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ORIGINAL PAPER

Addressing critical cross-cultural issues in elementary STEM education research and practice: a critical review essay of *Engineering in Elementary STEM Education*

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Abstract

The book, *Engineering in Elementary STEM Education: Curriculum Design, Instruction, Learning, and Assessment,* written by Cunningham (Engineering in elementary STEM education: curriculum design, instruction, learning, and assessment, Teachers College Press, New York, 2018), highlights examples of engineering curriculum and pedagogy that Cunningham and her team have developed for the last 15 years. Additionally, she contends that engineering education has the potential to provide underrepresented students with opportunities to experience authentic and relevant STEM education, as well as to help them understand their strengths and abilities as future scientists or engineers. Given the popularity of this book and of the *Engineering is Elementary* (EiE) curriculum on which it is based, we conducted a critical review essay to more closely examine Cunningham's claims. Using *sociotransformative constructivism*, as a theoretical framework, we found Cunningham's book and supporting EiE curriculum to be rich resources of well-intended concepts and activities for integrating engineering practices in the science classroom. However, the EiE curriculum—like many other curriculum materials in the field—fall short of meeting their equity and diversity goals. In this essay, we argue that some of the EiE curriculum highlighted in Cunningham's book seem to unintentionally promote colonized thinking, romanticized notions of engineering as a pure human endeavor; and culturally and socially unauthentic scenarios. Our goal is to generate reflection and transformative discussions so that we can elevate this and similar types of popular curriculum. To this end, we also offer suggestions for making STEM curriculum more culturally and socially relevant.

Keywords Equity · Social justice · Sociotransformative constructivism · STEM · Engineering

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Resumen ejecutivo
El libro, *Ingeniería en la Educación Primaria de STEM: Diseño Curricular, Instrucción, Aprendizaje y Evaluación*, escrito por Christine Cunningham (2018), destaca ejemplos de planes de estudios de ingeniería y pedagogía que Cunningham y sus colegas han desarrollado durante los últimos 15 años. Cunningham también sostiene que la educación en ingeniería tiene el potencial de proporcionar a los estudiantes marginalizados oportunidades para explorar una educación STEM auténtica y relevante, así como ayudarlos a comprender sus fortalezas y habilidades como futuros científicos o ingenieros. Dada la popularidad de este libro y del plan de estudios de *Ingeniería es Elemental* (EiE) en el que se basa, realizamos un ensayo de revisión crítico para examinar más de cerca las afirmaciones de Cunningham. Utilizando el *constructivismo sociotransformativo*, como marco teórico (Rodríguez, 2015a, b; 1998), proponemos que el libro de Cunningham y el plan de estudios EiE que lo apoya son recursos valiosos de conceptos y actividades para integrar con buenas intenciones las prácticas de ingeniería en el aula de ciencias. Sin embargo, los dos--el libro y el plan de estudios EiE--como muchos otros materiales curriculares en el campo, no cumplen con sus objetivos de equidad y diversidad. Por ejemplo, a pesar de que Cunningham alienta a los maestros y estudiantes a adoptar el "fracaso" como un aspecto normal y valioso en el proceso de diseño de ingeniería, su enfoque trivializa las demandas emocionales asociadas con el fracaso al proporcionar a los maestros ejemplos poco prácticos o "alegres" (exageradamente positivos) sobre cómo abordar el problema y los desafíos que ellos y sus estudiantes podrían enfrentar (Loterro-Perdue, 2015; Rodríguez, 2017). Del mismo modo, el plan de estudios EiE incluye imágenes de estudiantes culturalmente diversos, principalmente como "personajes coloridos" a través de sus libros de cuentos y hojas de actividades. Esto se hace sin tratar directamente de aumentar el conocimiento cultural y la conciencia de los estudiantes sobre la gran cantidad de problemas sociales que obstruyen la participación de mujeres y otras personas marginalizadas en STEM (Tolbert et al, 2018). Una vez más, este enfoque trivializa la complejidad de abordar los problemas de equidad y diversidad en las escuelas de hoy. Por lo tanto, aquí proporcionamos algunas sugerencias para evitar estos y otros escollos que se encuentran comúnmente cuando se busca hacer que el plan de estudios sea más culturalmente inclusivo y verdaderamente conectado con la vida de los estudiantes. En resumen, argumentamos que parte del currículo EiE destacado en el libro de Cunningham parece promover involuntariamente el pensamiento colonizado, las nociones románticas de la ingeniería como un esfuerzo humano puro; y escenarios cultural y socialmente poco auténticos. Nuestro objetivo es generar reflexión y discusiones transformadoras para que podamos elevar este y otros tipos similares de currículo popular. Con este fin, también ofrecemos sugerencias para hacer que el plan de estudios (currículo) STEM sea más relevante cultural y socialmente.

