A Sociotechnical Approach to Engineering Education: Engineering Social Justice for Elementary Preservice Teachers

by David Kimori, Minnesota State University, Mankato; & Charlene Ellingson, Minnesota State University, Mankato

Abstract

In this article, we describe an assignment that we have developed in our Engineering for Elementary Teachers course. The assignment was designed to address social justice within the engineering design process. In this course, preservice teachers (PSTs) develop an engineering project that integrates six criteria of engineering for social justice into their lesson plan as a way to make the social relevance of engineering more apparent. Beyond having teachers develop an engineering lesson plan, the goal is to increase awareness of the social justice dimension of engineering as a strategy for integrating culturally relevant pedagogies into engineering lessons. In this article, we share several lessons our PSTs have developed as well as insights that they gained about the relationship between engineering and social justice. We also share some of the challenges that the PSTs faced and the insights that we gained about integrating social justice criteria into engineering lessons.

Introduction

Science education reform goals call for engineering to have a larger presence in K–12 education (National Research Council, 2010); however, engineering education typically focuses on the technological aspects of engineering (Leydens & Lucena, 2018). Hynes and Swenson (2013) point out that this emphasis on the technological aspects without a similar emphasis on the social aspects creates a dichotomy between “hard” and “soft” sciences, inferring that the humanistic aspects of engineering are unreliable and that the engineering components are more important. They call for educators to “consider the humanistic side of engineering as a distinctly important, but not separate, part of engineering that needs to be systematically researched as such ideas are adopted across programs and curriculum” (p. 32). Leydens and Lucena (2018) support this position, pointing out that technical problems engineers deal with do not happen in a vacuum; they involve social factors that shape and are shaped by human needs. Integrating the social aspects of engineering problems into the technical aspects of engineering design provides an innovative approach to engineering education and a strategy for adopting a social justice lens (Leydens & Lucena, 2018). The phrase “social impact of engineering” refers to approaching engineering problems through a human-centered lens, designing for human well-being and environmental sustainability (Davis et al., 2009).

To define social justice in an educational context, we borrow from two fields of design, engineering (Leydens & Lucena, 2018) and human-centered design (IDEO.org, 2015). We define social justice as using human-centered design to emphasize the needs and experiences of the end user and create learning experiences and opportunities that reflect underrepresented groups. How the engineering field conceptualizes and designs for learning engineering is consequential for all youth because it is widely agreed that education in the STEM disciplines is important to the nation's economic and innovative future (Honey et al., 2014). This is especially important for "youth growing up in nondominant communities" who are underrepresented in the STEM disciplines (Tan et al., 2019, p. 1012).

Engineering education research has "largely ignored the power and importance of such social processes in relation to equity concerns (Sandoval, 2014)" (Tan et al. 2019, p. 1013). A few engineering curricula have addressed cultural dimensions, such as Engineering is Elementary (EiE), with their use of stories to provide multicultural contexts for engineering. One critique of the EiE curriculum is that it is ineffective at addressing cultural competency in teachers because "some of the EiE curriculum . . . seem[s] to unintentionally promote colonized thinking, romanticized notions of engineering as a pure human endeavor; and culturally and socially unauthentic scenarios" (Rodriguez & Shim, 2021, p. 1). To our knowledge, social justice has not been a focus of engineering curriculum and may provide a more authentic approach due to its grounding in real-world problems with a humanistic lens. Culturally responsive teaching has been successfully used in all content areas, but such approaches are more common in the humanities than in the sciences (Reddick et al., 2005). Like other educators, science educators must have the opportunity to refine their ideas, beliefs, and goals, including their multicultural awareness and understanding (Gipe et al., 1989).

The position that STEM teachers must be prepared to serve all students and provide them multiple perspectives (Lindholm-Leary & Borsato, 2006) is also supported by STEM education organizations, including the National Science Teachers Association and National Science Education Leadership Association (Rhoton & Bowers, 2001). For example, Wojnowski (2001) writes, "We [educators] must develop mindsets that allow our students to understand and be sensitive to the intricacies of cultures that are very different from our own" (p. ix). Therefore, there is a need to integrate the social and technological aspects of engineering design into PSTs learning experiences (Leydens & Lucena, 2018). Providing opportunities for preservice teachers (PSTs) to make engineering education relevant to their pedagogy and practice can provide a way to serve all students and change the perception of engineering as being largely technical. It is important that PSTs develop culturally responsive pedagogical practices, and engineering has the potential to be inclusive of historically marginalized students who may not see science as being relevant to their lives or future (NGSS Lead States, 2013). By solving engineering problems in local contexts, students gain knowledge of science content, view it as relevant to their lives and future, and engage in socially relevant ways (NGSS Lead States, 2013). According to Darling-Hammond et al.

