Engineering Your Own Liquid Soap

An example of how to use a culturally and socially responsible engineering design process

By Alberto J. Rodriguez

The concepts of *culturally relevant pedagogy* and *culturally responsive teaching* have been interpreted and enacted in various ways for over two decades. Informed by this research, I share a critical approach to teaching and learning using *sociotransformative constructivism* (sTc). This framework merges social constructivism (as a theory of learning) with critical cross-cultural education (as a theory of social justice; Rodriguez 1998). Therefore, sTc systematically takes into account *how* teachers teach (pedagogy); *what* they teach (curriculum); *to whom* they teach (students); and in *what cultural context* (diversity, socioeconomic status, language ability, physical ability, gender/sexual expression, etc.). While culturally relevant or inclusive pedagogy has been focused on teacher professional development, the sTc framework makes clear that teaching and learning are parts of an inseparable equation by which the success of one is dependent on the success of the other. Furthermore, the main goals of the sTc framework are to increase knowledge and awareness, leading to transformative action (see Rodriguez 2018).

To illustrate the use of sTc, I provide an example of an activity—engineering your own liquid soap—using its corresponding culturally and socially responsible engineering design process (Figure 1). We often find STEM activities that mainly focus on "competition," "meeting clients' needs," "profits," or "winning." These types of activities

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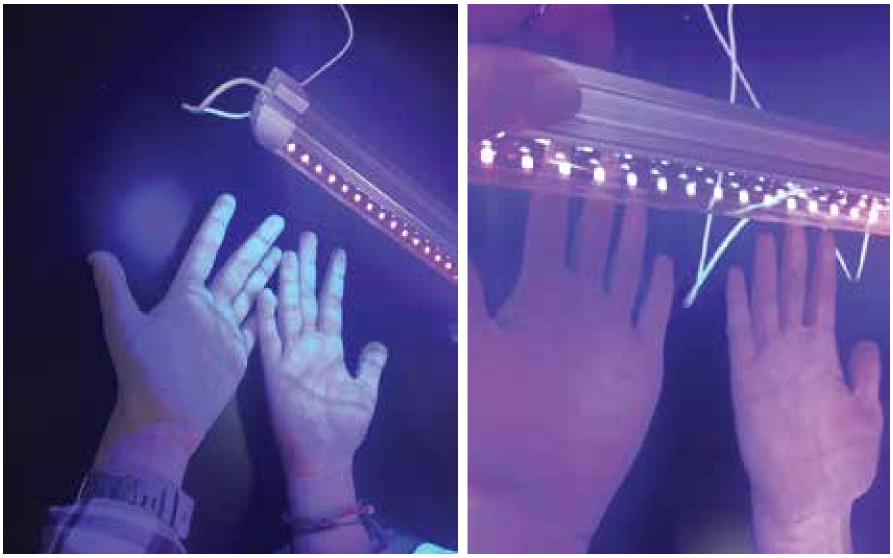
Preservice teachers explore soap making.

communicate an incongruent message with the *NGSS* call for making science and engineering practices more inclusive and engaging to all students. Furthermore, these profit-client-oriented formats rarely address ethical, social, and/or environmental issues. Similarly, this competitive and masculine approach ignores the National Society of Professional Engineers (NSPE) Code of Ethics: "Engineers, in the fulfillment of their professional duties, shall hold paramount the safety, health, and welfare of the public" (NSPE 2019). In contrast, a culturally and socially responsible engineering design process, informed by sTc, requires all STEM activities to be guided by these overarching questions: *Whose interests are represented? Who benefits? Whose voices are being heard/represented? What's the social and environmental impact?* (Figure 1). These questions help communicate that engineering and science are professions that must be guided by ethics, respect for the environment and society, and committed to being inclusive of and responsive to the diverse voices and cultures that enrich our humanity.

We conducted this activity in an afterschool program with diverse elementary and middle school children and in my elementary science methods course before schools were locked down due to the COVID-19 pandemic. However, to meet physical distancing requirements, we suggest using apps such as ZOOM, Google Hangouts, or WhatsApp for in or off-classroom group work. To reduce infection through sharing equipment and materials, students should divide specific tasks and have only one team member responsible for assembling components with guidance from other members. More specific details on student grouping, timing and sequence of activities, assessments, as well as additional teaching tips can be found in the Lesson Sequence document included in the Supplemental Materials link.

