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Keywords

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Elementary Teacher Adaptations to Engineering Curricula to Leverage Student and Community Resources

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Abstract

This paper addresses an important consideration for promoting equitable engineering instruction: understanding how teachers contextualize curricular materials to draw upon student and community resources. We present a descriptive case study of two 5th grade teachers who co-designed a Next Generation Science Standards (NGSS)-aligned curricular unit that integrated science, engineering, and computational modeling. The five-week project challenged students to redesign their school grounds to reduce water runoff and increase accessibility for students with disabilities. The teachers implemented the project with one Grade 5 class with a large proportion of students having individualized learning plans and cultural backgrounds minoritized in science, technology, engineering, and mathematics fields. Data sources include classroom videos, teacher interviews, and student artifacts. Findings demonstrate how teachers made helpful, important adaptations to contextualize the curriculum unit and draw upon students' community-based resources. This case highlights the role of the teacher in enacting engineering materials that privilege student and community resources in elementary classrooms. Findings also underscore the importance of teacher customizations to promote equitable, NGSS-based engineering instruction in elementary classrooms.

Keywords: elementary teachers, asset-based engineering curricula, NGSS-aligned curricula, teacher customizations

Introduction

The inclusion of engineering in current science education reform efforts, as expressed in the *K-12 Framework for Science Education* (National Research Council, 2012) and the Next Generation Science Standards (NGSS; National Research Council, 2013), underscores the growing importance of pre-college engineering education. Pre-college engineering instruction has the potential to make classrooms more equitable by leveraging student and community resources through the use of authentic, relevant, project-based approaches (Cunningham & Kelly, 2017). We describe equitable learning opportunities as those that (1) value and privilege students' backgrounds, including cultural and linguistic experiences, as assets or strengths (Gándara, 2015; Yosso, 2005), (2) connect students' existing knowledge and experiences to learning activities (e.g., Bang & Medin, 2010), and (3) sustain students' assets in pluralistic, multicultural classrooms (Paris, 2012). Equitable engineering instruction thus empowers and supports students to solve problems relevant to their own interests and communities by privileging student and community resources (Calabrese Barton & Tan, 2019). Incorporating engineering

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into pre-college settings can validate student and community resources within school contexts, leveraging these assets to solve meaningful problems.

Recent research investigates efforts to sustain student and community resources by developing NGSS-aligned curricular materials that promote authentic and relevant classroom experiences (e.g., Carlone et al., 2011; Miller et al., 2018). Although curriculum development is a necessary starting point, teachers are instrumental in making adaptations to curricula that are necessary to contextualize engineering projects to fit their students and local community. Teachers use curricular materials as tools to shape learning environments that draw on student and community resources to engage them with a compelling engineering problem (e.g., Remillard, 2005). Toward this end, teachers might implement classroom activities as designed. They may also adapt the classroom activities or use them as a starting point for the development of new activities (Davis & Varma, 2008; Remillard, 1999).

This paper describes an NGSS-aligned, upper elementary engineering curricular project that was co-designed with teachers to draw upon and center local student and community resources in the engineering design challenge. We focus on the ways a team of two elementary teachers productively adapted the project to privilege student and community resources. We present a descriptive case study to answer the question: How do elementary teachers contextualize NGSS-based curricular materials to leverage student and community resources?

Background and Rationale

Drawing Upon Student and Community Resources in Engineering Education

Students come to classrooms with their own cultural backgrounds, interests, experiences, and personal epistemologies (e.g., Moll & Gonzalez, 2004; Nasir et al., 2006; Sandoval, 2005). We define these student assets, or resources, as the set of experiences, languages, literacies, and cultural practices that students bring to educational settings. We build upon conceptualizations such as *funds of knowledge* (Moll & Gonzalez, 1994), *epistemological resources* (Hammer & Elby, 2003), and *repertoires of practice* (Gutiérrez & Rogoff, 2003; Martin et al., 2018) that reflect the set of students' experiences with and participation in cultural communities. These individual-level assets that learners bring to their educational experience serve not only as foundations upon which to build learning opportunities, but are also critically important to sustain, privilege, and nourish over time to support cultural and linguistic pluralism in classrooms (e.g., Paris, 2012; Paris & Alim, 2014). Each student has an individual set of assets and resources that are not fixed but rather dynamic, as both culture itself and how the student chooses to engage in different practices can shift and develop over time (e.g., Carlone & Johnson, 2012).

Furthermore, students' experiences are positioned within the cultural, historical, and geographical contexts of their classrooms and schools (Lave & Wenger, 1991). For instance, students draw from school-based, disciplinary, and community-based ways of knowing (Moje et al., 2004; Nasir, 2002). School-based ways of knowing emerge from students' experiences in classrooms and school contexts and can exist at both classroom and school levels. Community-based ways of knowing include resources that students develop through participating in their everyday lives within their communities. For example, Bang & Medin (2010) describe how Native American students navigate both community-based and Western science-based ways of knowing within science classrooms.

Equity in engineering education includes questioning what forms of knowledge matter, whose knowledge counts, and how these different forms of knowledge play a role in learning (Calabrese Barton & Tan, 2020). Traditional school practices can implicitly and explicitly devalue community-based ways of knowing, especially students from non-dominant cultures or backgrounds (e.g., Barrett et al., 2017; Lim & Calabrese Barton, 2006). These kinds of epistemological questions underscore the tension between students' personal and community epistemologies and epistemologies that have been institutionalized in educational settings. Unfortunately, engineering education has historically reproduced hierarchies of race, gender, class, sexuality, and nationality as evidenced by decreased access to and participation in engineering by minoritized groups (e.g., Apple, 2018; Gatto, 2002; Giroux & Penna, 1979; Jorgenson, 2002). Engineering education has thus unintentionally promoted deficit framing of students (Hoople et al., 2018). We view equity in engineering education as not just incorporating students' and community-based resources into instruction but also placing greater value on students' personal and community-based epistemologies within engineering learning experiences (e.g., Calabrese Barton & Tan, 2019).

Engineering approaches that leverage student and community resources should therefore explicitly draw upon and privilege students' experiences from which to define problems, generate and evaluate designs, and revise and communicate solutions (e.g., Verdín et al., 2016). For example, students can endeavor to define different problems that are relevant to their own interests, experiences, and/or of importance to their school or local community. Students can use out-of-school experiences and knowledge to generate designs and seek input from community stakeholders to evaluate their designs.

Students can communicate their solutions to members of their community who stand to be affected (either positively or negatively) by those solutions.

Research demonstrates how engineering projects can build upon student and community resources (e.g., Wilson-Lopez et al., 2016). For example, rural Hispanic adolescents used resources drawn from their own households, communities of practice, and classroom spaces to generate new knowledge and new discourse to brainstorm, develop, and evaluate and implement design solutions (Mejia et al., 2014). Calabrese Barton & Tan (2019) describe how a co-constructed engineering unit for upper elementary and middle school engaged students in community ethnography to help define problems relevant to their school community. Both studies exemplify how student and community resources can be privileged within engineering design.

In addition, engineering can not only leverage but also help privilege student and community resources within classroom settings (e.g., Wilson-Lopez et al., 2016). Engineering challenges can support cultural pluralism (e.g., Ladson-Billings, 2014; Paris, 2012) as each student or student group is able to devise their own solution based on their combined individual and community resources. For example, in a project to help redesign a school, one student could redesign their school in accordance with their knowledge of and passion for playing soccer. Another student could ensure accessibility for students with physical disabilities, out of empathy for a friend or family member. Given appropriate project criteria, both of these designs can be successful within the same overall design challenge. In this way, engineering design projects can not only foreground and value students' own personal and community resources within school contexts, but also disrupt typical norms of what knowledge is valued within classrooms (e.g., Calabrese Barton & Tan, 2019).

Role of the Teacher to Contextualize Engineering Curricula

Although engineering has the potential to incorporate and value community-based ways of knowing within classrooms (Cunningham & Kelly, 2017), engineering implemented in pre-college settings may still privilege traditional school-based knowledge, even when curricular materials are designed to leverage student and community resources. Curricula designed for broad dissemination are often generalized to fit a wide range of classrooms and school contexts, while leveraging student and community resources relies on knowledge of specific student and local context (e.g., Gutstein, 2003). Creating generalizable curricula can therefore be at odds with leveraging specific student and community resources. Thus, contextualization of high-quality curricular materials to students' local contexts is necessary to engage and sustain student and community-based resources (e.g., Kang et al., 2016).

We argue that teachers are crucial to enacting curricular materials in ways that leverage student strengths and value different ways of knowing (e.g., Buss et al., 2020). Teachers may use the materials as they are or change them to align with student and community resources (Davis & Varma, 2008; Remillard, 1999). For example, a curriculum guide or lesson plan can have educative supports (Davis & Krajcik, 2005) for teachers to make connections to students' assets. However, instead of flexibly adapting curricular materials to fit their classroom contexts, teachers may instead focus on adherence to the materials, standards alignment, or project completion. Thus, even if curricular materials have educative supports to build upon student and community resources, teachers may not necessarily implement them. Teachers may need various forms of support (individual, school, and systemic) in order to enact teaching strategies that leverage student and community resources.

Importantly, we note here that we take an asset-based approach to teachers and students. Instead of a deficit approach that can implicitly or explicitly devalue the experiences, knowledge, cultures, and beliefs of teachers, we believe teachers, like students, also come to classrooms with a wealth of resources. Teachers work within a complex educational system with many competing goals. Similar to student resources, teachers' resources should be sustained, privileged, and nourished throughout their careers. To say that teachers may not focus on adapting curricular materials to fit their classroom context could imply that they are mandated to meet other competing goals that are imposed on them, such as following curricula step-by-step.