핵심 개요
크리스틴 커닝햄 (2018)의 책 '초등 스템 (STEM) 교육에서의 공학교육: 교육과정 설계, 교수방법, 학습, 그리고 평가'는 커닝햄과 그녀의 팀이 지난 15년간 개발한 공학 교육과정과 교육방법의 예시들을 소개한다. 커닝햄은 이 책에서 공학교육이 소외 계층 학생들에게 진정한 STEM 교육과 그들이 미래의 과학자와 공학자가 될 수 있는 능력을 깨달을 수 있는 기회를 제공한다고 주장한다. 이 책과 이 책의 바탕이 되는 Engineering is Elementary (EiE) 교육과정이 초등교육에 널리 이용되고 있으므로 , 우리는 비평적 리뷰 에세이를 통해 커닝햄의 주장을 면밀히 점검하고자 한다. 사회변형적 구성주의 (sTc)를 이론적 틀로 이용하여 분석하였을 때 (Rodriguez, 2015a, b; 1998), 커닝햄의 책과 EiE 교육과정은 공학의 실제

를 과학 교실에 통합할 수 있는 다양한 활동과 좋은 의도의 교육 개념을 제공한다. 그러나 이 책과 EiE 교육과정은 이 분야 여타의 교육과정들과 비슷하게 형평성과 다양성의 목표를 달성하는 데 부족함이 있다. 예를 들어, 커닝햄은 교사와 학생들이 "실패"를 공학 설계 과정의 자연스럽고 값진 부분으로 받아들이도록 권장하지만, 교사들에게 비실용적이고 단순한 격려 차원의 예시를 제공하는 등 그녀의 접근은 학생들이 겪을 실패와 어려움에 관련된 감정적 요구를 경시할 수 있다 (Loterro-Perdue, 2015; Rodriguez, 2017). 또한 EiE 교육과정은 이야기 책이나 활동지 안에 문화적으로 다양한 학생들의 이미지를 주로 "다채로운 등장인물"로서 포함하고 있다. 이러한 접근은 여성이나 유색인종의 STEM 분야 참여를 저해하는 다양한 사회적 문제에 대한 학생들의 인식을 직접적으로 높이는 시도 없이 이루어진다 (Tolbert et al, 2018). 그리고 이것은 오늘날 학교가 다루는 형평성과 다양성 문제의 복잡성을 경시하는 것이다. 우리는 이 에세이에서 문화적으로 포용적이고 학생들의 삶과 연결된 교육과정을 만들 때 발생할 수 있는 보편적인 위험을 피하기 위한 방법을 제안한다. 요컨대, 커닝햄의 책에서 강조된 몇몇의 EiE 교육과정은 식민지화된 사고, 공학에 대한 미화된 개념, 문화적, 사회적으로 신뢰할 수 없는 시나리오 등을 의도치 않게 제안할 수 있음을 다룬다. 우리의 목표는 변화를 위한 재고와 논쟁을 통해 EiE 교육과정은 물론 광범위하게 적용되고 있는 교육과정들의 질을 향상시키는 것이다. 이를 위해 우리는 STEM교육과정을 문화적, 사회적으로 더욱더 적절한 교육과정으로 만들기 위한 대안을 제시한다.

