Students in public schools within the United States are increasing in racial and ethnic diversity, whereas the STEM workforce remains predominantly white (Hussar et al. 2020; Milner 2011). Relationships and knowledge gained from STEM professionals may grant the students who have been historically underrepresented in STEM fields, namely Black and Hispanic students, access to social and cultural capital that they may not otherwise receive in standardized academic science classrooms (Tenenbaum et al. 2014).
Engineering Design Process

From a logistical perspective, scheduling conflicts between professionals’ work hours and teachers’ school schedules make these partnerships difficult to implement (Ferdig and Kennedy 2014). The challenges are greater in underfunded schools, as science teachers are often pressured by high-stakes tests and scripted curricula, and they often perceive there to be little time to incorporate additional activities (Ryan et al. 2017). Despite these obstacles, such partnerships can create meaningful opportunities for teachers to enrich their instruction and for students of color to see STEM professionals who look like them during school. Guided by successful experiences of middle school teachers who partnered with STEM professionals of color, we believe the benefits to students are significant.

Despite challenges, benefits include:

1. Mentors as role models that provide guidance and support.
2. Opportunities for students to pursue interests in STEM.
3. Enhanced teacher knowledge and skills through collaboration.
4. Improved student engagement and achievement.

In this unit, we provide resources and strategies to help educators implement Culturally Relevant Partnerships in the Engineering Design Process, ensuring inclusivity and equity in the STEM classroom.
national grant-funded project, we provide empirically based practical steps for facilitating these collaborations. The novelty of our partnership model is that it connects historically underrepresented STEM professionals of color with middle school teachers and students in predominantly online spaces that alleviate some of the constraints of school and work schedules.

In addition to creating enriching opportunities for students to connect with underrepresented professionals of color virtually, our E-Communities partnership situates the engineering design process as an opportunity to humanize science and engineering by encouraging students to design solutions that foreground the needs of individuals from underserved communities. In this article, we describe the ways in which science teachers can establish a relationship with an underrepresented STEM professional of color, facilitate instruction using a collaborative Digital Design Notebook with a STEM professional, and incorporate culturally relevant engineering design tasks into their curriculum.

Step 1: Finding a STEM professional to volunteer in the classroom

There are several untapped resources to aid in creating partnerships between students and STEM professionals of color. First, we recommend contacting local branches of organizations that support the advancement of engineers of color, such as the National Society of Black Engineers or the Society of Hispanic Professional Engineers (see links for both in Online Resources). Calling local branches of large corporations and requesting to be connected to their outreach and community partnership leaders is another promising tactic. Companies often require staff to spend time volunteering each year. We found exceptional partners through Verizon, the U.S. Patent and Trademark Office, Dell, and Exxon Mobil (see links for all in Online Resources). Local engineering firms also have similar programs. Finally, we emailed underrepresented STEM faculty at local universities to support us in identifying STEM professionals of color to serve as virtual mentors for underrepresented middle school students. We were explicit in our communication that STEM professionals could be from any field or sector, and they needed to be able to support students in the engineering design process; specifically, we requested that professionals provide online feedback to students about their research, considerations of feasible solutions, materials, their rationale for design, and methods for evaluating their prototype to address the problem. While the process inevitably requires emails, phone calls, and personal outreach, we identified professionals who were passionate about supporting local teachers, students, and STEM education. Given the working schedules of industry professionals, one STEM professional generally only has the time to commit to one to two classes. Therefore, a teacher would likely need to connect with three STEM professionals to support all of their classes over a semester or academic year.

Step 2: Preparing STEM professionals to work with students

The first step our teachers took was to communicate with their STEM professional via email. These emails typically included three pieces of information: (1) how the teacher would like to connect an engineering design task to their science or mathematics curriculum (e.g., “I would like to apply engineering design to teach heat transfer and properties of water”), (2) a time when the engineer was available to plan with the teacher in a Zoom meeting, and (3) a request that the STEM professional complete the Storyboard Template (see Supplemental Materials).