Elementary teachers in particular face a wide range of unique challenges. Many elementary teachers are responsible for teaching all subjects to their students, regardless of their background or training. Many elementary teachers need support to teach subjects with which they may not be as comfortable or familiar, especially in science, technology, engineering, and mathematics (STEM) fields (e.g., Hill et al., 2005). Engineering in particular can be very unfamiliar to many elementary teachers as it is not typically a core subject that is taught or assessed in most states (Cunningham et al., 2006; Hsu et al., 2011; Katehi et al., 2009). Given the integration of engineering into science as called for by the NGSS, elementary teachers need help to understand (1) the discipline and concepts of engineering; (2) how engineering intersects with science, mathematics, and computational modeling; and (3) how to teach engineering concepts and practices and related STEM concepts and practices to their students (e.g., Porter et al., 2019; Purzer et al., 2014).

Research demonstrates that elementary teachers can effectively adapt existing curriculum materials and instruction to better align with their students' needs and unique experiences (Bauml, 2016). This ability to adapt curricular materials can result in instructional materials that are better contextualized for students (Burkhauser & Lesaux, 2017). For instance, elementary teachers can adapt curricular materials in response to perceived student needs and leverage students' diversity of interests, experiences, and knowledge to address best ways to engage students in relevant and meaningful ways (e.g., Rapp, 2014). Teachers can adapt or create their own activities to build upon students' prior knowledge (e.g., Bismack et al., 2014; Zangori et al., 2013), or create space for equitable participation (e.g., Haverly et al., 2020).

In addition to these adaptations, teachers can make conversational moves to contextualize classroom activities. We define contextualizing moves as similar to the definition of talk moves of Michaels & O'Conner (2015), or "simple families of conversational moves intended to accomplish local goals" (p. 334). Contextualizing moves are adaptations that the teacher makes to describing or enacting instruction to connect to what they know to be the knowledge and experience of students in their classroom. Teachers can use contextualizing moves to connect school content to students' out-of-school experiences (e.g., Hand, 2012), connect and honor students' individual strengths (e.g., van Es et al., 2017), or explicitly value and bring community resources into the classroom (e.g., Calabrese Barton et al., 2020). In this way, teachers intentionally use contextualizing moves to adapt curricula to their classrooms.

This paper focuses on how elementary teachers productively adapt an NGSS-based engineering curricular project to draw upon and privilege student and community resources. We present a case study of two teachers co-teaching one Grade 5 class to explore patterns in how the teachers adapt curricular materials to their classrooms. Our analysis of these elementary teachers' adaptations to these materials informs how professional learning experiences and curricular co-design can support elementary teachers to leverage student and community resources in engineering curricula.

Methods

Methodological Approach

We adopted the methodological approach of a descriptive case study for this qualitative research study (Merriam, 1998). A case study is a systematic inquiry that uses multiple sources of evidence to examine a phenomenon in its authentic setting, seeking deep descriptions of events of a bounded unit of study (Yin, 2017). Our unit of study was two elementary teachers co-teaching an NGSS-aligned curricular unit in one Grade 5 classroom, as they worked together to contextualize the project. The case is bounded by the teaching of the curricular unit with students and subsequent teacher interviews that prompted teachers to reflect upon the curricular enactment. Although the teachers were co-designers of the curricular unit, we describe that process in the methods section and focus our case study inquiry on how the teachers adapted and contextualized the co-designed curriculum during enactment into their classroom.

Study Context

This work is part of a National Science Foundation-funded research project that has developed NGSS-aligned curricular materials that integrate science, engineering, and computational modeling. The materials include a computational modeling environment to support upper elementary students to engage in an ambitious engineering challenge. The project has also developed and implemented professional development for teachers across multiple states. The professional development engages teachers with the curriculum unit as students; providing targeted strategies and support for teaching science, engineering, and computational modeling in upper elementary settings; and helping teachers plan classroom implementation.

Selection of Participants

We chose Paul and Anita for our case based on their involvement with the design of the curriculum and their school context. Paul is a White man and was a STEM coordinator for the only upper elementary school in the district. Paul and the district STEM coordinator participated in the conception and design of the curriculum over the course of two years. Paul's main role as the school STEM coordinator was to integrate engineering and design experiences with other core subject areas and work with other teachers to engage students in design-based activities. Anita is a Black woman and was a Grade 5 math/science classroom teacher at the same school as Paul. Paul and Anita each had more than 7 years of teaching experience. Both Anita and Paul hold undergraduate degrees in science but did not have any formal training in engineering. Although elementary teachers do not typically have this level of formal STEM disciplinary training, studying Anita and Paul as a case illustrates the kinds of adaptations that are possible for elementary school teachers and what role disciplinary STEM knowledge may play in these adaptations. Co-teaching was a regular occurrence for both Paul and Anita as they had co-taught on several occasions on prior STEM units.

School Context

Throughout this paper, we refer to the school as Ridge Elementary School. Ridge School is located within a school district with 32% Black, 12% Hispanic/Latinx, 7% Asian/Pacific Islander, 41% White, and 8% of 2+ or Other races. The district has a large diversity of emerging bilingual students, with 14% of students speaking 51 different languages. Additionally, 44% of students qualify for free or reduced-price lunch. Historically, the district's schools were segregated for over a decade after the *Brown v. Board* decision, with active efforts to keep schools segregated by White school leaders and parents. Working toward racial equity has been a major focus of the district in the past few years, with district-wide professional development focused on implicit bias.

The class selected as part of the case study had 28 students. The student demographics in this class were similar to district demographics. About a fourth of the students in the class had documented learning disabilities and/or individualized learning plans. With the exception of students who were pulled out for instruction with the special educator, Anita spent half of each day with the students in this class, teaching them both mathematics and science. This time with the students gave Anita specific knowledge of students' strengths and resources that they brought to the learning environment, such as their linguistic backgrounds and current mathematical understanding.

Curriculum Design

Design Process

Our design approach integrated evidence-centered design (Mislevy & Haertel, 2006) and design-based research methods (Barab, 2014; Design-Based Research Collective, 2003). In order to align the curriculum with NGSS performance expectations in a way that would leverage student and community resources, we used an equitable design approach (Fujii et al., 2020) based on evidence-centered design. This helps ensure that design features (such as those that leverage student assets) are appropriately anchored to learning goals from the outset of design and elicit evidence of these learning goals from students. Using backward design (e.g., Wiggins & McTighe, 2005), we began by identifying the specific learning targets for students, which in this case are the three upper elementary engineering design NGSS performance expectations (3-5ETS1-1, 3-5ETS1-2, 3-5ETS1-3). We then performed a domain analysis of these performance expectations by reviewing relevant literature in engineering education and explicitly articulating what knowledge and skills are required for upper elementary students to achieve engineering proficiency in a way that is consistent with the performance expectations and *The Framework*. The resulting unpacking document identified six engineering processes that together represent the upper elementary engineering DCIs and practices: (1) *defining and delimiting problems*, (2) *gathering information*, (3) *generating solutions*, (4) *evaluating solutions*, (5) *refining and optimizing solutions*, and (6) *communicating solutions*.

For each of these six engineering processes, we identified a set of equitable design considerations, which included considerations for leveraging student and community assets. This paper will focus on teachers' enactment of activities addressing processes (1) and (6): *defining and delimiting problems* and *communicating solutions*. Informed by our collaborations with the teachers and design-based curricular refinements using data gathered during a pilot test, these two engineering processes emerged as the strongest leverage points for asset-based engineering instruction. We subsequently strengthened design considerations focused on leveraging student and community assets at Ridge School. For example, design considerations for the process of *problem definition* include: (1) present a relevant and compelling problem anchored to students' own school context and (2) engage students in collectively articulating their own design criteria and (3) revisit these criteria throughout the design challenge. Example design considerations for the process of *communicating solutions* include (1) have students present designs to members of their community, such as peers, teachers, and school leaders, and (2) engage students in peer critique of design solutions based on design presentations. These considerations help ensure that teachers can leverage student, teacher, and community assets (such as prior knowledge, everyday experiences, and community members and resources) when they enact the curriculum. The supporting materials for teachers and professional development experiences emphasized these design considerations to inform their implementation of the unit.

Co-design/Refinement of Curriculum

The design of the Water Runoff Challenge (WRC) curricular materials was created from design-based research perspectives, where materials were iteratively refined using data gathered during previous classroom implementations. The pilot version of the WRC presented an engineering challenge to students of redesigning a fictitious playground to reduce flooding (Chiu et al., 2019). During the pilot implementation, teachers spontaneously made many direct connections to their own school and community. For example, teachers made connections that light rain events caused students' recess to be moved indoors. Even days after rain had stopped, water remained on ground surfaces because of the runoff onto their play areas and grounds. Students with physical disabilities faced many accessibility problems at their school, including limited avenues to enter the building itself and circuitous routes through the building to access particular spaces. Moreover, during the pilot version of the WRC the community had one of the largest rain events in recent history that caused many local playgrounds and sports fields to close for weeks. Teachers made many connections to the local weather events while the students were designing their playgrounds. As a result of the teachers' observations during the pilot implementation, researchers worked closely with Anita and Paul to co-design the WRC to refocus explicitly on redesigning the Ridge School grounds to reduce runoff, following the refined design considerations and learning performances.