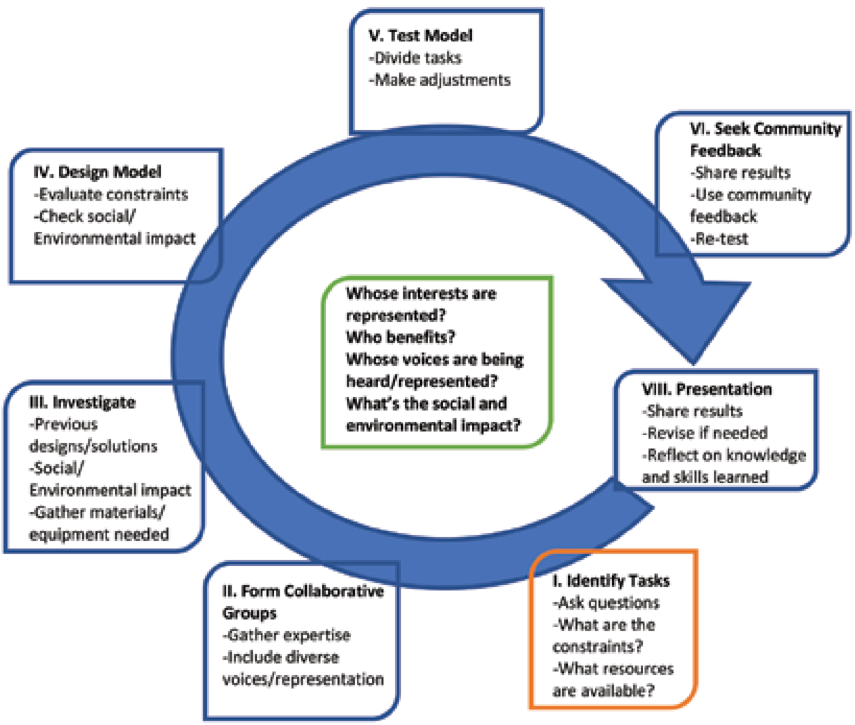
The main goal of this article is to describe how we used each step of the culturally and socially responsible design process (Figure 1) in hope that it may encourage readers to reflect on its importance and ignite their interest in enacting this activity in their classrooms.



Black light shows the presence of "germs" (GloGerm) before and after hand washing.

FIGURE 1

Culturally and socially responsible engineering design process.



I. IDENTIFY TASKS

Before presenting the design task, it is essential to contextualize it. Therefore, the first step is to create a "a need to know" (i.e., promote a sense of wonder and interest that engages students in culturally and socially relevant learning). I start by discretely rubbing a dab of *GloGerm* cream on my hands. This cream is nontoxic and contains tiny invisible pieces of plastic that glow under a black light (glogerm.com); thus, it is a popular tool for demonstrating how germs easily spread and the importance of effective handwashing. Next, I grab a paper plate and place it on a table. A student volunteer is asked to put gloves on and then examine the empty plate. She is asked to go back to her seat and take out her science book. By now, students are wondering what is going on. Using a black light, I show students all the areas we touched that are now "contaminated" with germs. This simple demonstration generates a lively discussion and provides an excellent opportunity for students to observe and practice effective hand-washing techniques (see Online Resources for a proper hand-washing technique video).

After grabbing students' attention, we do a brainstorm concept map to assess their knowledge about the COVID-19 virus. We discuss why they think the virus has disproportionally affected African American, Latino, and First Nations peoples. This discussion helps raise awareness among students about how socioeconomic status is closely tied to health inequalities. We often hear pre-and inservice teachers state that they do not feel "comfortable talking about these issues," or that students are "too young to understand" these inequalities. As a brown-skin Latino who grew up in poverty for most of my pre-college education, I can attest that throughout primary school and beyond some of us are quite cognizant of what poverty and inequality feels like. Having this reality affirmed in the classroom is empowering for everyone. Similarly, we use this opportunity to evoke a sense of agency by helping students recognize the significant role they play in helping prevent the spread of infectious diseases and in keeping friends and family members safe, just by keeping their hands clean.