The Storyboard Template is a tool our team developed to help STEM professionals introduce themselves to students asynchronously online. The template provides designated areas for STEM professionals to include pictures and text that describe to students who they are, their inspirations for their educational pathway and job, exciting experiences in their work, and questions that they hope to address with teachers and students. Teachers sent a link to this template to the STEM professional in an introductory email. See Figure 1 for an example section of an engineer’s completed storyboard.
Step 3: The Digital Design Notebook

Once you have connected with a STEM professional, you and your students will need to decide how to virtually collaborate and communicate with them. Video calls are a wonderful tool and make up a significant portion of our program, but we found them to be too tedious for day-to-day communication between students and the STEM professional. This is where we recommend the use of our Digital Design Notebook (DDN). The DDN (see Supplemental Materials) is an interactive Google Slides presentation shared among small student groups, a STEM professional, and the teacher. As students complete their DDN with questions, ideas, drawings, research, pictures, and videos during the engineering design process, the STEM professional and teacher can leave feedback in each slide’s “notes” tab. If access to technology is limited, these slides can be printed, scanned, and emailed back and forth instead. The DDN’s flexible format not only supports “valuing multiple modes of expression” (National Research Council [NRC] 2012, p. 289) by promoting differentiation for students throughout the design process, but also supports the STEM professional to maintain a meaningful, constructive relationship with your students on their own time, from home or work.

FIGURE 1: Example section of engineer’s storyboard.

STEM Professional “on the job”

Who are you and what do you do?

There were two things that drew me to my current profession. I work as a research physicist for the US Air Force. The first thing that drew me to this profession from a big picture perspective, was the opportunity to use science to serve a cause that’s greater than myself. I am by no means cut out to do what our soldiers do, however I can honestly say that I have been able to use the abilities I do have to serve our country by interacting with airmen and administrative figures to understand what current and future needs of the warfighter are, and I have been able to provide technological solutions that meet some of these needs. I look at what I do as a STEM equivalent of living with a heart of missionary sacrifice, where the greater good of your cause should supercede personal career ambitions, and desire for personal recognition.
scanned, and emailed back and forth instead. The DDN’s flexible format not only supports “valuing multiple modes of expression” (National Research Council [NRC] 2012, p. 289) by promoting differentiation for students throughout the design process, but also supports the STEM professional to maintain a meaningful, constructive relationship with your students on their own time, from home or work.

**Step 4: Crafting a culturally relevant engineering design task**

The next step is to begin planning your collaboration. To help guide you through the complex process of connecting engineering and STEM curricula to students’ lives, our team developed a series of planning meeting documents. The Planning Meeting 1 document (see Supplemental Materials) prompts teachers and STEM professionals to develop common goals, establish communication norms, schedule future meetings, and discuss ideas for an engineering design task that focuses on a societal challenge within the community or a challenge relevant to the everyday experiences of students. We found that centering the engineering design task on a relevant problem in students’ lives supported teachers to “build on prior interest and identity” (NRC 2012, p. 286) and fostered cultural connections to STEM. Here are some examples of engineering design tasks that teachers created with the support of a STEM professionals:

- Develop models or devices that can clean up oil spills in their community’s waterways.
- Design a way to keep food from spoiling to address local food shortage.
- Design a model that could serve communities without access to freshwater.

**Step 5: Classroom implementation**

Once you have established your partnership with the engineer and determined the culturally relevant design task, you are ready for the fun to begin! Our DDN is broken into five phases to help scaffold the engineering design process. Each phase typically takes one to two class periods (i.e., 50–100 minutes). To prepare for the unit, insert a link or a picture of the STEM professional’s completed Storyboard Template (see Supplemental Materials) into the DDN and divide students into groups. Next, copy the DDN to create one copy for each group in a Google Drive folder that will be shared with your STEM professional. Introduce students to the DDN and show them how to access it. The first task for student groups will be to create a fun team name and introduce themselves to the STEM professional, virtually. Allow groups time to read through the professional’s storyboard and ask questions using the “comment” feature in the notebook and/or completing the Storyboard Worksheet (see Supplemental Materials).