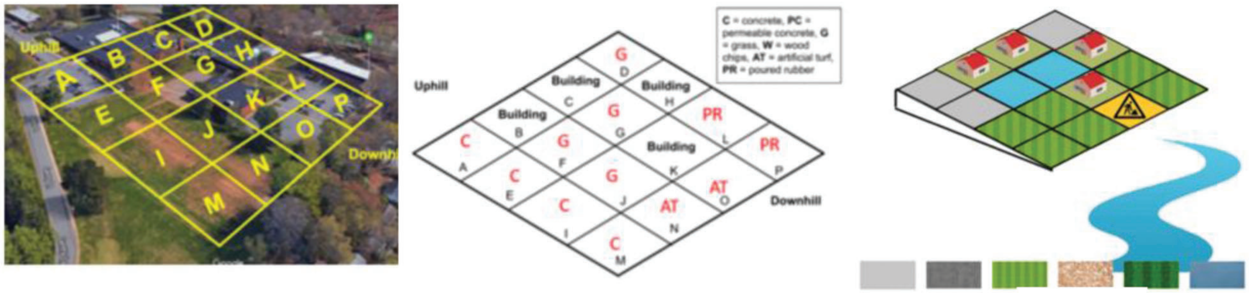
Specifically, Anita and Paul sought to leverage the students' shared school experience to contextualize the WRC. They both wanted to help students connect science to the school community and saw strong connections between the authentic practice of engineering and an ongoing problem at their own school. One problem that the school community repeatedly faced revolved around outdoor recess, an important part of school culture for students. Anita and Paul both served as teacher monitors for recess activities where students were able to socialize with their friends and play games or sports such as basketball or soccer. However, because of the school location and surrounding landscape, even after light rain the grass fields and asphalt play area would be inaccessible. Consequently, recess was necessarily moved indoors to the cafeteria, taking away an opportunity that students valued very highly. Anita and Paul believed this problem would be a powerful way for an engineering challenge to incorporate students' own knowledge of the school's operational and cultural norms around recess in a way that was not typically part of classroom instruction.

Curriculum Description

The WRC included 10 lessons, each of which was divided into a sequence of smaller activities (Table 1). In order to support students in creating designs and a computational model of water runoff at their school, the project team created an abstract 16-square grid that overlaid the school campus (Figure 1). The unit focused on students choosing the purpose (e.g., school building, parking, play area, grassy fields) and surface material (e.g., concrete, permeable concrete, grass, artificial turf, poured rubber) of each square, as well as determining what squares would be occupied by school buildings. Thus, students created different designs on paper within a 16-square grid. Within the computational modeling environment (Zhang et al., 2020), students were able to develop a program that could determine how much water would run off for

Table 1
Overview of WRC design.

Lesson	Focus	Number of designed activities	Expected time of lesson
1	What is the problem? *Students uncover and define problems at Ridge School*	7	1 hour
2	What happens to water when it rains? *Students develop a conceptual model to explain how water runoff and absorption relate to surface materials, slope, and amount of rainfall*	4	1 hour
3	How do we know how much water falls when it rains? *Students engage in investigations to explain the relationship between amount of rainfall and hourly rainfall*	11	1 hour
4	How do different surfaces affect where water goes? *Students engage in investigations to show how water absorption relates to surface material and amount of rainfall*	9	1 hour
5	How can we find the amount of water runoff? *Students engage in investigations to show how water runoff and absorption relate to surface material and slope*	9	1 hour
6	Generate solutions for Ridge School. *Students create design solutions to minimize water runoff and meet criteria*	4	1 hour
7	How can we test our solutions? *Students develop a computational model to test the effectiveness of solutions*	16	5 hours
8	Generate and compare solutions. *Students develop additional solutions and test using the computational model*	7	1 hour
9	Conducting fair tests to improve your design. *Students systematically compare different designs to find failure points*	8	2 hours
10	Communicate your design. *Students create and present design proposals to their principal*	4	2 hours



(a) (b) (c)

Figure 1. The WRC used (a) a grid overlaid on a map of the school as a basis for (b) students' designs and (c) the computational model.

different surface materials for one square. The environment would automatically populate their model code into the 16-square environment to enable testing of their full designs.

The unit began with a video introduction of the problem by the principal at Ridge School, discussing the water runoff that makes the soccer fields muddy, the play area dangerous, and certain areas of the school inaccessible to students with physical disabilities. From there, students collectively built upon what they knew and experienced at the school to define the problem by deciding on the class criteria for how many squares should be used for what purpose (e.g., school buildings, parking, grassy field, and play area), with a given set criterion of seven squares that must be accessible to community members who use wheelchairs. During subsequent lessons, students worked on understanding the problem by investigating the science behind water runoff. This investigation involved creating and revising conceptual models and written explanations using a claim–evidence–reasoning framework (e.g., McNeill & Krajcik, 2011) of how water runoff and absorption relate to surface materials. Hands-on investigations provided concrete experiences for students to develop conceptual understanding, with particular focus for supporting emerging bilinguals who may benefit from multiple representations of concepts. The investigations served as evidence for the students' revisions of their conceptual models and explanations (lessons 2 through 5).

Within these science-focused lessons, there were explicit connections to student and community resources. For example, in lesson 3, students explored the heaviest rainfall events for the past five years in their town, then used that information to decide as a class how much rainfall their designs should be able to withstand. This amount of rainfall constituted a key engineering design criterion that the class revisited throughout the engineering challenge. At the end of the science activities, students redefined and summarized the design challenge using what they had learned, responding to prompts such as "Explain where water goes when it rains on [Ridge]," and "Explain why water runoff is a problem for the school community." After this extended problem definition that included investigation into the science driving the problem, students generated designs for their school in lesson 6. Their designs helped students recognize the need to develop the computational models, as testing their designs without a computational model would be infeasible.

Students then transitioned to computational modeling (lesson 7), beginning with an introductory activity to programming where students provided a set of instructions in pseudocode to make their teacher dance. This activity emerged from the first version to leverage students' interest in dancing. The rest of lesson 7 focused on helping students translate their conceptual models and explanations of water runoff into the computational environment. For example, the next activity focused on helping students identify key variables (e.g., total rainfall, total absorption, absorption ratio, and total runoff), the initial values of these variables, and if/how these variable values change after a rainfall event. The next activity used a use–modify–create approach (e.g., Lytle et al., 2019), where students were provided with starter code in the computational modeling environment and asked to explore, modify, and then create the rest of the code to produce their own working computational model (Figure 2). For example, students were asked to run the model and record what happened, to identify the variables they saw in the computer code, describe what the computer code did in words, and then modify certain parameters in the code to see what would happen. In the next activity, students manually calculated the amount of rain that would fall in each hour for one surface material, identified patterns in their data table (e.g., that total absorption = total rainfall × absorption ratio), used those patterns to write out a set of instructions for the computer in pseudocode, and then used their pseudocode to program their model. The subsequent activities used the same progression to help students calculate the total runoff (e.g., total runoff = total rainfall − total absorption) and extend the code to simulate multiple materials so that they had a fully functional model (for a more detailed description of the computational models and modeling activities, see Zhang et al., 2020).

(a)

```
when clicked
set total rainfall (inch) to 0
set elapsed time (hour) to 0
set hourly rainfall (inch) to 0.3
set rain duration (hour) to 5
start raining
repeat until < elapsed time (hour) is equal to rain duration (hour) >
    change elapsed time (hour) by adding 1
    change total rainfall (inch) by adding hourly rainfall (inch)
    update simulation history
stop raining
```

(b)

```
when clicked
set total rainfall (inch) to 0
set elapsed time (hour) to 0
set hourly rainfall (inch) to 0.3
set rain duration (hour) to 5
set total absorption (inch) to 0
set total runoff (inch) to 0
start raining
repeat until < elapsed time (hour) is equal to rain duration (hour) >
    change elapsed time (hour) by adding 1
    change total rainfall (inch) by adding hourly rainfall (inch)
    change total absorption (inch) by adding
        ( hourly rainfall (inch) × absorption ratio )
    set total runoff (inch) to
        ( total rainfall (inch) − total absorption (inch) )
    update simulation history
stop raining
```

Figure 2. Computational model (a) that students began with using and (b) an example of a final computational model that students created to predict absorption and runoff for different materials.

The unit culminated in students using their computational model to develop engineering solutions and generate evidence to support their solutions. In lesson 8, students used their computational model to test and compare their designs. Lesson 9 was designed to support students in conducting fair tests that systematically compared different parts of their designs. This activity was instantiated by supporting students in isolating different areas of their designs one at a time (e.g., parking area, play area, grassy field) and comparing the impact of choosing different surface materials for just that area on the overall performance of their design. In lesson 10, students prepared a presentation about their work and presented it to their principal, using the design considerations mentioned above.

Supporting Resources for Teachers

In order to support teachers in successfully implementing the unit, we provided three types of supporting materials for both Paul and Anita. (1) The *Teachers' Guide* included the pages from the student notebook with information about facilitating class activities around the curricular activities. The guide included educative supports around mathematical concepts and the crosscutting concepts of systems. (2) *Instructional presentation slides* were developed around most activities in the lessons, which included screenshots of student notebook pages, the computational modeling environment, and suggestions for information to guide student work. (3) *Professional development,* which involved a two-day workshop and two subsequent follow-up meetings. During the workshop teachers were guided through the in-development activities as students and were invited to provide feedback about the classroom feasibility of the activities. Paul and Anita also experienced the coding and computational modeling activities as students. For each of the activities, the group of professional development leaders, Paul, and Anita discussed some of the potential pitfalls and benefits of each activity, both for their instruction and to inform design refinements to the activity itself.