(2017), this process of engaging teachers in both designing and participating in the same type of learning is referred to as active learning. Active learning forces PSTs to adopt two perspectives, that of the learner and that of the teacher. This process of shifting perspective helps our PSTs begin to adopt an understanding of what it takes to help students learn and develop an awareness of how social justice can serve as a culturally relevant pedagogy.

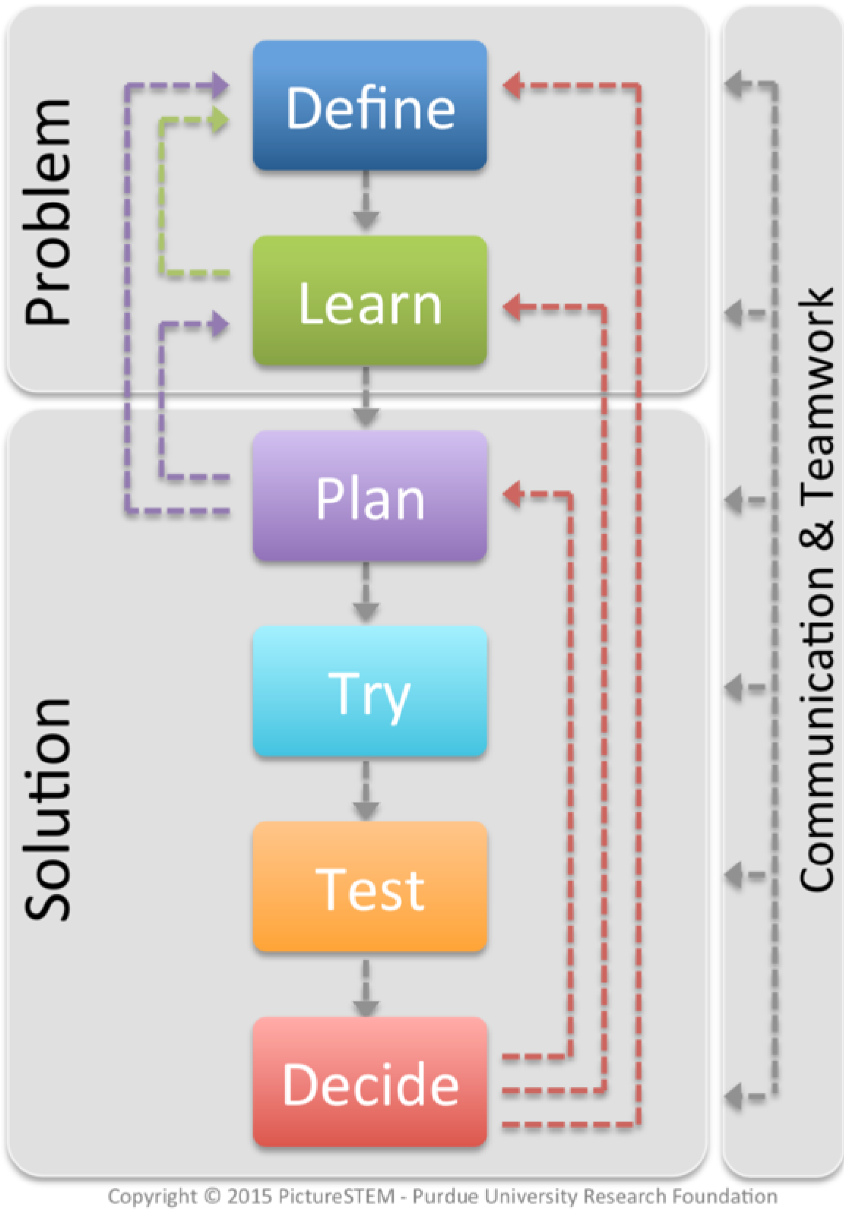
In our efforts to integrate social justice into our engineering course, we sought to address the gaps in STEM PSTs' preparation (Wendell, 2014) by introducing sociotechnical issues into the engineering course. The purpose of this article is to demonstrate how we have embedded social justice into our engineering course for elementary teachers using the Engineering for Social Justice (E4SJ) criteria to introduce human-centered design into the technical aspects of engineering. Though well-established in engineering circles, E4SJ criteria have not, as far as we know, been utilized in engineering education.