After contextualizing the activity, students are ready for our engineering design task:

The COVID-19 pandemic has created a shortage of liquid soap. In addition, some people complain that regular soaps are irritating their hands because of frequent washing or allergies. On top of that, some soaps' perfumes are too strong or smell awful. Design an organic liquid soap that: (1) It is not too expensive; (2) Provides more moisturizing protection; (3) Has a pleasant fragrance; and (4) Effectively cleans hands.

Figure 2 lists the materials needed for soap making.

FIGURE 2

Materials.

- GloGerm cream (8 fl. oz.) $19.50 (*glogerm.com*)
- Castile soap (organic and unscented plant-based liquid soap base) e.g., Dr. Bronner's Pure-Castile Liquid Soap (Baby Unscented, 32 fl. oz.) $18.46 (*Amazon.com*)
- Cocoa oils with vitamin E (moisturizes) e.g., Palmer's Cocoa Butter formula (8.5 fl. oz) $5.68 (*Amazon.com*)
- Aloe Vera oil (moisturizes) e.g., Premium Organic Aloe Vera Oil Pure Health Hair Skin Care Moisturizing (8 fl. oz.) $13.39
- Organic essential oils (fragrance) e.g., Essential Oils Set TOP 8 - Therapeutic Grade Aromatherapy Essential Oils – Pure and Natural - Lavender, Peppermint, Rosemary, Orange, Tea Tree, Eucalyptus, Lemon, Anxiety Relief - Blend Kit (0.33 fl. oz. each) $15.99 (*Amazon.com*)
- 20 × 2 oz Clear Plastic Empty Squeeze Bottles with Flip Cap - BPA-free (set of six $7.99; *Amazon.com*)
- Black lights e.g., UV LED Black Light Fixtures, Leciel 6W Portable (USB) Blacklight $14.99 (*Amazon.com*)
- Distilled water $1.00
- Measuring teaspoons
- Plastic graduated cylinders

II. FORM COLLABORATIVE GROUPS

At this stage, students are organized into groups of three or four, making sure that they are working with different peers to encourage learning about each other. We also pay attention to students' special needs (language, ability, etc.). Students are also asked to share any unique expertise, including their parents or siblings' expertise. That is, some family members may be chemists, lab technicians, artists, cosmeticians, gardeners, etc. We urge students to talk to family members about our classroom activities and seek to involve them. We promote creativity and sharing, not competition. Therefore, any student with special knowledge is encouraged to act as a "coach" (i.e., someone any team can ask for help) (Rodriguez, Zozakiewicz, and Yerrick 2008).

III. INVESTIGATE

Before beginning their designs, students are guided through a series of learning stations to explore their questions and gain more knowledge. These stations are listed, with suggested timing and other tips, in the Lesson Sequence document included in the Supplemental Materials link. Three of the stations are short and engaging BrainPop videos: One is about the hydrophilic and hydrophobic properties of soap and how it works to kills germs; another about how the coronavirus infects cells; and the third one is about how the virus is transmitted (e.g., person-to-person vs. contaminated surfaces). Additional learning stations are listed for older children (grades 5+) to help them distinguish between what chemical engineers and chemists do and learn about how indigenous peoples from around the world use essential oils (for fragrance, medicine, rituals, etc.). Each of these stations has short and engaging videos and reading materials (see Lesson Sequence document for details and corresponding references in the Online Resources section). These stations also promote students' language literacy skills and cultural knowledge.

Our aim is to ensure students gain sufficient science knowledge to create informed designs, and we stress paying attention to environmental and social impact. That is, designs should be environmentally friendly and socially/culturally responsible as well as responsive. We find that children embrace this approach well, but some pre- and inservice teachers often find this aspect challenging. To assist with this issue, we point out how science and STEM resources tend to focus on the contributions of Western science and/or Anglo males—underplaying the contributions of peoples of color, indigenous peoples, and women to science/STEM. For example, it is easier to find information about the French chemist René-Maurice Gattefossé, who coined the term *aromatherapy* in the 1900s than to find information about copal ("the blood of trees"). This is a tree resin mainly used as incense in Mayan and Aztecs cultures in a variety of religious rituals and ceremonies. Copal is still used by indigenous peoples of the Americas. By providing multiple examples such as this one, we urge teachers to recognize that it is not that information is not available about the contributions of peoples of color to science/STEM, it is just less publicized. The main concern is that we often do not bother to look because of our predisposition to "seeing" science as only Western.