Data Sources

Data sources included audio transcripts of the whole class videos and researcher field notes for all of the class sessions where teachers taught the unit. We also collected student artifacts generated in the lesson activities, teachers' responses to daily surveys, interview notes from weekly teacher interviews, and audio recordings of teacher interviews after the completion of the curricular unit. Daily teacher surveys asked what lessons they taught and what they believed their students were successful with on that day. Weekly teacher interviews asked what students were successful with, what students struggled with, and what changes they made during the week to support student learning. The teacher interviews after the enactment of the unit asked teachers to reflect upon how the WRC went overall, what went well, and what was challenging about the implementations.

Data Analysis

We analyzed audio transcripts of the whole class videos using NVivo qualitative software by QSR International Pty Ltd (released in March 2020) with constant comparative analysis (Strauss & Corbin, 1990). Based on classroom observations by the second author, we knew that the teachers added instructional elements to the base curriculum. These additions occurred at both the activity level and the turn-of-talk level, so we coded the lesson implementation at both of these levels.

In order to identify which activities were from the original curriculum and which activities were added or modified, we used the Teachers' Guide to compare enacted activities to curricular activities. We chunked the transcripts of the whole class discussion into segments that represented a single type of activity (whole class discussion, small group work, etc.) around a single topic of discussion (e.g., fractions and decimals, rain events, etc.). Two coders chunked the curriculum and discussed any differences in where a chunk should begin and end. Ultimately, all of the transcripts were checked by the first author. Each of these activity chunks was then matched to the Teacher's Guide as either something added or something that aligned with the existing activities. If the activity was part of the Teachers' Guide, then it was coded as curricular-based. For example, the Teachers' Guide had many suggestions for opening and closing discussions of lessons. Any activity related to those discussions was coded as curricular-based. If the activity was not part of the Teachers' Guide, then it was coded as an added activity. Once the activities were coded, we looked for patterns among the added activities that drew upon student and community-based resources. Both researchers discussed the coding of all activities until agreement was reached.

The next round of coding addressed the teachers' use of language in each lesson at the turn-of-talk level to examine how teachers used language to contextualize the unit and connect it to student and community resources. These instances were coded as contextualizing moves. Once the contextualizing moves were identified, we looked for patterns among the turns of talk.

Findings

Summary of Teacher Adaptations

Although the WRC was intended to be structured as fifteen 1-hour classes, the WRC was implemented as twenty-three 40-minute class periods over 5 weeks. Overall, the teachers spent more time than planned in the investigation lessons and less time than planned implementing the computational modeling activities. Due to time constraints, the teachers chose to skip lesson 9, where students were to have conducted fair tests of their designs. Instead, teachers had students generate and test additional problem solutions and prepare their final presentation to the principal.

Teachers added the most activities to the science-focused investigations (lessons 3, 4, and 5) and to the computational modeling tasks (lesson 7; Figure 3). Teachers added fewer activities to the engineering design-focused lessons (lessons 1, 2, 6, and 10). Teachers made contextualizing moves most frequently in lessons 2 (developing conceptual models), 5 (hands-on investigation of surface material and slope), and 6 (generating design solutions; Figure 4). Very few contextualizing moves were found in lesson 8, where students were testing and evaluating their designs with the computational model. No contextualizing moves were found in lesson 10 by the teachers; however, during students' presentations the principal asked questions to the teams asking them to further refine or clarify their solutions with respect to the school context.

Three themes emerged across the added activities and the contextualizing moves: (1) connecting to Ridge School; (2) drawing upon students' school-based resources; and (3) connecting to students' out-of-school experiences (Table 2). Connecting to Ridge School involved connecting the WRC activities and lessons to the problem at Ridge School. Drawing upon students' school-based resources included connecting to students' prior mathematical or scientific knowledge and making connections among different lessons and activities within the WRC. Connecting to students' out-of-school experiences involved making links to students' everyday knowledge. The rest of this section describes themes and evidence of the teachers' reasoning underlying their instructional decisions.

Connecting to Ridge School

Added Contextualizing Activities

The teachers created their own activities to enable students to further situate themselves within the WRC because the teachers believed the students would benefit from connecting their classroom activities to the real-life problem on their school campus. Being familiar with the muddy field and drainage problems, the teachers added activities for students to (1) observe and document the areas at their school they were designing and (2) explicitly connect them to their design challenge. Toward this end, the teachers added four of their own activities prompting students to go outside and observe instances of problems at the beginning of lesson 4. The first activity involved a whole-class introduction of the activity; the

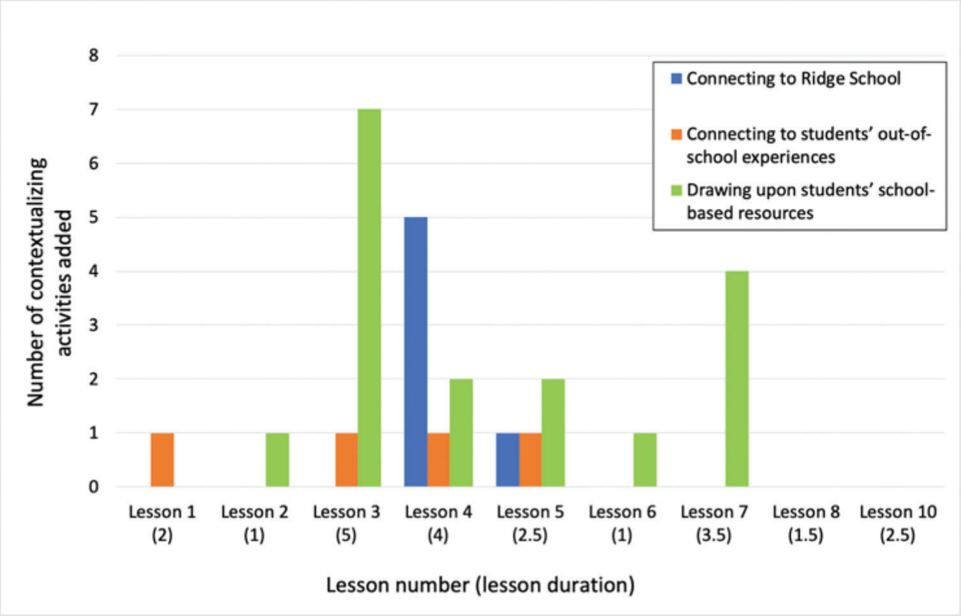


Figure 3. Number of contextualizing activities added by teachers by theme and lesson. Note that lesson 9 is not included because teachers skipped the lesson.

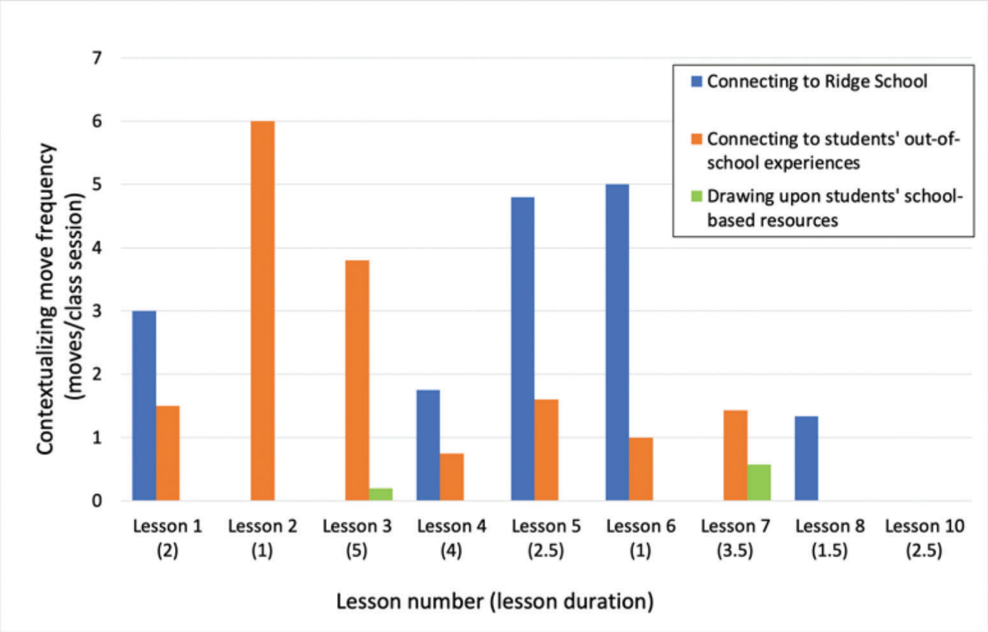


Figure 4. Contextualizing move frequency (moves per class session) by lesson and theme. Note that lesson 9 is not included because teachers skipped the lesson.

second consisted of students capturing pictures or videos of their observations; the third had students share out their pictures and videos; and the fourth involved introducing the next day's activities by presenting one student's video and using it to connect the WRC to the school's runoff problem. Anita and Paul planned where the students would go, anticipated what they would see, and addressed logistics of going outside with computers in the rain (the teachers brought extra umbrellas). The students then went outside and documented observations. Many students found muddy puddles, some students observed the mud in the middle of the "grassy field," and others made observations of the mud and puddles on the blacktop. When the students returned inside, the teachers asked students to share some of their pictures and videos. As the students shared their observations the teachers asked questions such as: Why did you take this picture? Why do you think the water is here? What do we know about the blacktop? At the end of the lesson, the teachers connected what the students

Table 2
Emergent themes from added activities and contextualizing moves.