Christine Cunningham's (2018) *Engineering in Elementary STEM Education: Curriculum Design, Instruction, Learning, and Assessment,* offers a comprehensive guide for how to integrate engineering into elementary education. She states, "If you have ever wondered how to infuse engineering into your teaching, school, or district curriculum in age-appropriate, inclusive, and engaging way, this book is for you" (p. 3). She adds, "For the last 14 years, I've led a team of talented curriculum developers and educational researchers at the Museum of Science in Boston in an effort to create and disseminate engineering curriculum for elementary students" (p. 2). In fact, Cunningham and her team are pioneers in this field, as they worked (and continue to work) on the integration of engineering practices at the elementary school level over a decade before this topic became the current craze it is today in response to the Next Generation Science Standards (NGSS; NGSS Lead States 2013).

Given the popularity of the *Engineering is Elementary Curriculum* (EiE) highlighted in Cunningham's book, and the ongoing expectation for elementary school teachers to integrate engineering practices in the science curriculum, we conducted a critical review essay of Cunningham's book (and the associated EiE curriculum). Our goal is to highlight common (but seldom addressed) pitfalls in developing STEM curriculum (Rodriguez under review). This is particularly important when the proposed STEM curriculum claims to address equity and diversity issues. While Cunningham's book offers more insights and details about her EiE curriculum, we aim to elicit a more critical review of these activities and to demonstrate how they fall short of their well-intended aims.

To this end, we use sociotransformative constructivism as a theoretical framework to guide our critique, and to deconstruct some of the EiE activities and arguments highlighted in Cunningham's book. Through this analysis, we argue that some of the EiE curriculum actually serve to reify colonized thinking and romanticized notions of engineering, both of which contradict Cunningham's stated "inclusivity" goals. We offer suggestions for making the highlighted activities more culturally inclusive and socially relevant in an effort to encourage readers (teachers, researchers, curriculum developers, policymakers, and teacher educators) to avoid common pitfalls in STEM curriculum development and implementation.

We begin with a brief explanation of sociotransformative constructivism and our rationale for using this framework to guide our critique. This is followed by a general description of Cunningham's book and its most useful features. We then offer a more detailed critique using the *Engineering is Elementary* activities highlighted in Cunningham's book. To close, we use Cunningham's own words: "we cannot change the education landscape today without asking questions about how we can improve, how we can best serve all students" (p. 144). We agree, and we urge all those interested in increasing the participation and success of traditionally marginalized students in STEM to avoid the pitfalls discussed herein.

Sociotransformative constructivism

This critical review essay is informed by *sociotransformative constructivism* (sTc; Rodriguez 1998). This framework enables the blending of critical cross-cultural education (as a theory of social justice) with social constructivism (as a theory of learning). Thus, we draw from Lev Vygotsky's (1978) notion of learning as a social activity dependent on the context and experiences of participants. Vygotsky argues that an individual's language (in whatever form and including symbolic language), culture, and experiences are indivisibly linked to how that person learns during social interactions with others. If we believe that sociocultural contexts and experiences mediate learning then we must also acknowledge the historical, institutional, and sociocultural factors that promote or obstruct people's access to power. It is at this junction that sTc serves as a bridge between social constructivism and critical cross-cultural education because the individuals' (teachers and/or students) positionalities determine their access to (and influence upon) the culture of power (agency). In other words, when we consider how an individual's positionality—be it ideological, socioeconomic, academic, ability status, sexual expression, skin color, or others—might influence his or her access to power, then we can better appreciate how power is also a principal construct mediating teaching and learning interactions.

By using this critical stance, sTc rejects neoliberal notions of multicultural education focused on "acceptance," "tolerance," "diversity," "awareness," and superficial understandings of "equality." Instead, sTc promotes critical cross-cultural understandings of not only how webs of oppression obstruct access to meaningful education for everyone, but also understandings of the systemic roots that sustain those webs of oppression, as well as the urgent need to dismantle them (May and Sleeter 2010).