IV. DESIGN MODEL

Using Table 1, we promote students' application of mathematical knowledge by helping them calculate (or estimate) the volumes and costs associated with engineering their own liquid soap. We also remind them of the four aforementioned criteria (i.e., engineer a liquid soap that: (1) is not too expensive; (2) provides more moisturizing protection; (3) has a pleasant fragrance; and (4) effectively cleans hands. We find that students like to mix the scents of their preferred essential oils; some wish to add more moisturizing oil whereas others prefer soap with a very mild fragrance. They value having choices and exploring their own formulations instead of strictly

TABLE 1

Procedure for making organic liquid soap.

Instructions: Use the values below to estimate the approximate volumes and costs for your test. Note that your test vial can only hold 1/5 of the volumes shown in column B below or up to 2 oz (59 ml).

a. Use the values from Column B to calculate 1/5 of those volumes and then enter your answers in Column D.

b. Use the values from Column C to calculate 1/5 of those costs for your test vial. Enter your answers in Column E.

c. If you use additional ingredients, add the volume you used in Column D and the cost in Column E.

d. Add all the costs in Column E to estimate the total cost of your test vial.

A	B	C	D	E
Regular recipe	**Volume**	**Approximate Cost ($)**	**Test vial** (2 oz/59 ml) **Volume**	**Approximate Cost ($)**
Castile soap	1/2 cup (125 ml)	2.20	1/5=	1/5=
Distilled water	1/2 cup (125 ml)	0.25	1/5=	1/5=
Nourishing oil (Aloe Vera oil or cocoa oil with Vitamin E)	1 Table spoon (14.8 ml)	0.80	1/5= Write type of nourishing oil: ________________	1/5=
Essential oil (fragrance)	25 drops (1.25 ml)	0.25	1/5= Write type of essential oil ________________	1/5=
Additional ingredients (e.g., extra nourishing oils)			Write type of nourishing oil: ________________	
Additional ingredients (e.g., extra essential oils)			Write type of essential oil ________________	
Additional ingredient (optional)			Write additional ingredient ________________	

Total Costs:

Rationale: Explain how your team is addressing the four criteria.

following recipes (Rodriguez and Zozakiewicz 2010). As shown in Table 1, students are required to articulate a rationale for their choices before they are allowed to test their designs.

V. TEST MODEL

After each team member selects various tasks, we require those handling liquids to wear gloves and goggles even though all materials are nontoxic. The Lesson Sequence document in the Supplemental Materials link includes additional safety measures. To meet physical distancing requirements, we recommend having only one team member handle all materials for mixing while the other team members provide guidance. Students make design adjustments if needed, complete an efficiency test; moisturizing, fragrance and cost assessment; and conduct analysis of their results (see the Lesson Sequence document in the Supplemental Resources section for additional tables to help students organize these data sets). The integration of mathematics, critical thinking, and language literacy skills is also promoted (e.g., language literacy: comprehend informational text, assess evidence to support authors' claims, etc. Mathematics: solving real-word problems using division; solve problems involving measurement; represent and interpret data, etc.)

VI. SEEK COMMUNITY FEEDBACK

This is an important stage in the culturally and socially relevant engineering design process because we urge students to provide critical feedback on each other's design. Again, the focus is on supporting collective creativity, not competition. Multiple solutions to the engineering task are welcome. This helps students believe that there is no one answer the teacher is expecting. After teams share their results, we have one volunteer from a different team test another team's soap. Feedback from this volunteer and the classroom community are then used to make adjustments and retest the soap formulation. Students use the same table to record new data and explain their revised findings.