Theme	Description	Example (activity)	Example (contextualizing move)
Connecting to Ridge School	Connecting WRC activities and lessons to the problem at Ridge School	Students taking pictures and videos of Ridge School during a rain event	"You can only play soccer in certain areas. Right? So we have some problems that we are trying to tackle. That's what this challenge is all about, yes?"
Drawing upon students' school-based resources	Connecting to students' prior mathematical or scientific knowledge	Discussion of patterns in data	"How many people remember the hour of code this past year? When you were doing the hour of code, what was like the goal for one of the things that you did?"
	Connecting to other parts of the WRC	Review of WRC criteria for success before students generate solutions	"When [principal] talked about this challenge, which one do you think he's going to care about the most? Is he going to care that you got it within budget or is he going to care that you got the runoff as low as possible?"
Connecting to students' out-of-school experiences	Connecting to students' everyday knowledge	Discussion of students' experiences during recent rain events	"How do people get places without driving? Do you guys drive to school? You're on the bus, right? I take my bike some days, right? You walk to school."

had just done to the design challenge by saying, "These are the problems you are trying to solve. You just saw it! How do we fix it?"

The next day, Anita used one of the student videos to introduce lesson 4, building upon her student's voice by saying:

> What Oler just said was really powerful. So, this is why we are doing a project. We're trying to figure out how do we fix this problem of runoff at our school, so that when there is, so when it does rain, you guys can still have outdoor recess. (Anita, lesson 4)

Anita ended by telling the students that they went "back to well why the heck are we in the [lab] doing this project. That's why. Our problems are outside."

Contextualizing Moves

The teachers used many contextualizing moves to connect the activities in the WRC directly to their school setting, mostly in lessons 1, 4, 5, and 6. During problem definition, the teachers spent time contextualizing the WRC to their school. For example, Anita asked the students about what water runoff means in the context of their school, soliciting responses from students that mentioned water running down the hill "flooding our areas" and "stopping the water from running downhill onto the soccer field." Similarly, Anita asked students about accessibility and their school, such as, "What do you think makes Ridge more accessible? What does that mean?" Paul also made connections to students having difficulty playing soccer on the school fields after rainfalls, such as, "You can only play soccer in certain areas. Right? So, we have some problems that we're trying to tackle. That's what this challenge is all about. Yes?"

The teachers also emphasized connections to their school setting when students were refining their conceptual models and scientific explanations (lessons 4 and 5). For example, when students were making final revisions to their conceptual models in lesson 5, Paul asked "Why is water runoff a problem for our school?" followed shortly by Anita asking, "Why can't we go outside all the time?" and "What happens when it rains? What happens to our playground area?" Similarly, before students generated their first design in lesson 6, Paul again reminded students of where water goes at Ridge School when it rains, stating, "So we just talked about where water goes when it rains, you said the blacktop, you said the soccer field, what about when it hits the building, where does it go?"

Rationale for Adaptations

Anita and Paul purposefully made these instructional decisions based on their perceptions of students needing more links between their classroom activities and their real-life school context. In the weekly interviews, the teachers highlighted the need to "help students make connections between lessons and what was happening outside." They noted that students felt lesson 3 (conducting hands-on investigations and learning about absorption and hourly rainfall) was disconnected from the overall WRC design problem, and that students were generally struggling to see the relevance of their classroom scientific investigations to issues surrounding their school. Anita and Paul made these adaptations to help students apply their knowledge of the school (such as ground surfaces) and its problems (such as water runoff) to the investigation. In this way, Anita and Paul contextualized the WRC to make explicit connections from students' experiences around their school to the classroom activities.

Drawing Upon Students' School-Based Resources

Added Activities

Anita and Paul frequently added activities in lessons 3, 4, and 5 that focused on review of scientific concepts or mathematical skills emphasized in the lessons after students had initially completed the activities in small-group work. For example, in lesson 3, Anita and Paul noticed students having difficulty multiplying decimals during small-group work, so they inserted a whole-class discussion about how to multiply decimals. Similarly, the teachers noticed students having difficulty understanding differences between hourly rainfall and total rainfall, so they inserted a whole-class discussion to help students step through a rain event hour by hour to relate the total amount of rainfall to hourly rainfall.

Another theme that emerged from the added activities was making connections across the curricular activities within the WRC itself. Many added activities centered on connecting back to criteria (added in lessons 2, 3, 5, and 6) as well as referring back to results from prior activities to inform the current activity. For example, when students began programming the computational model, Paul and Anita added an activity where students revisited previous pages in their workbook to emphasize the mathematical rules they created in conceptual modeling activities. Anita and Paul also inserted an activity after students programmed their computational models to connect these models back to their underlying mathematical equations (e.g., total runoff = total rainfall − water absorbed).

Contextualizing Moves

A few contextualizing moves aimed to help students connect the WRC activities to other school-based experiences. For example, in lesson 3, Anita made a connection about a previous classroom activity to the claim–evidence–reasoning activity, stating, "So this is kind of like the time that we played that game in homeroom where you had to finish each other's sentences or add on to the story. So here you're just adding on to the reasoning." Similarly, when starting the computational modeling in lesson 7, Paul asked the students about their prior programming experiences:

> How many people remember the Hour of Code this past year? When you were doing the Hour of Code, what was like the goal for one of the things that you did? What were you trying to do? Do you remember? (Paul, lesson 7)

Anita used another contextualizing move to connect the concept of elapsed time to students' experiences with the school lunch hour:

> So it's—it's kind of like from the start, from a starting point to a finishing point. So, like, if I said what's the elapsed time from now to lunch, right? That would be an elapsed time, you have a beginning point and an ending point. (Anita, lesson 7)

Rationale for Adaptations

Anita and Paul consistently made instructional decisions to draw upon students' school-based knowledge. For example, in interviews Anita stated that she typically organized her science class as discussion-oriented with whole-class writing activities because of the "multiple level 1 English learners" (students with little to no previous English experience) in her class. She also described her reasoning for adapting many of the WRC activities to a whole group to reduce the load for students who struggled with writing, explicitly mentioning changing the claim–evidence–reasoning explanations to a "class consensus rather than students working on their own" for lessons 4 and 5. In interviews Anita and Paul also mentioned that students needed extra support to understand and use some of the concepts and vocabulary, such as *ratio*, *variable*, *impermeable*, and *permeable*. Paul also noted in the daily reflections that students had difficulty "remembering previous lessons, particularly about duration and hourly rainfall." Both Anita and Paul described how the added activities and contextualizing moves responded to the perceived needs of the students to connect and support other school-based knowledge that emerged during the WRC.

Connecting to Out-of-School Experiences

Added Activities

The teachers added discussions to help students connect the WRC activities to their out-of-school experiences. For example, Paul added a discussion about a data table showing the school's most recent rain events in order to connect those dates to students' everyday lives, asking "How many people remember [date], like before the school year started we had some intense rain. Can anyone remember that day?" Paul then helped students connect their experience with the rainstorm to the numbers in the table for hourly rainfall and duration. Another added discussion used students' knowledge of basketball to illustrate the concept of average when Paul was helping the class compute the average amount of how much water was absorbed across students' designs:

> Some basketball players um they keep statistics right? For each game or for each like whole bunch of games that they play. So if I'm a basketball player and I average or my mean for the number of points that I score per game is 10.7 points. The way they figure that out is they take all games that I play and then the points from each game and they add them all up and then divide by the number of games so they can find the center point. Is that mean my score of points in one game? You can't score .7 points or seven tenths of a point. Can't do that. So the way that they get that decimal point is they add up all the numbers from each game and then they divide by the number of games. (Paul, lesson 4)

Paul then connected the basketball example to the average rain absorbed by different materials:

> That's essentially what we did here because you guys all took data from different experiments. So we tried to find the center point. And what we found was the concrete left 13 sixteenths of an inch on water on top and only absorbed 3 sixteenths. And then we looked at the grass. This is everybody's data. (Paul, lesson 4)

Contextualizing Moves

During many of the activities, Anita and Paul used contextualizing moves to connect to students' everyday experiences of weather events. For example, as part of defining the problem in lesson 1, Paul introduced the WRC activities by reminding students of heavy rain events in the community:

> There was something crazy that happened last May. Really intense weather that happened right before school ended. Can anybody remember what happened in [city]? We had a real wild thing take place. There were pictures of it all over the news. Yeah? (Paul, lesson 1, day 2)

After a few students answered with what they remembered, Paul proceeded to connect these events to the class activities:

> I don't know how many people saw pictures of this, but [Name] park, which is right there at the end of [Name] Street, down by the [name] river...So [name] river overflowed its banks. The playground equipment was covered in water, like two feet of it. We had some crazy heavy rainstorms. That was one of our criteria and constraints is that our challenge, what our design has to withstand those heavy rainstorms and we want to get rid of that runoff that's causing our playgrounds to be all kinds of, you know, muddy and dirty and really hard to access. (Paul, lesson 1, day 2)

Similarly, during computational modeling, Anita connected the concept of variable initialization to students' real-life experiences with rain: "How much total rain are we going to have at the beginning of a storm? And it's not a trick question. What's the total amount of rain at the beginning of a storm?" These questions launched an activity where students stepped through a hypothetical rain event at hourly intervals to determine which model variables changed and which stayed the same. Subsequently, when students discussed whether rain duration is a fixed number or a variable, Anita stated, "Yes, not every storm is going to be four hours. Sometimes it rains for two hours, sometimes it rains for like five minutes, right?" Generally, teachers made frequent connections to students' experiences with weather to help anchor the WRC to everyday life.

Rationale for Adaptations

Through co-design of the WRC, professional development, and enactment of the WRC, Anita and Paul engaged in multiple conversations about the importance of connecting to the students' everyday knowledge and experiences. For example, in the interviews, Paul mentioned that he "felt confident eliciting prior knowledge of storm events and helping students draw out their reasoning for choosing a certain hourly rainfall for the class." Building upon students' prior knowledge and experiences was a theme during the co-design process and framed many discussions with the researchers of what to include and how to structure the activities.