The Engineering Design Process

The hallmark of engineering is the use of real-world issues and its reliance on science and mathematics to inform designed solutions (Moore et al., 2014), which can make learning in the sciences more motivating for students (Honey et al., 2014). The engineering design process model is widely used to introduce students to the engineering design process. Although there are many different versions of the engineering design process, we find the one created by Moore and colleagues for the PictureSTEM Project (2015) to be easy to read and in alignment with the *Next Generation Science Standards* (NGSS). The PictureSTEM engineering design procces is shown in Figure 1.

Figure 1

Visual Overview of the Engineering Design Process (PictureSTEM, 2015)



Note. From *Engineering Design Process: A Way to Improve*, by PictureSTEM, 2015 (http://picturestem.org/wp-content/uploads/2017/07/PictureSTEM-Slider-Poster.pdf) Copyright by PictureSTEM, 2015. Reprinted with permission.

The engineering design process begins with the identification of an engineering problem, background research on the problem, and identification of the criteria and constraints that define successful designed solutions (Moore et al., 2014). Development of solutions involves an iterative process of planning, prototyping, testing, and evaluating the degree to which designed solutions meet stated criteria (Moore et al., 2014). As Moore et al. note, throughout the process, students learn about engineering processes, the ability to work under constraints, and that the work of engineers is driven by the client. In order to solve complex, real-world problems, the engineering design process also considers safety, effective use of resources, and the impact of designed solutions on people and the environment. In our experience, these human aspects of engineering often get overlooked. To address this problem, our innovation was to explicitly emphasize the social dimensions of engineering, utilizing the E4SJ criteria. The E4SJ framework provides a way for educators to incorporate the human dimensions of engineering practice while preserving the technical dimensions of engineering (Leydens & Lucena, 2018).

Engineering for Social Justice Criteria

The E4SJ framework makes the human dimensions of engineering visible to engineering practice and shifts the emphasis from "problem solvers" to "problem definers" by emphasizing the impact of engineering design solutions on people, especially communities who are often marginalized (Leydens & Lucena, 2018, p. 20). In this sense, the E4SJ framework reconceptualizes traditional approaches to engineering as sociotechnical (Leydens & Lucena, 2018). The E4SJ framework emphasizes six criteria: "listening contextually," "identifying structural conditions," "acknowledging political agency/mobilizing power," "increasing opportunities and resources," "reducing imposed risks and harms," and "enhancing human capabilities" (p. 21). These criteria are defined in Table 1.

Table 1

E4SJ Criteria for Integrating Social Justice in Engineering Design (Leydens & Lucena, 2018)

E4SJ criterion	Definition
Listening Contextually	"Listen to different human perspectives" to ensure that the social context shapes the technical outcomes (p. 21).
Identifying Structural Conditions	Emphasis on the structural conditions "that facilitate or constrain . . . possibilities," which challenge or maintain inequality (p. 23).
Acknowledging Political Agency and Mobilizing Power	Help stakeholders acknowledge and mobilize political power and enact a more socially just engineering product or service.
Increasing Opportunities and Resources	Ensure engineering designs that can increase opportunity for end users and are accessible to individuals without large resources.
Reducing Imposed Risks and Harms	Decrease risks (e.g., safety, environmental) and harms (e.g., restricted access to education, technology, and/or infrastructure).
Enhancing Human Capabilities	Ensure that project outcomes enhance human capabilities and "control over one's . . . environment" (p. 29).

At the elementary level, a typical engineering design challenge uses engineering to establish a real-world context for the learning to follow and emphasizes the technical aspects of a problem or issue to be solved through the engineering design process. For example, students might be asked to establish a context with a real-world scenario that introduces an engineering problem and emphasizes the technical criteria that define successful solutions and constraints within which they must work. By expanding the emphasis to include attention to the end user within the problem definition phase, the E4SJ framework draws attention to social justice issues and has the potential to make real-world contexts more authentic.