---

**FIGURE 2:** Engineering challenge design brief in Digital Design Notebook.

*Problem: [Students write a succinct summary of the problem.]*

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>Tools</td>
</tr>
</tbody>
</table>

*Teacher, engineer, and students collaborate to list the criteria, constraints, materials, and tools for the challenge.*
Step 6: Identifying materials and constraints

At this point in the process, you and the STEM professional will have selected an area of focus for your design task, connected it to a social issue, and virtually introduced your students to the professional through the DDN. In this step, you need to identify the constraints of the task, identify resources, and purchase necessary materials. For example, you may want your students to build a model of a bridge over a creek that will allow easier access for walking to school. Some constraints of this challenge are the bridge’s length and carrying capacity. But what other constraints could you introduce to further challenge your students? Perhaps the banks of the river are home to a species of plant that prevents erosion. Too large of a base on either side would kill too many plants and, therefore, subject fish to unsafe conditions. Maybe parents in the neighborhood are concerned about their young children falling off of the bridge while walking to school. What safety features could your students incorporate into solutions to ease parents’ worries? These are just two examples of infinite possible design constraints. Take a moment with your STEM professional during this meeting to establish your constraints. Then, determine resources most appropriate for your students to guide their research and ways to investigate the problem. Determine which materials students will be able to use while constructing their designs. We have designed a planning document to guide you through this process as well as a rubric for assessing student work (see Student Rubric in Supplemental Materials). Students will describe their problem on Slide 8 of the DDN (the engineering design challenge brief shown in Figure 2) as well as list their criteria, constraints, materials, and tools needed.

Step 7: Engineering design process

Phase 1: Unpack the problem

Based on your conversation with the STEM professional, insert the resources and/or investigatory labs you identified for students to explore the problem.
Next, allow time for students to work as a group to read the resources provided, analyze multiple facets of the problem, and generate questions for the engineer. Because the DDNs will be saved on a shared Google Drive with the STEM professional, he or she can access students’ questions in advance of the first synchronous virtual meeting.

**Phase 2: Imagine solutions**

Next, you will facilitate a virtual event to introduce students to their STEM professional mentor. Be sure to do a technology check before the event to make sure everything is ready to go. In our experiences with these meetings, STEM professionals discussed the work they do, the impact they have on the community, as well as their journeys to success and struggles along the way (see Figure 3). Allow some time for live questions; it may be beneficial to prepare questions with students ahead of time. Through these interactions, you are “making diversity visible in STEM” and supporting opportunities to connect students of color to mentors who look like them, who may have shared similar social experiences, and who are successful in STEM (NRC 2012, p. 288).

Your students can then discuss the problem and design task that was crafted by you and the STEM professional prior to implementation. During this time, the STEM professional can directly respond to questions posed by students in the DDN. Provide any additional background and context for students to find ways to connect their lives to the problem. This platform provides a great opportunity to “leverage students’ funds of knowledge” (NRC 2012, p. 287) as they grapple with ideas and connect the engineering task to their lived experiences. Students will also list real-world solutions they saw in their research, brainstorm ideas of their own, and upload prototype sketches to the DDN. The engineer can draw connections between these model solutions and real-world solutions directly on the slides, providing additional context to how the formation of designs influences their function.

**Phase 3: Build prototype**

Based on your conversations in Planning Meeting 2 (see Supplemental Materials), gather appropriate ma-
terials for students’ designs. This may include recyclable materials such as cardboard, sand, tacks, paper clips, and skewers; nonconsumables such as duct tape and clay; and tools such as laser cutters, hot glue guns, 3D printing pens, and coding software. Oftentimes, a brief discussion about how each material/tool can be used and the safety precautions associated with using them is helpful at the beginning of class. Allow students time to use the feedback and resources from the professional mentor to adjust their sketched prototypes accordingly and begin to build their solution (see Figure 4). These virtual conversations where students share their ideas and the STEM professional makes relevant connections helps to “relate youth discourses to scientific discourses” (NRC 2012, p. 285) through the collaborative process. During this phase, students should grapple with concepts, engage in trial and error, and learn from failure. As one teacher noted, “[the design process] will teach them how to keep pressing on . . . they’ll be ok with failing and making mistakes and then learning from them.”