Discussion

This paper describes two teachers' roles in co-designing and contextualizing an NGSS-aligned engineering curricular unit to build upon school-based and community resources. Teachers' role as co-designers helped give students agency and advocate for solutions to school problems while learning about and using engineering design practices, computational modeling, and scientific practices. Our findings highlight the role of the teacher in enacting engineering materials in ways that privilege student and community resources in elementary settings. Other than the omitted lesson 9 and lesson 10 where students only presented their designs to their principal, the teachers made adaptations that built upon students' school-based and contextual prior knowledge and everyday experiences.

For example, as part of problem definition in lesson 1, students used their knowledge of their school to decide upon a set of design criteria by eliciting students' ideas and then holding a blinded class vote. Few, if any, elementary engineering curricula have engaged students in authentic problem definition where students set their own criteria for success (e.g., Cunningham, 2009). Instead, most engineering curricula at the elementary level present a fixed design problem for students to solve. Our case analysis demonstrates that elementary teachers and students have the capacity to co-create design criteria, adding to literature that highlights the potential of elementary teachers and students to engage in ambitious, asset-based engineering instruction (e.g., Dalvi & Wendell, 2015). However, given that teachers decided to cut out lesson 9 due to time constraints, this rich engagement with problem definition may have come at the expense of the subsequent activity on fair tests. Teachers therefore may not be able to dive deeply into every engineering practice in every design challenge. Instead, curricula can intentionally be designed and/or enacted in ways that emphasize different design practices, so that students gain more in-depth experience across design practices over time.

Our findings also illustrate the importance of teachers' adaptations of curricular materials to build upon students' school-based and community resources. These adaptations may be especially important when curricular materials have not been specifically tailored for their location context, or when teachers did not participate as co-designers of the activities. Given that the WRC was designed for a specific problem at a particular school, teachers may need targeted support to adapt engineering curricular materials to their own student and community contexts. For example, teachers may need peer support such as the opportunity to collaborate with other teachers who may be more familiar with asset-based or engineering instruction. Teachers may also need school-level supports such as the time to plan and potentially co-teach with their peers, as well as the ability to participate in professional learning experiences around asset-based or engineering approaches. Teachers also need district-level supports such as instructional coaches and/or STEM specialists to help plan and enact engineering instruction that privileges student and community resources.

Anita and Paul found ways to adapt the activities to better connect them (in their view) to the students' experiences and allowed for more opportunities for student expression. Anita's and Paul's sense of agency to adapt materials may be a result of how they viewed themselves in relationship to the curricular materials. Research demonstrates that how teachers frame classroom activities can have an impact on their enactment of lessons (e.g., Russ & Luna, 2013; Wendell et al., 2019). Anita and Paul did not limit their teaching to being dispensers of content, but instead added what they believed was needed to contextualize the materials for their students. These adaptations entailed reviewing prior knowledge, connecting to other school-based knowledge, and connecting to out-of-school experiences. The teachers assumed a curricular frame that enabled them to interact with the materials, rather than strictly and passively adhering to them.

The teachers' curricular frame may have been influenced by their role as co-designers of the curricular materials. Having participated in the pilot and been actively involved in the curricular redesign may have helped Anita and Paul view the materials as dynamic and flexible instead of static and rigid. These findings relate to other research that underscores the importance of co-designing curricula with educators and including student voice to be able to create asset-based instruction (e.g., Guzey et al., 2016). These experiences may have helped Anita and Paul reflect upon and analyze their teaching, including ways to tailor experiences to their students and learn from each other (e.g., Voogt et al., 2011).

In addition to co-designing before the WRC started, Anita and Paul engaged in constant reflection (through the daily surveys and weekly interviews) upon the strengths and challenges of their students and their own instruction. Anita and Paul also continued to play a large role in the subsequent refinement of the WRC. In the daily surveys and weekly interviews, both Paul and Anita continued to offer ways that they would refine or redesign the activities for the next implementation based on what they noticed with their students. This critical, active engagement in their own practice may also have helped Paul and Anita shift their perspectives from viewing curriculum as a source of activities to a resource to support their own learning and professional goals (Marco-Bujosa et al., 2017). Ongoing co-design and active reflection throughout the enactment and subsequent refinement of the materials may have strengthened not only the curricular materials but also teachers' own development and practice (e.g., Davis et al., 2016).

Results also point to the challenges to enact engineering curricular materials in ways that draw upon individual student resources. There were no instances of teachers using contextualizing moves to support or privilege individual-level assets that students bring with them to the school context (e.g., language, literacies, or culture). Instead, in all of the adaptations, teachers drew from school- and community-based resources. The teachers did reflect on and intentionally include the students' general experiences during recess, rainfall events at their school and in the community, as well as general accessibility concerns for students with disabilities; however, the teachers did not explicitly provide contextualizing moves for specific individual-level student assets. This finding could be due to limitations in our data sources, as the data analyzed were whole-class dialogue and not teacher-to-student dialogue that may have occurred while students were conducting the activities in small groups. However, these findings align with other research that demonstrates how challenging it can be for teachers to build upon students' individual-level assets and individual cultures, norms, and experiences that each student brings to the class (Young, 2010).

Results also demonstrate challenges to designing engineering curricular materials that draw upon community resources. Although the WRC was explicitly co-designed, then redesigned, to tackle a problem at Ridge School, teachers still felt the need to help students make connections from the project to their school setting. The teachers' interview responses indicate their belief that students needed extra support to bring their experiences at recess and other kinds of out-of-school knowledge into their classroom. One possible explanation could be that students may have already formed ideas about what kinds of knowledge counts within their science classroom (e.g., Aikenhead & Jegede, 1999), and students may have these same ideas about engineering projects in science class. Future research can explore in more detail how teachers can support students' ideas about what knowledge counts within engineering curricula implemented in pre-college classrooms.

This curriculum unit was developed for a very specific school, enacted by two elementary teachers with strong science backgrounds. These findings raise questions about what kinds of support other teachers might need to be able to contextualize more generic engineering curricular materials and about what is needed for teachers to adapt these curricular materials so that students could solve a design problem around their own schools. The context of the WRC facilitated teachers' efforts to make connections to students' knowledge of their own school community. Moving this curriculum unit to other contexts would take a substantial effort for teachers to recontextualize to their local context. Although the WRC uses a 4 × 4 grid overlaid on the school setting that may be transferable to other school settings, it has not been tested in other school settings. Future research can investigate the kinds of curricular tools that may support local adaptations of customizable engineering projects addressing community issues.

Findings also point to the importance of student voice to enact engineering activities that draw upon student and community resources. Although teachers are crucial to the enactment of equitable engineering curricular materials, instruction that privileges student and community ways of knowing needs to take student resources and perspectives into account (e.g., Carlone et al., 2011). Problems that teachers or curriculum designers might think of as relevant to students (such as not being able to go outside during recess because of rain) might be perceived differently by students (more time in the lunchroom with friends). Understanding what students find relevant and what students see as problems can naturally fit with engineering design. Although the students determined the criteria for success in the WRC, having the elementary students identify the problems at their school might have further helped foreground existing student and community resources.

Implications for Promoting NGSS-Aligned Engineering Instruction

We see teacher contextualization as promoting the NGSS's vision of equitable engineering instruction in two important ways. First, contextualization helps make the engineering disciplinary core idea and practice of defining and delimiting problems meaningful to students as members of a community (e.g., Wright et al., 2018). Aspects of problem definitions such as solution criteria respond to the needs or wants of the individuals or communities who stand to benefit from the solution. Teachers are in an excellent position to scaffold problem definition so that it is authentic and meaningful to a particular community, bringing specific community needs to the forefront of the design challenge. Meaningful problem definition is a particularly strong leverage point because it is continually and necessarily being revisited during other phases of engineering design such as generating, testing, refining, and communicating solutions. Moments in an engineering challenge when connections to the community needs will be most salient to students may not be predictable by curriculum designers—they may depend on teachers' spontaneous contextualizing moves to foreground them in classroom conversation.

Second, a central aspect of the NGSS vision is the authentic integration of STEM disciplines toward solving meaningful problems. This integration is realized in numerous ways, such as the integration of science and engineering across the *Framework* and in the science and engineering practice of *using mathematical and computational thinking*. As teachers contextualize curricular materials to privilege students' prior knowledge and ways of knowing during engineering projects, teachers can help students see not only how their everyday experiences and resources have value for solving community problems, but also how student and community resources may also have a place within science, mathematics, and computational contexts.

Our findings also have implications for how best to support teachers to contextualize curricular materials to privilege student and community assets. Designers should engage teachers as co-designers where possible, so that teachers can contribute their valuable insights on student and community assets toward the design of materials. Teacher learning experiences should encourage and empower teachers to contextualize instructional materials for their classroom settings. Professional learning experiences can engage teachers in identifying examples of relevant school-based assets, important school-based knowledge, and everyday knowledge and common experiences students have outside of class, and then prompt teachers to connect these resources to specific aspects of the engineering curricular materials. While curriculum designers who target broad audiences may not be able include details for every specific school context, supporting resources such as teachers' guides or short videos can prompt teachers to identify these resources and connect them to specific lessons. Moreover, such professional learning experiences can be educative for teachers around engineering instruction. For example, prompting teachers explicitly to connect community assets to a particular engineering problem can highlight the important role of problem definition in engineering design processes. Asking teachers to explicitly consider what mathematical or computational knowledge and skills students are likely to bring to the problem can make connections between technology, science, mathematics, and engineering more salient.

