In physics class, we speak with great reverence of Galileo and Newton for their accomplishments and contributions to our bank of science knowledge. Our textbooks are filled with examples of equations related to linear motion, momentum, and other aspects of classical mechanics and beyond. So much of our world can be understood through a lens of physics; however, the teaching of physics has often been done within the silo of narrow perspectives. Fortunately, the Next Generation Science Standards (NGSS) address issues of equity and diversity in multiple ways, including examining what counts as science, who does science, and recognizing how engineering has been central to many cultures (Januszyk, Miller, and Lee 2016).

Science is a human endeavor; the way we teach it, apply it, and in some cases exclude populations from having access to it, may affect us for generations (NGSS Lead States 2013). Science education continues to be a complex civil rights issue (Tate 2001), but there is hope. Movements to promote just, equitable, and inclusive opportunities to learn within the context of community, identity, and action are being developed and implemented in classrooms across the country.

This article describes lessons planned with a lens on gender equity, community needs, and engineering for a diverse population. It sits within a larger framework of physics knowledge for social justice and community applications. Before beginning a modeling, design, and construction project (HS-PS2-3; see Online Connections), students at an urban high school in southern California considered the implications of who participates on the design team for a science project. The following questions framed the exploration:

- How does the perspective of the design team affect the product outcome?
- Who should be selected for a design team?
- How can we communicate the need for a diverse design team to the larger community?

The focus of this article is not on the physics content, most of which would be familiar to physics teachers, but instead on the ways in which we helped our diverse population of students...
feel capable and welcome, and to understand why they belong in physics when traditionally there have been so few physicists to whom they can relate.

Due to Covid-19, the 27 students in this physics class (see Table 1) used the Canvas LMS and Zoom for four, 90-minute, synchronous course sessions each week plus asynchronous assignments. The science teachers at this school continually strive to simultaneously meet science standards (NGSS) and social justice standards (see Table 2) based on the framework for anti-bias teaching (Teaching Tolerance 2020).

Guiding students to integrate the NGSS Science and Engineering Practices (SEP) with issues of social justice in this unit was strategic and thoughtful. The central SEP for these lessons was Constructing Explanations and Designing Solutions. The lessons began by exploring who in society participates in design and engineering, then moved to design, evaluation, and modification using the concepts of force and impact. To tie these two instructional areas together, students designed their own projects. Additionally, they were challenged to offer modifications to their design that support a targeted population that could benefit from modifications or adaptations.

Before we began the unit, we identified physicists to highlight using Profiles of Minority Physicists from the American Physical Society (see Online Connections). On the first day, we explained to the students that we wanted them to explore a variety of career options related to physics and to become familiar with physicists from diverse backgrounds. We then selected a day, halfway through the unit, to examine the 10 most famous physicists in history. Students did an internet search and repeatedly found the same 10–12 physicists. On some lists, all are white men. Other lists include Marie Curie. This promoted a lively discussion about historical access to and exclusion from science.

Reciprocal teaching to foster conversation and comprehension

Early in the unit, we incorporated some videos and readings to set the stage and show students we were serious about the integration of physics with issues of equity, access, and social justice. To build background knowledge and to engage students in discussions around justice and iterative design, we provided resources including a Science News video called “Calling all Scientists of Color,” Jedidah Isler’s PBS Newshour video “Dr. Jedidah Isler on bringing more women of color into STEM,” and excerpts from TUC’s “Personal Protective Equipment and Women” (see Online Connections).

Because conversations in either the classroom or on an online platform like Zoom can be dominated by one or two voices within a classroom context, we wanted to incorporate a strategy that would value all student voices and to meet one of the social justice standards—making sure that students have opportunities to express themselves and to engage respectfully with others (see Table 2). Reciprocal teaching, developed by Palincsar and Brown (1984), engages students in the aspects of reading essential to deep learning from complex texts, and offers a structure for engaging students in conversations around texts.

To consider a section from “Personal Protective Equipment and Women” at a meaningful level, we organized students into groups of four. Each group member had one of the following primary roles: predictor, questioner, clarifier, or summarizer.