To this end, sTc is composed of four interconnected elements: *the dialogic conversation*, *authentic activity*, *metacognition*, and *reflexivity*. These constructs are not "stages," or "phases," nor any kind of traditional (Western) linear thinking ensemble. They are simply conceptual devices meant to facilitate teaching and learning for understanding and transformative action through culturally and socially relevant pedagogical strategies and curriculum. Thus, any one or more of these four elements can be enacted at any time in response to the challenges and opportunities typically found in school contexts. (For more information on how sTc has been used in various learning contexts see: Tolbert et al. 2018; Morales-Doyle 2019; Rodriguez 2015a; Rodriguez and Zozakiewicz 2010; Rodriguez 1998).

In order to better define and explain the elements of sTc and how we used them to inform our critique of Cunningham's book, each of these elements is described below in further detail after the next section, which provides a general description of Cunningham's book and how it is organized.

Highlights of engineering in elementary STEM education

Cunningham's *Engineering in Elementary STEM Education* book consists of three parts: "Introducing Engineering to Elementary Education" (p. 7); "Considerations for Curriculum Design, Instruction and Learning" (p. 37); and "Looking toward the Future" (p. 123). In this section, we briefly elaborate on some of the most helpful elements described in each section of this book.

Introducing engineering to elementary education

In the first chapter "Why Make Engineering Part of Elementary Instruction?" (p. 9), readers are presented with the various kinds of perspectives elementary students often have about engineering, technology, and engineers. Based on insights gathered from these students' perspectives over the years, Cunningham developed the *Engineering is Elementary* (EiE) curriculum (https://www.eie.org/eie-curriculum), which is highlighted throughout her book.

Essentially, through the EiE curriculum, Cunningham positions engineering education in STEM fields by describing the relationships between science, technology, engineering, and mathematics at the elementary level. She explains that "engineering is the application of knowledge to creatively design, build, and maintain technologies" (p. 22) and "technology is the body of knowledge, artifacts, processes, and systems that results from engineering" (p. 21). She adds that engineering in her book means "both the process of engineering and the resulting products (technologies)" (p. 22). Also, she provides a very useful chart that highlights the key features of science, engineering, technology, and mathematics (Table 2.1., p. 23). We often find that pre- and in-service teachers struggle with differentiating among science, engineering and technology, and Cunningham's explanations and examples here are very useful.

Another valuable aspect of the EiE curriculum promoted by Cunningham in her book is the inclusion of "problem-based engineering challenges" (p. 26). These challenges are meant to promote students' motivation and encourage them to use knowledge of other disciplines in order to resolve problems. In this sense, she suggests that by integrating science and engineering in a thoughtful way, students can learn science concepts meaningfully. In addition, Cunningham identifies the current constraints and barriers to implementing a STEM curriculum in elementary schools. Thus, she explains that by primarily integrating engineering with science, this will enable teachers to save time and cover more content without having to teach separate engineering units.

In the first section of her book, Cunningham also explains eight reasons why engineering should be taught at the elementary level (p. 14), such as "engineering can increase motivation, engagement, responsibility and agency" (p. 16) and "engineering promotes educational equity" (p. 17). Cunningham argues that engineering education can increase educational equity and reconstruct students' roles, classroom hierarchies, and students' perceptions about themselves and their peers. We are in agreement with this assertion. We also believe that all of these eight reasons for integrating engineering are intuitive, and Cunningham provides some research evidence supporting her claims (especially in Chapter 7). However, as we elaborate below, we are skeptical about whether some of the EiE curriculum activities do advance equity and diversity understandings as intended or reported.

Considerations for curriculum design, instruction, and learning

The second part of *Engineering in Elementary STEM Education* focuses on further defining core engineering concepts; how students engage in authentic engineering work; how teachers can make engineering lessons inclusive; and how teachers can navigate barriers in engineering education. Here, Cunningham also describes her version of the engineering design process (EDP) for elementary students and explains each step with relevant examples (p. 43).