Finally, an important implication of our findings is the individual, school, and systemic supports needed to help teachers privilege student and community-based resources in an engineering unit. For example, Paul and Anita were able to collaborate together to contextualize the project. This kind of peer-to-peer collaboration can help teachers learn from and support each other in this work and can be used in other school settings. In addition, on a school level, teachers can work together in their professional learning communities with STEM coordinators and/or instructional coaches to be able to learn effective strength- and asset-based approaches and employ them in engineering contexts. On a district level, having instructional coaches with engineering and strength-based pedagogical expertise is necessary to support the school- and individual-level supports. Although this study is limited by its focus on a single pair of teachers, it provides insight into ways to support teachers in providing more equitable engineering education experiences for students.

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References

Aikenhead, G. S., & Jegede, O. J. (1999). Cross-cultural science education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching*, *36*(3), 269–287. https://doi.org/10.1002/(SICI)1098-2736(199903)36:3<269::AID-TEA3>3.0.CO;2-T

Apple, M. W. (2018). Critical curriculum studies and the concrete problems of curriculum policy and practice. *Journal of Curriculum Studies*, *50*(6), 685–690. https://doi.org/10.1080/00220272.2018.1537373

Bang, M., & Medin, D. (2010). Cultural processes in science education: Supporting the navigation of multiple epistemologies. *Science Education*, *94*(6), 1008–1026. https://onlinelibrary.wiley.com/doi/pdf/10.1002/sce.20392

Barab, S. (2014). Design-based research: A methodological toolkit for engineering change. In *The Cambridge handbook of the learning sciences* (2nd ed.) (pp. 151–170). Cambridge University Press. https://doi.org/10.1017/CBO9781139519526.011

Barrett, B., Hoadley, U., & Morgan, J. (Eds.). (2017). *Knowledge, curriculum and equity: Social realist perspectives*. Routledge. https://doi.org/10.4324/9781315111360

Bauml, M. (2016). One size never fits all: Teachers' responses to standardized curriculum materials and implications for early childhood teacher educators. *Journal of Early Childhood Teacher Education*, *37*(1), 76–95. https://doi.org/10.1080/10901027.2015.1133461

Bismack, A. S., Arias, A. M., Davis, E. A., & Palincsar, A. S. (2014). Connecting curriculum materials and teachers: Elementary science teachers' enactment of a reform-based curricular unit. *Journal of Science Teacher Education*, *25*(4), 489–512. https://doi.org/10.1007/s10972-013-9372-x

Burkhauser, M. A., & Lesaux, N. K. (2017). Exercising a bounded autonomy: Novice and experienced teachers' adaptations to curriculum materials in an age of accountability. *Journal of Curriculum Studies*, *49*(3), 291–312. https://doi.org/10.1080/00220272.2015.1088065

Buss, A., Leonard, J., & Moss-Redman, I. (2020). Leveraging teachers' cultural and place-based knowledge to enhance STEM learning. In D. Schmidt-Crawford (Ed.), *Proceedings of Society for Information Technology & Teacher Education International Conference* (pp. 850–854). Association for the Advancement of Computing in Education (AACE). https://www.learntechlib.org/primary/p/215837/

Calabrese Barton, A., & Tan, E. (2019). Designing for rightful presence in STEM: The role of making present practices. *Journal of the Learning Sciences*, *28*(4-5), 616–658. https://doi.org/10.1080/10508406.2019.1591411

Calabrese Barton, A., & Tan, E. (2020). Beyond equity as inclusion: A framework of "rightful presence" for guiding justice-oriented studies in teaching and learning. *Educational Researcher*, *49*(6), 433–440. https://doi.org/10.3102/0013189X20927363

Calabrese Barton, A., Tan, E., & Birmingham, D. (2020). Rethinking high-leverage practices in justice-oriented ways. *Journal of Teacher Education*, *71*(4), 477–494. https://doi.org/10.1177/0022487119900209

Carlone, H. B., Haun-Frank, J., & Webb, A. (2011). Assessing equity beyond knowledge-and skills-based outcomes: A comparative ethnography of two fourth-grade reform-based science classrooms. *Journal of Research in Science Teaching*, *48*(5), 459–485. https://doi.org/10.1002/tea.20413

Carlone, H., & Johnson, A. (2012). Unpacking "culture" in cultural studies of science education: Cultural difference versus cultural production. *Ethnography and Education*, *7*(2), 151–173. https://doi.org/10.1080/17457823.2012.693691

Chiu, J. C., McElhaney, K. W., Zhang, N., Biswas, G., Fried, R., Basu, S., & Alozie, N. (2019). A principled approach to NGSS-aligned curriculum development integrating science, engineering, and computation: A pilot study. Paper presented at the NARST Annual International Conference. Retrieved from http://spiceprojects.org/wp-content/uploads/2019/05/SPICE-NARST-2019-Three-Dimensional-Assessment-of-NGSS-Upper-Elementary-Engineering-Design-Performance-Expectations.pdf

Cunningham, C. M. (2009). Engineering is elementary. *The Bridge*, *30*(3), 11–17. https://d7.eie.org/sites/default/files/research_article/research_file/2009-bridge_fall2009.pdf

Cunningham, C., Lachapelle, C., & Lindgren-Streicher, A. (2006, June). Elementary teachers' understandings of engineering and technology. Paper presented at 2006 Annual Conference & Exposition, Chicago, IL. Retrieved from https://www.researchgate.net/profile/Cathy-Lachapelle/publication/265579826_Elementary_Teachers%27_Understandings_Of_Engineering_And_Technology/links/553e3a470cf294deef6fcb1f/Elementary-Teachers-Understandings-Of-Engineering-And-Technology.pdf

Cunningham, C. M., & Kelly, G. J. (2017). Framing engineering practices in elementary school classrooms. *International Journal of Engineering Education*, *33*(1), 295–307. http://www.ijee.ie/contents/c330117B.html

Dalvi, T., & Wendell, K. (2015). Community-based engineering. *Science and Children*, *53*(1), 67. https://www.nsta.org/resources/community-based-engineering

Davis, E. A., Janssen, F. J., & Van Driel, J. H. (2016). Teachers and science curriculum materials: Where we are and where we need to go. *Studies in Science Education*, *52*(2), 127–160. https://doi.org/10.1080/03057267.2016.1161701

Davis, E. A., & Krajcik, J. S. (2005). Designing educative curriculum materials to promote teacher learning. *Educational Researcher*, *34*(3), 3–14. https://doi.org/10.3102/0013189X034003003

Davis, E. A., & Varma, K. (2008). Supporting teachers in productive adaptation. In Y. Kali, M. Linn, & J. E. Roseman (Eds.), *Designing coherent science education: Implications for curriculum, instruction, and policy* (pp. 94–122). Teachers College Press. https://www.tcpress.com/designing-coherent-science-education-9780807749135

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher*, *32*(1), 5–8. https://doi.org/10.3102/0013189X032001005

Fujii, R., McElhaney, K. W., & Alozie, M. (2020). Promoting equity and inclusion in STEM curriculum design. *Proceedings of the 14th International Conference of the Learning Sciences*. International Society of the Learning Sciences. https://repository.isls.org//handle/1/6422

Gándara, P. (2015). With the future on the line: Why studying Latino education is so urgent. *American Journal of Education*, *121*, 451–463. https://doi.org/10.1086/680411

Gatto, J. T. (2002). *Dumbing us down: The hidden curriculum of compulsory schooling*. New Society Publishers.

Giroux, H. A., & Penna, A. N. (1979). Social education in the classroom: The dynamics of the hidden curriculum. *Theory & Research in Social Education*, *7*(1), 21–42.

Gutiérrez, K. D., & Rogoff, B. (2003). Cultural ways of learning: Individual traits or repertoires of practice. *Educational Researcher*, *32*(5), 19–25. https://doi.org/10.3102/0013189X032005019

Gutstein, E. (2003). Teaching and learning mathematics for social justice in an urban, Latino school. *Journal for Research in Mathematics Education*, *34*(1), 37–73. https://doi.org/10.2307/30034699

Guzey, S. S., Moore, T. J., & Harwell, M. (2016). Building up STEM: An analysis of teacher-developed engineering design-based STEM integration curricular materials. *Journal of Pre-College Engineering Education Research (J-PEER)*, *6*(1), Article 2. https://doi.org/10.7771/2157-9288.1129

Hammer, D., & Elby, A. (2003). Tapping epistemological resources for learning physics. *Journal of the Learning Sciences*, *12*(1), 53–90. https://doi.org/10.1207/S15327809JLS1201_3

Hand, V. (2012). Seeing culture and power in mathematical learning: Toward a model of equitable instruction. *Educational Studies in Mathematics*, *80*(1), 233–247.

Haverly, C., Calabrese Barton, A., Schwarz, C. V., & Braaten, M. (2020). "Making space": How novice teachers create opportunities for equitable sense-making in elementary science. *Journal of Teacher Education*, *71*(1), 63–79. https://doi.org/10.1177/0022487118800706

Hill, H. C., Rowan, B., & Ball, D. L. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. *American Educational Research Journal*, *42*(2), 371–406. https://doi.org/10.3102/00028312042002371

Hoople, G. D., Mejia, J. A., Chen, D. A., & Lord, S. M. (2018). Reimagining energy: deconstructing traditional engineering silos using culturally sustaining pedagogies. Proceedings of the 2018 American Society for Engineering Education Annual Conference. Downloaded from https://peer.asee.org/30929

Hsu, M. C., Purzer, S., & Cardella, M. E. (2011). Elementary teachers' views about teaching design, engineering, and technology. *Journal of Pre-College Engineering Education Research (J-PEER)*, *1*(2), Article 5. https://doi.org/10.5703/1288284314639

Jorgenson, J. (2002). Engineering selves: Negotiating gender and identity in technical work. *Management Communication Quarterly*, *15*(3), 350–380. https://doi.org/10.1177/0893318902153002

Kang, H., Windschitl, M., Stroupe, D., & Thompson, J. (2016). Designing, launching, and implementing high quality learning opportunities for students that advance scientific thinking. *Journal of Research in Science Teaching*, *53*(9), 1316–1340. https://doi.org/10.1002/tea.21329

Katehi, L., Pearson, G., & Feder, M. (2009). *Engineering in K-12 education: Understanding the status and improving the prospectus*. National Academies Press.