Context and Course Overview

Our elementary PSTs have an opportunity to include additional certifications, including a certification in STEM. To earn the Elementary Education STEM Certificate, PSTs take courses such as Engineering for Elementary Teachers, new technologies for elementary learners, integrated STEM curriculum, and related topics courses. Our Engineering for Elementary Teacherscourse examines current research on inclusive teaching and learning, and it also gives PSTs the opportunity to engage in a hands-on engineering design challenge (see Table 2). Furthermore, the use of the E4SJ framework in this course introduces PSTs to what Leydens and Lucena (2018) refer to as "sociotechnical" elements (p. 50). We have used this sociotechnical approach to engineering education with PSTs for three semesters, with a total of 53 PSTs.

Table 2
Overview of the Engineering for Elementary Teachers Course

Timeline	Topic	Assignment
Week 1	Conceptions of Engineering	Research types of engineering
Week 2	Engineering and Engineering Design Process	Applied engineering design process to mature technology
Week 3	Engineering Education and Engineering for Social Justice	Analyze lesson plan and technological artifact using 6 Engineering for Social Justice Criteria (E4SJ)
Week 4	Engineering Drawing: Tinkercad, Orthographic, & Isometric	Drawing portfolio
Week 5	Reverse Engineering and System Thinking	Assemble and disassemble a disposable camera and create a lesson plan
Week 6	Engineering Education & Engineering Curriculum in Elementary	Evaluation of preexisting EiE curriculum
Week 7	Engineering Lesson Planning and Prototyping	Prototype Interview
Week 8	Final Engineering and Social Justice Project & Reflection	Engineering for Social Justice Lesson Plan, presentation and reflection

Course Assignment on Sociotechnical Engineering

In order to help PSTs successfully navigate the creation of an engineering lesson plan that engages students in real-world, ill-structured problem-solving, we first had PSTs evaluate a preexisting engineering design task for sociotechnical elements. We provided them with EiE curriculum, and they selected a lesson plan to evaluate. This helped them see what social or technical components might be present or missing. We introduced PSTs to the technological aspects of the engineering design process and the social dimensions of engineering using the E4SJ framework, thereby addressing the sociotechnical perspective of this assignment.

Following introduction of the engineering design process and engineering criteria for social justice, we proceed with a discussion about the implications for embedding elements of social justice into engineering. In particular, a discussion of the fact that a separation of the technical and social aspects of engineering does not fully reflect the real-world goals of engineering education because engineered products are for people and communities and, therefore, have social, cultural, and political dimensions (Leydens & Lucena, 2018). Thus, we extend the technical problem definition and the problem-solving dimension of engineering by asking questions guided by those posed by Leydens and Lucena, such as: “Who and what is engineering for,” and how can engineering be a force to counter oppression in historically marginalized communities (p. 9)?

Evaluate Engineering Technological Design. To help the PSTs understand the criteria better, they are given an assignment to evaluate a mature technology using the E4SJ criteria. A mature technology refers to a well-established, human-engineered technology such as phones, television, bicycles, or cars. Through this activity, PSTs learn to apply the E4SJ criteria to technical designs to find which of the criteria are evident and which are missing. This aligns with the Framework for Quality K-12 Engineering Education (Moore et al., 2014) and the NGSS. For example, to address NGSS Performance Expectation 3-5-ETS1-2 for Engineering Design (“Generate and compare multiple possible solutions toa problem based on how well each is likely to meet the criteria and constraits of the problem” [NGSS Lead States, 2013, p. 53]), PSTs might be asked to describe how science and engineering influence and are influenced by local traditions and beliefs, such as sustainable agriculture practices used by many cultures*.*

Introduction of the Assignment*.* Following evaluation of a preexisting engineering lesson, PSTs develop an engineering lesson plan that integrates sociotechnical elements from the E4SJ framework into an engineering design challenge. The assignment requires PSTs to write a lesson plan in which students create a prototype of a new product or improve on an existing product. The activity is focused on coming up with an engineering design challenge that has a social dimension. Because of the complexity of generating an authentic engineering task and learning to write a lesson plan with a coherent scope and sequence, we scaffold the activity by having PSTs move between student and teacher perspectives by engaging as a learner. This models the engineering design process and helps them gain insight into how PSTs might experience the lesson by taking a broader perspective, identifying content and skills necessary for their future students to be successful with the task.