**Phase 4: Test and evaluate prototype**

In this stage, students will capture a live-action video of their group testing the effectiveness of their prototype. They will upload this video to the DDN. Remind students that the STEM professional will provide thoughtful feedback to each group so that they can make their designs even better the next time around. Peer feedback is also important during this phase. Students can provide either verbal feedback or comments to other groups in the DDN. After students upload videos of their solutions, they will document the strengths and weaknesses of their designs in the DDN. Students should then be provided with time to revise their designs.

**Phase 5: Communicate engineering design process**

Create another live, virtual meeting so the engineer can watch students showcase their final prototypes and communicate their design process. You can also use this opportunity to extend the project’s impact by sharing student work beyond your classroom, which can truly empower students of color to recognize their voice and support social justice causes in their community. In doing so, you are “approaching learning as a cultural accomplishment” (NRC 2012, p. 283) and leading change in the community! Here are some ideas:

- Invite a local organization that does work on the societal issue you are addressing to your students’ presentations.
- Host a parents’ night where students share their work with families.
- Create a website or utilize social media to share their work with the community.
- Showcase their work in a school exhibit or school newspaper.

After the final event, be sure to take some time for you and the engineer to reflect on the experience by discussing what worked, what didn’t work, and other ways you might collaborate in the future. A Final Reflection document is provided (see Supplemental Materials).

**Conclusion**

All students, regardless of race or socioeconomic status, deserve access to professional role models, engaging STEM lessons, and opportunities to connect science and engineering to the real world. We believe that these accessible, online tools will not only foster meaningful engagement in your classroom, but also challenge you to think critically about the lived experiences of your students of color. As educators across the country work to promote equitable outcomes for students, we offer an easy-to-follow framework and resources to create meaningful engineering experiences for students by partnering with incredible STEM professionals of color. By utilizing synchronous and asynchronous digital tools, teachers, students, and engineers work together to solve real-world problems through design processes. The facilitation of this partnership through digital tools also allows for creative STEM engagement and instruction for students outside of school. By virtually connecting STEM profes-
CULTURALLY RELEVANT PARTNERSHIPS IN THE ENGINEERING DESIGN PROCESS


ACKNOWLEDGMENT
This research was funded by an ITEST grant (2015–2021) from the National Science Foundation [Award #1510347]. The opinions expressed are those of the authors and do not represent the views of the National Science Foundation.

REFERENCES


ONLINE RESOURCES
National Society of Black Engineers—https://www.nsbe.org/
Society of Hispanic Professional Engineers—https://www.shpe.org/
Dell—https://corporate.delltechnologies.com/en-us/social-impact.htm#tab0=2

SUPPLEMENTAL MATERIALS
Final Reflection—https://www.nsta.org/online-connections-science-scope
Planning Meeting 1—https://www.nsta.org/online-connections-science-scope
Planning Meeting 2—https://www.nsta.org/online-connections-science-scope
Storyboard Template—https://www.nsta.org/online-connections-science-scope
Storyboard Worksheet—https://www.nsta.org/online-connections-science-scope
Student Rubric—https://www.nsta.org/online-connections-science-scope

Meredith W. Kier [mwkier@wm.edu] is an associate professor in the Department of Curriculum and Instruction; Lauren A. Grob is an undergraduate student majoring in Education Policy, Planning, and Leadership; and Kelly G. Leffel is a PhD student in Curriculum and Learning Design, all in the School of Education at William & Mary in Williamsburg, Virginia. Deena Khalil is an associate professor in the School of Education at Howard University in Washington, DC. Turhan Carroll is a PhD student in the Department of Engineering Education at Ohio State University in Columbus.