### TABLE 1

**Demographics in percentages for the physics class (percentages may not add up to 100 due to rounding).**

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latinx/Hispanic</td>
<td>63</td>
</tr>
<tr>
<td>Black</td>
<td>22</td>
</tr>
<tr>
<td>Asian/Pacific Islander</td>
<td>7</td>
</tr>
<tr>
<td>White</td>
<td>7</td>
</tr>
<tr>
<td>Other/Decline to State</td>
<td>1</td>
</tr>
<tr>
<td>Male</td>
<td>18</td>
</tr>
<tr>
<td>Female</td>
<td>81</td>
</tr>
<tr>
<td>Free/reduced lunch</td>
<td>66</td>
</tr>
<tr>
<td>Other/Decline to State</td>
<td>1</td>
</tr>
</tbody>
</table>

### TABLE 2

**Social justice standards addressed in this physics unit.**

<table>
<thead>
<tr>
<th>Number</th>
<th>Domain</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Diversity</td>
<td>Students will express comfort with people who are both similar to and different from them and engage respectfully with all people.</td>
</tr>
<tr>
<td>12</td>
<td>Justice</td>
<td>Students will recognize unfairness on the individual level (e.g., biased speech) and injustice at the institutional or systemic level (e.g., discrimination).</td>
</tr>
<tr>
<td>17</td>
<td>Action</td>
<td>Students will recognize their own responsibility to stand up to exclusion, prejudice and injustice.</td>
</tr>
<tr>
<td>20</td>
<td>Action</td>
<td>Students will plan and carry out collective action against bias and injustice in the world and will evaluate what strategies are most effective.</td>
</tr>
</tbody>
</table>
For this particular activity, we intentionally created groups including two students who had higher-than-average reading skills, who could support two group members with lower reading skills. To showcase how this strategy works, the teacher first modeled each role using a think-aloud strategy. Guided modeling provides the scaffolding that allows students to see and practice the monitoring skills (Lapp, Fisher, and Grant 2008). The teacher thinks aloud strategically, with the purpose of modeling the cognitive processes used in the reciprocal teaching strategy. Specifically, the teacher uses “I” statements to scaffold the elements of the strategy. Here’s an example of teacher modeling in the role of predictor:

As predictor, I’m going to notice the title and side notes that are in a grey box with italicized print. This box stands out, so this might be key information. I might even take a look at the first line of the text. It says, ‘The Women’s Engineering Society (WES) explored the issue of poor fitting and unsuitable PPE in construction by conducting a large-scale safety clothing and footwear survey.’ I do remember what PPE stands for—personal protective equipment. We’ve been hearing a lot about that lately. The text talks about a survey. I wonder if there’s some data that will be shared if I read on. Let’s read more to see.

The teacher continued to think aloud about all four roles before turning the responsibility of the reading, and subsequent conversation, over to the students. To support their implementation of the reciprocal teaching strategy, we provided sentence frames on cue cards, which served to build the language of conversation (Figure 1). Once students became more expert in their individual roles, the teacher asked them to try other roles when they deemed it necessary. For instance, when Evelin needed clarification around this sentence, “The 2016 survey showed that very few women had worn maternity PPE and of those that had been pregnant, half had curtailed their normal range of duties or had to change their role in the run up to maternity leave.” She offered a clarification query to her group members: “What do they mean by curtailed? They are talking about duties.” Realizing that the class had learned about the term curtailed when previously reading about desalination, group member Sammy suggested that it had to do with limits, and Edgar looked it up on his phone. Together, the students were exploring, interrogating, and formulating opinions about the text they were reading.

We selected resources that honestly addressed the shortage of underrepresented minorities in STEM fields while highlighting narratives of strength among marginalized groups, as recommended by Long, Steller, and Suh (2021). The student conversations that ensued during the reading of the article and the viewing of the videos, prompted students to ask questions such as Why don’t we hear more about research on PPE focused on the problems of gloves and clothes that don’t fit properly? and Isn’t it wrong that black women aren’t in more physics programs in college? and Why do underrepresented minorities only have 11% of the STEM jobs? Students were also overheard saying “I didn’t know people like me were astrophysicists.” As students

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**FIGURE 1**

**Sentence frames for reciprocal teaching**

**Predict**
I think this will be about....
The title makes me think...
I expect ____ will happen next.
I wonder if ____ will occur.