In shifting their perspective between student and teacher lenses, PSTs engage as learners to gain first-hand experience with incorporating E4SJ criteria into engineering lesson plans as well as brainstorming and creating prototypes that meet the criteria and constraints they established, including the sociotechnical aspects. This process informs their curriculum design ideas, both conceptually and physically, which provides insight into how their future students may experience their lesson, including the potential challenges students might face.

E4SJ Class Project

In this section, we describe how we model the project and provide teaching tips for scaffolding it.

Brainstorming Ideas and Sharing Ideas in Class

During class, PSTs are given time to brainstorm and research design challenge ideas. Brainstorming aligns with the Framework for Quality K-12 Engineering Education (Moore et al., 2014) and the NGSS through the engineering design process, which is referred to as the “Process of Design” in the framework, particularly the “Problem and background” stage during which students identify an engineering problem and develop a plan to address it (Moore et al., 2014, p. 5). One example is NGSS Performance Expectation 3-5-ETS1-1. “Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.” (NGSS Lead States, 2013, p. 53).

Brainstorming Teaching Tips. We have found that being intentional about separating brainstorming and research can be helpful for getting a better diversity of ideas across the class. Group size has a big impact on brainstorming. In the past, we have placed PSTs in groups of two or four; however, many PSTs find it difficult to think of ideas. Placing PSTs in groups of five or six and structuring the brainstorming session can elicit more ideas and, often, better ideas. In their brainstorming sessions, we instruct PST groups to list as many ideas as they can generate in 10 minutes and post each idea in a public space. Posting their ideas turns the process into a bit of a game and prevents them from focusing in on one idea too early. It also creates a separation between brainstorming and doing the background research on lesson plan ideas, which allows for more focus on each task.

Design and Build Prototypes

At this point, the PSTs are allowed time to design and build the prototype of their innovated product or an improvement of an existing product. This aligns with the “Process of Design” indicator in the Framework for Quality K-12 Engineering Education (Moore et al., 2014, p. 5).

One example is NGSS Performance Expectation 3-5 ETS1-1 for Engineering Design: “Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost” (NGSS Lead States, 2013, p. 53).

Prototyping Tips. We have found that it is tempting to skim over the iterative testing and redesigning of prototypes due to time limitations. However, we have also found that reprototyping can be very helpful for bringing greater understanding to underappreciated aspects of engineering, such as the role of materials in engineering and systems thinking. For example, giving PSTs redesign instructions to improve functionality forces them to think about how their prototype functions as a system. Providing them with additional resources, such as figuring out ways to fasten different materials together without tape or glue, for example, can grow their awareness of materials.

Interviewing Potential End Users

After the PSTs have developed an idea for the prototype they will create, they interview potential end users of their products to get feedback about the products and improve their lessons. It should be noted that this is an iterative process, so the PSTs utilize the end users’ comments to improve their ideas and prototypes. This aligns with the “Issues, Solutions, and Impacts” indicator in the Framework for Quality K-12 Engineering Education (Moore et al., 2014, p. 6). One example is NGSS Performance Expectation 4-ESS3-2 for Earth and Human Activity: “Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans” (NGSS Lead States, 2013, p. 41).

Interview Tips. Interviewing end users is a pillar of integrating social justice into engineering education. To ensure that they are able to gain insights that can lead to improved engineering lesson plans with a sociotechnical element, we require PSTs to conduct interviews with people that represent the end users they are designing for. In addition, the format and purpose of the interview must be made explicit. The interview of end users is not intended to ask closed-ended questions; rather, questions must be open-ended to help PSTs understand the experiences of the end users. For example, if the issue is how to improve student engagement using the engineering design process, the interviewer should not simply ask students if they like it. Rather, the interviewer should ask students if they have participated in a design challenge then and ask them to describe their experiences. Better yet, they could have a small group of students actually participate in building the prototype.