VII. PRESENTATION

During the final stage, students present findings using multiple modalities (e.g., PowerPoint, slideshow, video, posters, pamphlets, public service announcement, etc.). We find that when students are given choices in presentation formats, they are more engaged and it is easier to assess their understanding. Students are also asked to explain the social/environmental impact of their products, as well as to reflect on the new knowledge and skills acquired. This last component is very rewarding because students often talk about how they will use what they learned in transformative ways. For example, one student said, "I'm gonna do this at home. Can I keep my soap?" Another mentioned that she wanted to show a sibling how to wash her hands properly. Others mentioned that they wanted to talk to their parents about making their own organic liquid soap because it "smells better and is good for the environment." Overall, students demonstrated being more aware about how viruses work, how infections spread, and what they can do to keep their family safe.

CONCLUSION

This article provides an example of how to use a culturally and socially responsible engineering design process using sociotransformative constructivism. Although we carried out this activity in a culturally diverse afterschool program with elementary and middle school children as well as in an elementary science methods course, this activity can be modified for any grade level. We recognize that addressing equity and social justice issues can be challenging. In fact, sometimes preservice teachers in my methods courses or teachers participating in our projects point out that "there is too much emphasis on equity issues." This reaction is often due to many years of exposure to science as a decontextualized and mono-cultural (Western) field. Furthermore, it is well established that addressing equity and social issues evokes feelings of guilt and shame sometimes leaving members of the predominant culture overwhelmed, paralyzed, and frustrated (Rodriguez 2021). However, we know that systemic inequalities in our schools and society are not going to be removed unless all of us take steps to do so. Engaging more children and teachers in culturally/socially relevant activities as described here is just one approach toward expanding not only our students' understanding of science and the engineering design process but toward promoting their sense of agency and empowerment.

ONLINE RESOURCES

Brainpop.com

Corona virus: *www.brainpop.com/health/diseasesinjuriesandconditions/coronavirus*

How soap works: *www.brainpop.com/socialstudies/news/howsoapworks*

Flu and flu vaccine: www.brainpop.com/health/diseasesinjuriesandconditions/fluandfluvaccine

Effective Hand Washing Technique *https://twitter.com/2footgiraffe/status/1241504810932867077)*

National Society of Professional Engineers Code of Ethics *www.nspe.org/sites/default/files/resources/pdfs/Ethics/CodeofEthics/NSPECodeofEthicsforEngineers.pdf*

STEM Teaching Tools - Practice Brief#55: Why is it crucial to make cultural diversity visible in STEM education *http://stemteachingtools.org/brief/55*

STEM Teaching Tools - Practice Brief#53: How to avoid known pitfalls associated with culturally responsive instruction *http://stemteachingtools.org/brief/53*

REFERENCES

Rodriguez, A.J. 1998. Strategies for counterresistance: Toward sociotransformative constructivism and learning to teach science for diversity and for understanding. *Journal of Research in Science Teaching* 35 (6): 589–622.

Rodriguez, A.J. 2018. Sociotransformative Constructivism: What is it and how can I use it in my classroom? Available at *www.researchgate.net/publication/237834825_Sociotransformative_Constructivism_What_is_it_and_how_can_I_use_it_in_my_classroom*

Rodriguez, A.J. 2021. Sociotransformative STEM education. In *STEM road map 2.0: A framework for integrated STEM education*, eds. Carla C. Johnson, Erin E. Peters-Burton, and Tamara J. Moore. New York: Routledge.

Rodriguez, A.J., C. Zozakiewicz, and R. Yerrick. 2008. Students acting as change agents in culturally diverse schools. In *The multiple faces of agency: Innovative strategies for effecting change in urban school contexts*, ed. A.J. Rodriguez, 47–72. Rotterdam, Netherlands: Sense Publishing.

Rodriguez, A.J., and C. Zozakiewicz. 2010. Facilitating the integration of multiple literacies through science education and learning technologies. In *Science education as a pathway to teaching language literacy*, ed. A.J. Rodriguez, 23-45. Rotterdam, Netherlands: Sense Publishing.

SUPPLEMENTAL MATERIALS

Download the Lesson Sequence at *https://bit.ly/3sF0Dkv.*

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