Another noteworthy aspect in this section is Cunningham's effort to organize engineering practices into 14 comprehensive design principles that could be further grouped into four broad categories: *Set learning in a real-world context; present design challenges that are authentic to engineering practice; scaffold student work; and demonstrate that everyone can engineer* (p. 90). Cunningham adds, "with equity as our focus, my team and I drew from educational literature and our experiences in classrooms to articulate a set of 14 design principles for engineering curricula and resources" (p. 89). While these conceptualizations are very useful pedagogically and relevant to the NGSS, we encountered multiple contradictory points in terms of enacting equity, diversity, and social justice issues. These contradictions are the focus of this critique.

Look*ing toward the future*

The final section of Cunningham's book provides a synthesis of some of the research that has been conducted using the EiE curriculum. Overall, Cunningham does not explicitly articulate the learning theoretical framework(s) informing her study, but she and her team seem to draw mainly from Vygotsky's (1978) sociocultural theory of knowledge construction. In this section, readers are exposed to various studies highlighting the apparent impact of the EiE curriculum on students, teachers, and schools over the years. While the studies cited only report strikingly positive results, this section could have benefited from a more critical analysis of the effectiveness of the EiE curriculum. There are many empirical claims offered in this section that are underexplained, and as a consequence, this diminishes their impact (i.e., their transferability to the complex and demanding contexts of today's schools). Nevertheless, we must recognize that Cunningham and her team have developed an unprecedented and comprehensive set of curriculum resources (including videos and other materials) with a focus on engineering practices. Thus, our primary goal through this critique is to advance this important work, as well as to offer a social justice lens through which some of the most popular EiE curriculum activities could be critically re-examined. To this end, we are guided by the four elements of sociotransformative constructivism (sTc) beginning with the *Dialogic Conversation*.

Dialogic conversation

Mikhail Bakhtin's (1986) construct of dialogicality is a useful tool for understanding the complexity of meaning-making, and this construct is particularly powerful for examining teacher–student and student–student interactions. For Bakhtin, dialogicality involves the spaces where the speaker's voice (spoken, written, or symbolic) comes into contact with the listener's voice resulting in either the construction (or re-construction) of meaning, or the tension produced by its dissonance (Koschmann 1999). In sociotransformative constructivism (sTc), we use the term *dialogic conversation* to apply the construct of dialogicality more directly in formal and informal learning contexts (Rodriguez 2015a). Thus, the dialogic conversation draws attention to the critical role teachers play (as the authoritative voices) in facilitating learning; especially, in culturally diverse classrooms. This dialogic aspect seems to be taken for granted throughout Cunningham's book, and it is perhaps most evident in her suggestions for how to address students' failure when attempting engineering design activities. The construct of "failure" in the engineering design process—and the complexity of emotions—both positive and negative—that could be evoked by this construct, have been mostly left unattended in the current rush to implement the Next Generation Science Education Standards (Rodriguez 2017). Therefore, we appreciate Cunningham's effort for encouraging teachers and their students to embrace "failure" as a normal and valuable aspect of the engineering design process in elementary classrooms. She states: "When failure is presented as a learning opportunity and an unavoidable step in engineering, failure is destigmatized. Students come to accept and expect failure. Instead of worrying about being wrong or looking stupid, students come to focus on learning from their failed attempts" (p. 86). However, helping students manage failure is a great deal more complex than just asking them to see it as an "opportunity."