Classroom Presentation of Prototypes

Following this project, PSTs created prototypes and presented them to the class. In their presentations, PSTs were required to highlight the E4SJ criteria used to inform their design process and highlight the steps they followed in building their prototype. Then they would demonstrate how their prototype functions to serve the end users. One of the ongoing challenges we have found with teaching engineering in general is that time is a significant constraint. In planning for the social justice-infused engineering lesson, we included prototype redesign as a requirement of the assignment. However, much of the project was done independently outside of class. During the presentation of their projects, many PSTs reported redesigning their prototypes but acknowledged they did not test the initial prototypes. Upon reflection on and evaluation of the assignment, we suggest that future lessons address this problem by having a midproject presentation in which students present their initial prototypes, how they tested them, and how they plan to redesign them.

Lesson Planning

In the final step of this project, the PSTs wrote a lesson plan on how they plan to teach their project to elementary students. In their lesson, PSTs were asked to include detailed activities for each day or class period that they will have students work on this project, each aligned with content standards addressed in the lesson. As part of the lesson planning process, the PSTs did not peer review each other's lessons, but they did provide feedback during the brainstorming stage before building the prototypes.

Most engineering lessons available online utilize an iterative framework that defines the engineering design process. Though the frameworks vary, most embody two main dimensions: defining the problem and designing a solution. For example, the EiE engineering design process identifies five dimensions: *ask*, *imagine*, *plan*, *create*, and *improve* (EiE Team, 2020). The ask and improve dimensions are aligned with defining the problem, whereas the imagine, plan, and create dimensions are aligned with designing solutions. The same is true of the engineering design process described in Figure 1. The lessons our PSTs designed using the E4SJ criteria differ in that there is a third dimension: considering the human impact of designed solutions on the potential users.

Discussion of a Sociotechnical Approach to Engineering Assignment Outcomes

In the following section, we highlight examples of the prototypes PSTs came up with to demonstrate their integration of sociotechnical aspects into engineering designs. We also highlight how the PSTs paid attention to the E4SJ criteria, specifically to the questions raised by Leydens and Lucena (2018) such as: "Who and what is engineering for?," and how can engineering be a force for change in historically marginalized communities (p. 9)?

Listening Contextually

To begin this project, PSTs were assigned the task of interviewing potential end users of their products. In their end-of-project reflections, PSTs reported getting positive reviews, gaining insights they did not initially have, and receiving input about use of the prototypes. One of the unanticipated issues that arose was that the PSTs did not conduct interviews as intended. Rather, they tended to share their prototypes with and interview friends and family members.

Though friends and family members could be end users, the PSTs did not go further and seek opportunities to listen to a wide variety of end users who might critique their prototypes without bias. As a result, we did not get good examples of the listening contextually criterion.

Identifying Structural Conditions and Acknowledging Political Agency and Mobilizing Power

These criteria were not represented in the prototypes that the PSTs came up with. Our interpretation of why these were not well represented is that both criteria emerge from listening contextually, which, as we already mentioned, was not done as intended. The takeaway for us, as instructors, is that it is important to establish parameters and guidance around how PSTs should conduct interviews. In other words, they will be required to interview end users of their product and not simply people who are convenient to interview, such as friends and family members.

Increasing Opportunities and Resources

This criterion distinguishes between opportunities and resources. Enhanced opportunities refer to making products accessible to all people. Leydens and Lucena (2018) give the example of making a bike accessible to quadriplegics by modifying the seat and braking system. In this context, resources refer to accessibility in terms of affordability, making products available to those that do not have a lot of money. This category was well-represented and included an array of items such as a baby changing table with adjustable height to make it more wheelchair accessible, a shopping cart with an adjustable seat to accommodate children of different sizes, an undetected pod that automatically dispenses insulin for people without a smartphone, and a drink holder for a basket or cart with a handle that fits both. To illustrate a prototypical example in this category, we describe an ergonomic toilet stool prototype in greater detail.(Although this product alreasy exists, the PST was not aware of its existence at the time).

Figure 2
“Stool Stool” Prototype of Ergonomic Toilet Stool

The problem the PST was addressing with this prototype was that toilets in America are designed for people to sit at roughly a 90-degree angle, which is not ergonomically ideal. In addition, the ergonomically correct toilets available are expensive. To solve these problems, she imagined a more ergonomically correct toilet by placing a footstool at the base of the toilet. To simulate a squatting position, the PST designed a footstool to alter the angle while sitting on the toilet seat and placing your feet on the stool (see Figure 2). In her prototype, she designed it with foldable hinges to make it affordable and easy to carry for use in different places.