**Question**
Who did ____?
What happened when ____?
Why did ____?
Where does ____?
When did ____?
How does ____?

**Clarify**
I think this word means...
This phrase is confusing but maybe...
I wonder if this means...

**Summarize**
The main ideas are ...
This article discusses...
After reading this, I know that.
engaged in conversations, they began to consider aspects of social justice and equity that impelled both inquiry and a drive for action. In addition to in-class discussions, they engaged in a discussion forum conversation using our online learning management system (Figure 2).

Thompson et al. (2021) and Calabrese Barton, Tan, and Birmingham (2020) make the case that teachers must do more than just offer access; we must also address historical wrongs in science education. Similarly, Philip and Azeveda (2017) argue that we must study the authentic struggles of different groups to understand how learning science can be part of social change. Throughout this unit, interspersed with more traditional activities to learn about force and impact, students considered other articles and data connected to equity in science, such as UNESCO’s data on the gender gap in science (UNESCO 2019).

A particularly interesting whole-class discussion arose later in the unit after using the reciprocal teaching strategy to read the New York Times opinion piece “The Benefits of Black Physics Students” (Isler 2015; see Online Connections), which explores the feelings of a Black scientist. We found this to be a crucial discussion in our class because it encouraged students to share feelings about their own science identity. In the piece, the author makes the case that science is for all students, and that by asking “What do Black students bring to the physics classroom?” there may be an implication that students of color are only welcome if their presence benefits others. One student said “Ooh, that is cold, but they do benefit others, like in that car test.”

The high school students experienced some cognitive dissonance as they wrestled with the idea from the first article that design teams benefit from diversity, while also agreeing with the second article that all people should be welcomed to science and engineering, not only because they offer a different perspective, but because it is where they belong (see Table 2). The class is diverse (Table 1) and these conversations highlighted the fact that many of the Black and Latinx students had not considered physics as a career. Additionally, students frequently commented that other people were surprised that “students like them” were enrolled in physics. We do not suggest that this one course alone can solve these problems, but it was evident that the conversations were very meaningful to our students.

**FIGURE 2**

**Student discussion on Canvas discussion board.**
When content, strategy, and learning goals intersect

To connect the elements of social justice to the physics content of this lesson, we provided an opportunity for students to engage in a tried-and-true-physics design task related to this NGSS performance expectation: Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision (HS-PS2-3, see Online Connections). For this assignment, students were intentionally assigned to heterogeneous groups. Patterson (2019) argues that equitable group work features student voice, visibility (of all students), and student authority. We carefully selected our groups to promote heterogeneity with respect to grades on a previous unit; cultural, linguistic, or ethnic backgrounds; and student authority and voice within the class. We also attempted to avoid placing good friends in the same group.

The task: design and construct a container for an egg that could withstand a drop of at least 5 meters (Higgins 2016). We asked students to design their container while considering specific needs of a population that might not always be the focus of a design team. Patty, Hieu, and Ahmed decided to focus on the safety needs of a “pregnant egg” to represent pregnant women traveling in vehicles. Martina, Teresa, and Matthew targeted people over 65 years of age as they developed an easy entrance for “the old egg.” The groups engaged in structured feedback conversations, intended to focus them on the iterative design process of testing, data collection, review and revision. They researched the specific needs of their targeted population, often by talking with family members, for the purpose of designing for members of that community.

To further explore the relationship between mass and velocity within the context of both elastic and inelastic collisions...
during the planning stage of their egg drop, students engaged with a bumper car simulation (see Online Connections). They explored how the post-collision velocity of two cars colliding changes when mass and initial velocity vary. While in Zoom breakout rooms, groups of four students, intentionally selected to be placed so that plurilingual students could converse in home languages if needed, used a Google Jamboard to document their group observations. In one scenario, in which students tested what happens during a collision when the mass of car 1 is 100 kg and the mass of car 2 is 200 kg, they moved the simulation slider to vary the velocity of each car prior to the collision, often discussing the results in their home language. During the simulation, we asked them to think about the crash-test dummy article they read and consider how the lack of women on the design team influenced the decision-making. Students deepened their understanding of collisions, while considering issues of equity, in advance of future lessons related to impulse and momentum of their egg drop containers.