Ladson-Billings, G. (2014). Culturally relevant pedagogy 2.0: aka the remix. *Harvard Educational Review*, *84*(1), 74–84. https://doi.org/10.17763/haer.84.1.p2rj131485484751

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.

Lim, M., & Barton, A. C. (2006). Science learning and a sense of place in an urban middle school. *Cultural Studies of Science Education*, *1*(1), 107–142. https://doi.org/10.1007/s11422-005-9002-9

Lytle, N., Cateté, V., Boulden, D., Dong, Y., Houchins, J., Milliken, A.,… Barnes, T. (2019). Use, modify, create: Comparing computational thinking lesson progressions for STEM classes. *Proceedings of the 2019 ACM Conference on Innovation and Technology in Computer Science Education* (pp. 395–401). https://doi.org/10.1145/3304221.3319786

Marco-Bujosa, L. M., McNeill, K. L., González-Howard, M., & Loper, S. (2017). An exploration of teacher learning from an educative reform-oriented science curriculum: Case studies of teacher curriculum use. *Journal of Research in Science Teaching*, *54*(2), 141–168. https://doi.org/10.1002/tea.21340

Martin, L., Dixon, C., & Betser, S. (2018). Iterative design toward equity: Youth repertoires of practice in a high school maker space. *Equity & Excellence in Education*, *51*(1), 36–47. https://doi.org/10.1080/10665684.2018.1436997

McNeill, K. L., & Krajcik, J. S. (2011). *Supporting grade 5-8 students in constructing explanations in science: The claim, evidence, and reasoning framework for talk and writing*. Pearson.

Mejia, J. A., Wilson, A. A., Hailey, C. E., Hasbun, I. M., & Householder, D. L. (2014). Funds of knowledge in Hispanic students' communities and households that enhance engineering design thinking. *Proceedings of the 2014 American Society for Engineering Education Annual Conference* (pp. 1–20). https://pdfs.semanticscholar.org/578d/2a1711bfdeb87ae009f9805c3a09e9b69e98.pdf

Merriam, S. B. (1998). *Qualitative research and case study applications in education*. Jossey-Bass Publishers.

Michaels, S., & O'Connor, C. (2015). Conceptualizing talk moves as tools: Professional development approaches for academically productive discussion. In L. B. Resnick, C. S. C. Asterhan, & S. N. Clarke (Eds.), *Socializing intelligence through academic talk and dialogue* (pp. 346–361). American Educational Research Association.

Miller, E., Manz, E., Russ, R., Stroupe, D., & Berland, L. (2018). Addressing the epistemic elephant in the room: Epistemic agency and the next generation science standards. *Journal of Research in Science Teaching*, *55*(7), 1053–1075.

Mislevy, R. J., & Haertel, G. D. (2006). Implications of evidence-centered design for educational testing. *Educational Measurement: Issues and Practice*, *25*(4), 6–20. https://doi.org/10.1111/j.1745-3992.2006.00075.x

Moje, E. B., Ciechanowski, K. M., Kramer, K., Ellis, L., Carrillo, R., & Collazo, T. (2004). Working toward third space in content area literacy: An examination of everyday funds of knowledge and discourse. *Reading Research Quarterly*, *39*(1), 38–70. https://doi.org/10.1598/RRQ.39.1.4

Moll, L. C., & Gonzalez, N. (1994). Lessons from research with language-minority children. *Journal of Reading Behavior*, *26*(4), 439–456. https://doi.org/10.1080/10862969409547862

Moll, L. C., & González, N. (2004). Engaging life: A funds-of-knowledge approach to multicultural education. In J. Banks & C. McGee Banks (Eds.), *Handbook of research on multicultural education* (2nd ed.) (pp. 699–715). Jossey-Bass.

Nasir, N. I. S. (2002). Identity, goals, and learning: Mathematics in cultural practice. *Mathematical Thinking and Learning*, *4*(2–3), 213–247. https://doi.org/10.1207/S15327833MTL04023_6

Nasir, N. S., Rosebery, A. S., Warren, B., & Lee, C. D. (2006). Learning as a cultural process: Achieving equity through diversity. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 489–504). Cambridge University Press. https://doi.org/10.1017/CBO9781139519526.041

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. The National Academies Press. https://doi.org/10.17226/13165

National Research Council. (2013). *Next generation science standards: For states, by states*. The National Academies Press. https://doi.org/10.17226/18290

NVivo by QSR International Pty Ltd. (2020). https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home

Paris, D. (2012). Culturally sustaining pedagogy: A needed change in stance, terminology, and practice. *Educational Researcher*, *41*(3), 93–97. http://www.jstor.org/stable/41477769

Paris, D., & Alim, H. S. (2014). What are we seeking to sustain through culturally sustaining pedagogy? A loving critique forward. *Harvard Educational Review*, *84*(1), 85–100. https://doi.org/10.17763/haer.84.1.982l873k2ht16m77

Porter, T., West, M. E., Kajfez, R. L., Malone, K. L., & Irving, K. E. (2019). The effect of teacher professional development on implementing engineering in elementary schools. *Journal of Pre-College Engineering Education Research (J-PEER), 9*(2), Article 5. https://doi.org/10.7771/2157-9288.1246

Purzer, S., Moore, T., Baker, D., & Berland, L. (2014). *Supporting the implementation of the Next Generation Science Standards (NGSS) through research: Engineering*. https://narst.org/ngsspapers/engineering.cfm

Rapp, W. (2014). *Universal design for learning in action*. Brooks.

Remillard, J. T. (1999). Curriculum materials in mathematics education reform: A framework for examining teachers' curriculum development. *Curriculum Inquiry*, *29*(3), 315–342. http://www.jstor.org/stable/3185911

Remillard, J. T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. *Review of Educational Research*, *75*(2), 211–246. https://doi.org/10.3102/00346543075002211

Russ, R. S., & Luna, M. J. (2013). Inferring teacher epistemological framing from local patterns in teacher noticing. *Journal of Research in Science Teaching*, *50*(3), 284–314. https://doi.org/10.1002/tea.21063

Sandoval, W. A. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education*, *89*(4), 634–656. https://doi.org/10.1002/sce.20065

Strauss, A., & Corbin, J. (1990). *Basics of qualitative research*. Sage Publications.

van Es, E. A., Hand, V., & Mercado, J. (2017). Making visible the relationship between teachers' noticing for equity and equitable teaching practice. In *Teacher noticing: Bridging and broadening perspectives, contexts, and frameworks* (pp. 251–270). Springer.

Verdín, D., Godwin, A., & Capobianco, B. (2016, June). Systematic review of the funds of knowledge framework in STEM education. Paper presented at 2016 ASEE Annual Conference & Exposition. https://doi.org/10.18260/p.25999

Voogt, J., Westbroek, H., Handelzalts, A., Walraven, A., McKenney, S., Pieters, J., & De Vries, B. (2011). Teacher learning in collaborative curriculum design. *Teaching and Teacher Education*, *27*(8), 1235–1244. https://doi.org/10.1016/j.tate.2011.07.003

Wendell, K. B., Swenson, J. E., & Dalvi, T. S. (2019). Epistemological framing and novice elementary teachers' approaches to learning and teaching engineering design. *Journal of Research in Science Teaching*, *56*(7), 956–982. https://doi.org/10.1002/tea.21541

Wiggins, G. T., & McTighe, J. (2005). *Understanding by design*. Association for Supervision and Curriculum Development.

Wilson-Lopez, A., Mejia, J. A., Hasbún, I. M., & Kasun, G. S. (2016). Latina/o adolescents' funds of knowledge related to engineering. *Journal of Engineering Education*, *105*(2), 278–311. https://doi.org/10.1002/jee.20117

Wright, C., Wendell, K. B., & Paugh, P. P. (2018). "Just put it together to make no commotion": Re-imagining urban elementary students' participation in engineering design practices. *International Journal of Education in Mathematics, Science and Technology*, *6*(3), 285–301. https://www.ijemst.org/index.php/ijemst/article/view/198

Yin, R. K. (2017). *Case study research and applications: Design and methods*. Sage Publications.

Yosso, T. J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race Ethnicity and Education*, *8*(1), 69–91. https://doi.org/10.1080/1361332052000341006

Young, E. (2010). Challenges to conceptualizing and actualizing culturally relevant pedagogy: How viable is the theory in classroom practice? *Journal of Teacher Education*, *61*(3), 248–260.

Zangori, L., Forbes, C. T., & Biggers, M. (2013). Fostering student sense making in elementary science learning environments: Elementary teachers' use of science curriculum materials to promote explanation construction. *Journal of Research in Science Teaching*, *50*(8), 989–1017. https://doi.org/10.1002/tea.21104

Zhang, N., Biswas, G., McElhaney, K. W., Basu, S., McBride, E., & Chiu, J. L. (2020). Studying the interactions between science, engineering, and computational thinking in a learning-by-modeling environment. In I. Bittencourt, M. Cukurova, K. Muldner, R. Luckin, & E. Millán (Eds.), *AIED: 2020: Artificial Intelligence in Education* (Vol, 12163, pp. 598–609). Springer. https://doi.org/10.1007/978-3-030-52237-7_48