Reduce Imposed Risks and Harm

Many PSTs addressed this criterion in terms of resources and the environment; examples include a modified food storage container with an ice pack to keep food cold; a cereal bag that stands on its own and has a resealable top, reducing the need for excess packaging; and an antidistraction device that does not allow the car to start unless the phone is locked in the console. Below, we describe a recyclable toothpaste can (see Figure 3) in more detail.

Figure 3
Recyclable Toothpaste Container

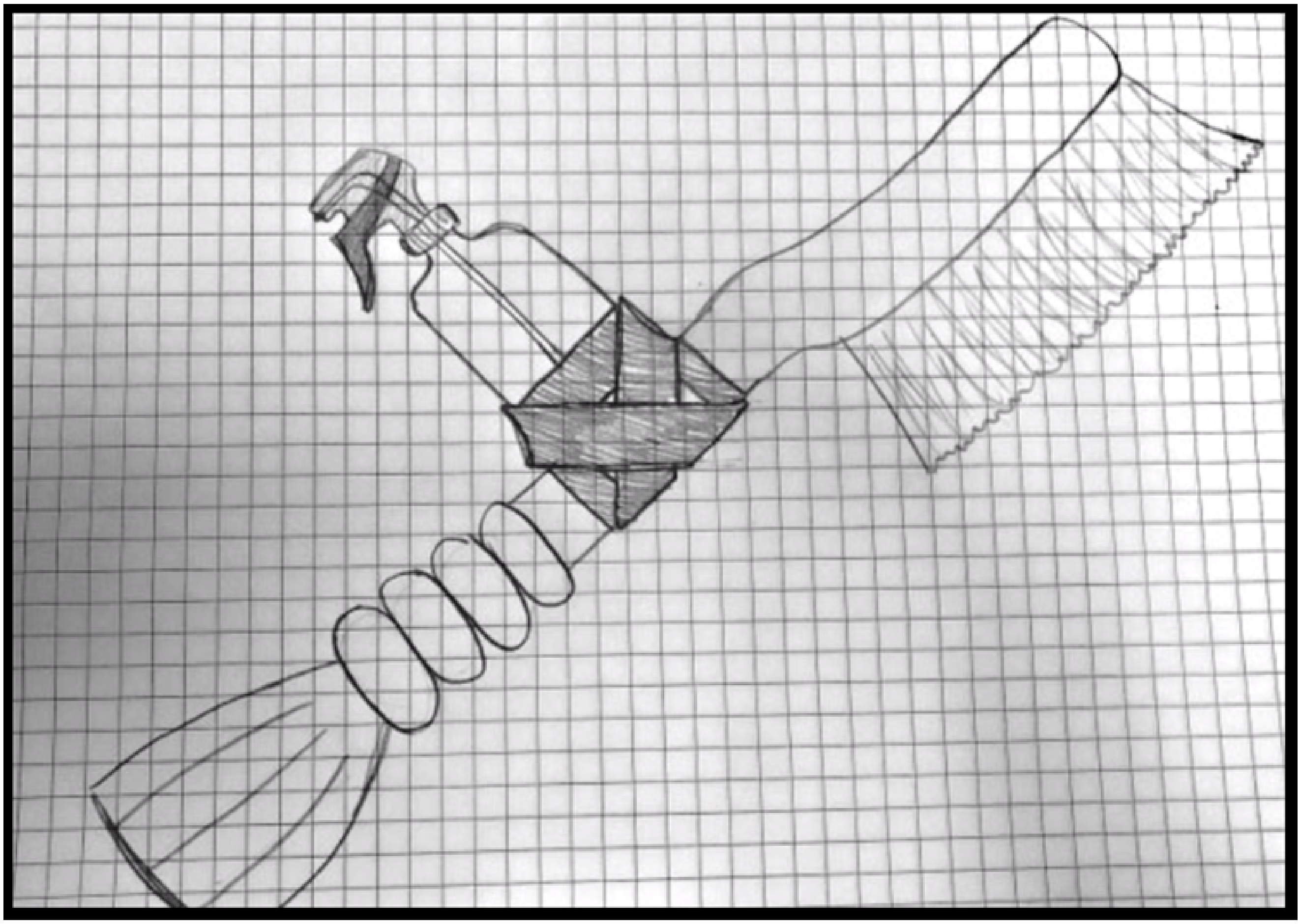
One PST designed a recyclable toothpaste can with a scooping popsicle stick to replace toothpaste tubes that end up the landfills and water bodies. The PST noted that:

> redesigning the toothpaste tube reduces imposed risks and harms by giving humans materials that can be recycled and reused, creating a healthier environment for ourselves, our future children, animals, and other ecosystems. Ultimately, creating this reinvention slows down global warming and reduces the chance of not having a livable Earth.