**Moving toward action**

As students progressed towards revising their egg-drop containers, they completed an exit slip with the prompt, “How does having a diverse design team help your egg drop project?” Students commented on how other people in their groups had ideas that were different from their own. Some mentioned that it caused conflict, but generally they saw the diverse perspectives as a benefit. Despite occasional disagreements, 93% of the students were able to identify a valuable new idea from a different member of their group. During a whole-class discussion, the students briefly talked about the challenges and benefits of working with others. Not surprisingly, while they were outraged that companies did not always have diverse design teams—thereby inadvertently creating products that were not suitable for all populations—they simultaneously found it a little challenging to see the benefits of multiple perspectives on their own egg drop projects. As they discussed and reconciled their conflicting views, they continued to make progress toward the Social Justice Standards (Table 2).

Teachers must actively support and encourage students of color and those from low-income communities to engage with science and to use it in ways that matter to their communities (Calabrese Barton, Schenkel, and Tan 2021). In the culminating activity, students identified a product that, in their opinion, could benefit from a redesign by a more diverse design team, to meet the needs of a community that is not served by the current design. Students looked for ideas around their own homes and community, and talked with family members and friends. Ezekiel was concerned with the height of the handle on his vacuum cleaner, which was too short for him to use comfortably. Although he tried to use it as an excuse to get out of chores, he thought it should be designed with an adjustable handle. Zahra noted that cosmetics companies need to consider a wider array of complexion types when developing their color palettes. She offered several suggestions for products and packaging. Jose mentioned that on his trip to American Samoa the flight attendants brought a tray with headphones and seat belt extenders and passed them around to everyone. He thought this was better than forcing people to go and ask for the extenders, but wondered why the extenders couldn’t be built into the arms of the seat.
Connecting science to problems in the students’ own communities is a form of place-based pedagogy that serves several purposes, including generating strong interest among the students while promoting an awareness of and improvement upon the “ways of thinking instilled by the dominant culture” (Buxton 2010).

After identifying products in need of a redesign, students composed letters to a producer of these products, and offered their suggestions (SJS 17 & 20). Criteria for the letters included:

1. An explanation of what is lacking in the current product offerings,
2. Detailed suggestions for a new product idea or novel innovation that would serve a particular community or population not served by the current product,
3. Connections to science, data, technology, and iterative design, and
4. An explanation of why they believe design teams should be diverse.

It is incumbent on teachers to show students how physics can play a role in their own communities. As a final reflection on physics learning throughout the semester, our students shared their shared key insights and understandings. They could choose from three options: writing an essay, creating a concept map, or producing a video. Figure 3 shows a concept map created by Yolanda to showcase her growing understanding of, and connection to, physics in her world. Through the social justice domains of identity, diversity, justice, and action, students can see the relevance of their studies, acknowledge the need for diverse thinking, and feel like they belong in the physics class, all while engaging in actions that empower and affect diverse communities. Our goal as educators is to provide opportunities for our students to share their lived experiences, incorporating their own funds of knowledge to extend their learning. Through this effort, science students can use their growing insights and resultant innovations to make this world a more equitable and inclusive place for all.

**ONLINE CONNECTIONS**


Profiles of Minority Physicists from the American Physical Society: https://www.aps.org/careers/physicists/profiles/mason.cfm

Science News: Calling All Scientists of Color: https://www.sciencenewsforstudents.org/article/calling-scientists-all-colors

PBS Newshour: Dr. Jedidah Isler on bringing more women of color into STEM: https://www.pbs.org/video/brief-but-spectacular-1546641557/

TUC’s Personal Protective Equipment and Women: https://www.tuc.org.uk/sites/default/files/PPEandwomenguidance.pdf


**REFERENCES**


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