and their peers and communities to be welcome and celebrated. As students make their communities happier and healthier, they are creating new norms that recognize the humanity of their community.



> **People are like, I can't believe sixth graders did that. They just can't believe it . . . And it shows we're smart, and we can stick with it.**
>
> ANALEIGH, *on reactions to her engineering work*

I think they would be probably surprised because I'm not like, I'm younger and I made this and it really does work. So, if they found out I made it they'd be like, 'oh my gosh' because I made it with my group, and it was actually pretty hard to do so I think they'd be surprised.

MCKENZIE, *predicting how people would react when they found out that Lucena, Cory and she made a light-up limbo-stick.*

EXAMPLE

The Occupied

Consider how three youth built the Occupied to solve the problem of bathroom bullying, a problem the youth demonstrated targeted the boys of color in their classroom.

The Occupied used the bathroom light as a switch to activate a solar panel, which powered three LED lights, in parallel circuit, affixed to the bathroom's outer wall. When the bathroom light is turned on, the LEDs on the outer wall light up.

Meg said, "Sometimes kids make a mistake. We want to stop the kids who do this on purpose" and "then spread rumors" about the students barged-in upon.

Mateo explained, "We call it 'The Occupied' because it's supposed to show you when the bathroom is **occupied** . . . I think this is a good problem to solve. I think it will help our community. Especially boys. The girls usually have someone watch the door, but a lot of us don't. Tomas got walked in on twice! Now he never goes to the bathroom during the day . . . In the 6th grade hallway, they make up rumors. It's ridiculous."

With teacher support, students studied the bathroom problem by conducting, then analyzing, surveys, interviews and observations in their school as a part of STEM class. They used these data to design a way to implement their lighting system so that it could effect change.

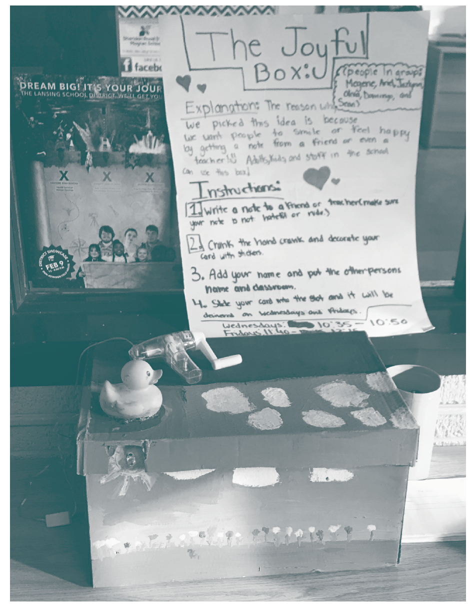
Using Community ethnography data across the design cycle supported youths' STEM identity work and agency because these data became public epistemic resources that made youths' lives and the possibilities for social change visible and important. When students modeled their data through charts, graphs, and bubble maps, it created space for new STEM/community hybrid discourses to emerge as they talked about what these representations meant. These discourses integrated STEM knowledge and knowledge of the needs of communities.

For example, in referencing their observations and mapping them onto the survey data, Mateo pointed out that kids barged in a lot, in the classroom and in the bathroom. As he stated, "It [the survey] got us thinking about how the bathroom, it is a real problem." The group then conducted further observations and interviews to learn more about how the problem played out across different school spaces.

Community Ethnography also became a space for their teacher to learn more about how her classrooms operated as well. Ms J said, "Having the ethnography and survey, and putting it in the spotlight, their interests and everyday concerns, I was surprised . . . This project—and I really was not sure they could get it done—is actually changing my classroom."

Youth produced postcards to share with family and friends that showed pictures of their engineering designs, the problem space, descriptions of how and why they work, including the technical and social specifications, and information about themselves.

ACKNOWLEDGMENTS



You know how when you do something nice for someone else and your heart feels big? That is how I felt.

MALIA

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It says I am determined. I can push through, and that I care about people. I am creative and smart.

SAGE, *on how the electric art she designed represents her.*

For more information on i-Engineering

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