Enhancing Human Capabilities

This criterion was addressed by many of the prototype designs as well. Some examples include a bathrobe with a heating pad embedded in the robe, a Velcro pencil holder that attaches to a chair or school desk, and a plate with compartments that can simultaneously keep food hot and cold. Below, we describe an improved ice scraper (see Figure 4) in more detail.

Figure 4
Prototype of Ice Scraper With Spray Antifreeze



This prototype combines two common winter resources into one product, an ice scraper that is also able to spray antifreeze to make cleaning car windows in the winter of ice easier. The PST noted that this product will make life easier for people because “it allows them to clean their windshield faster; therefore, it saves time and waiting for the car to defrost in cold temperatures” (PST)

Innovation Lesson Improvement and Conclusions

In our pedagogical approach to emphasizing the social relevance of engineering, we took a two-pronged approach. First, we had PSTs develop a lesson plan that integrates the ES4J criteria and then participate as learners in the activity they created. Next, the PSTs adopt two perspectives, that of the learner and that of the teacher. This process of shifting perspective helps PSTs develop an understanding of what it takes to help students learn and develop an awareness of how social justice can serve as a culturally relevant pedagogy. After having done this assignment, we analyzed the PSTs prototypes and their reflections. In the future, we will take it a step further and have the PSTs think more deeply about who engineering is for and who it leaves out by having them address two questions in their presentations: “Does this lesson include different human perspectives,” and “whose perspectives might it leave out?” We also have the PSTs conduct interviews to help them to listen to multiple perspectives and get feedback on their design, both of which shaped their ideas of engineering design and ensured that they consider the needs, culture, and values of the end user. In the future, we will insist that the interviews are not conducted with friends and family.

We also had PSTs reflect on the integration of social justice into engineering design to consider the sociotechnical criteria. In carrying out this project, most of the PSTs focused on the increasing opportunities and resources criterion to ensure equitable distribution of resources among all groups of people, particularly marginalized groups. It is through the E4SJ criteria that PSTs designed prototypes for items to be used by children, persons with disabilities, elderly people, homeless people, and many others. More importantly, students became aware of the engineering design solutions and the importance of considering E4SJ criteria, especially for marginalized groups. In the end, the use of E4SJ criteria informed how the PSTs thought about engineering in their future classrooms and about incorporating social justice issues and inclusivity into engineering design.

An important revelation for us, as instructors, is that the PSTs struggled to come up with ideas that met the E4SJ criteria. Therefore, it is important to further explore how we engage elementary PSTs in deep consideration of E4SJ within the context of engineering. One possible way of deepening consideration of E4SJ is through emphasizing listening contextually through the end user interviews. Listening contextually is an integral part of the process because it directly influences the other criteria. Another possibility would be to put more structure around the brainstorming processes. There are differing brainstorming strategies, depending upon if the groups are trying to make preexisting products better or if the team’s goal is to come up with a completely new product (Kudrowitz & Wallace, 2013). Explicitly teaching these strategies and encouraging PSTs to use them during the brainstorming stage could help mitigate some of the struggles that they experienced.

Usually, our engineering lessons have predetermined scenarios for the engineering design challenge that identifies a problem and presents criteria and constraints that define successful prototype designs. These criteria are then used to test and evaluate prototypes. In our lesson, the students stated which of the E4SJ criteria informed their prototypes, but we need to be clearer about what defines the criteria and pay closer attention to the listening contextually criterion. To evaluate the listening contextually component, the first author had his students interview end users outside of the classroom to get feedback on their idea. However, students typically interviewed family members. In the next phase of this lesson, we are reconsidering how to make the interviews more constructive and inform the social justice component by requiring multiple interviews and not interviewing personal acquaintances. We recommend a social justice approach to engineering education because, by infusing the social justice criteria in this course, PSTs realized that the engineering field needs to be socially and technically balanced to solve human-centered problems and grow their sociotechnical awareness.

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