In fact, Cunningham's overall approach trivializes the emotional demands associated with failure by not providing teachers with practical examples for how to address the challenges they and their students might encounter when experiencing it. This is where the need for dialogic conversations is most evident because we know that schools with high populations of culturally diverse students are most likely to be underfunded, experience high teacher turnover, and offer the least opportunities for professional development (Banilower et al. 2018). Thus, providing only cheery examples of successful narratives, "students do not seem upset that their designs did not work the first time" (p. 85), diminish the potential impact of the Engineering is Elementary (EiE) curriculum and of Cunningham's book. In our previous work, we urge researchers to share instead *narratives of engagement* (Rodriguez 2015a). That is, balanced narratives that more closely approximate the complexity and realities of teaching and learning in today's schools. In this way, educators and researchers are enabled to critically engage with examples of real challenges to innovation, as well as with successful strategies for addressing them. This brings us back to the dialogic conversation component of sTc. When using the dialogic conversation in the classroom, it is not enough to just expect students to "collaborate," "share," "listen to each other," when those words are uttered. It is essential for teachers to reflect upon (and act) on their own ideological and sociocultural positionings (or reflexivity, which is explained below) in order to better facilitate respectful, inclusive, and productive interactions in the learning environment. For example, in the USA, most elementary school teachers are Anglo, middle class, and females who are most likely going to be working with increasingly diverse student groups in underfunded schools (Banilower et al. 2018). Therefore, teachers need more specific examples for how to facilitate culturally responsive communication and collaboration between native and non-native language speakers; among male, female, and gender-fluid students; between economically disadvantaged and privileged students; and between physically challenged and unchallenged students. We recognize that Cunningham seeks to address some of these issues through symbolism by including images of culturally diverse students throughout her EiE curriculum, photos in her book, and characters in her storybooks connected to the EiE curriculum. Nevertheless, as we elaborate below in the section on reflexivity, this surface approach to addressing diversity and equity trivializes the complexity of this work and negates the importance of engaging in honest and productive dialogues (dialogic conversations) in school classrooms.

In this same vein, a dialogic conversation with the reader would have expected Cunningham to also directly acknowledge and discuss the costs of acquiring the EiE curriculum. Again, teachers working at disadvantaged and culturally diverse schools are most likely not going to be able to secure funding for the EiE curriculum units advertised throughout her book. For example, the cost of running the *Designing Hand Pollinators Unit* (highlighted in Cunningham's book) would cost approximately: $55 for one teacher's guide; $225 for the storybooks (@ $9 each for a class of 25 students); and $235 for the materials kit (which includes scotch tape, small tubes with caps, popsicle sticks, marbles, aluminum foil, string, and some other basic materials). The refill kit costs $130 (for details, see https://www.eiestore.com/designing-hand-pollinators-unit.html). We appreciate that the EiE website allows the free download of some units and some other useful resources (such as videos). However, considering that some of the EiE curricula have been developed through federal and state funds, and considering its goals to promote engineering in all elementary schools, one would have expected that all curriculum materials to be available for free download by now. More affluent schools could of course have the option to order the hard curriculum copies and the materials kits.

Authentic activity

The next element of sTc used for this critique is *authentic activity*. This involves "inquiry-based, hands-on, minds-on activities that are socio-culturally relevant and tied to the everyday life of the learner" (Rodriguez and Morrison 2019, p. 449). Related to this aspect, we value the variety of engineering activities highlighted throughout Cunningham's book. She also argues that "students' learning is more profound when they engage in realistic disciplinary practices and put key concepts into productive use" (Duschl 2008; Kelly 2011, as cited in Cunningham 2018, p. 99). In addition, she stresses that "putting learning in a real-world context increases students' engagement, enthusiasm, and achievement" (p. 91). Cunningham then goes on to further explain three design principles (out of the sixteen previously mentioned), which have a focus on setting engineering problems within real-world contexts and that particularly benefit "groups of underrepresented students in engineering" (p. 91).

Nevertheless, we are troubled by Cunningham's surface approach for addressing cultural and socially relevant issues and for making the engineering curriculum truly authentic. To elaborate on the first concern, we borrow from Rodriguez's (under review) How to *Avoid Seven Common (but Seldom Discussed) STEM Curriculum Pitfalls*. In that manuscript, Pitfall #5, *Peoples of Color as Cultural Background Props*, involves the use of traditionally underrepresented students (and/or their families) as characters of a story/engineering design problem only as "cultural props." That is, they are used as "colorful" characters in culturally decontextualized scenarios that neither permit the readers (students) to gain cultural knowledge about them nor awareness about their cultural agency (ability to use culturally based knowledge). When we examine Cunningham's storybook, *Mariana Becomes a Butterfly* (p. 93), for example, we are introduced to a precocious girl, who might be Latina or Blatina (African Latina)—her ethnicity is not mentioned; however, the story takes place in the Dominican Republic. Mariana is concerned that her ohelo plant—a gift sent to her from a friend in Hawaii—is no longer producing berries. She asks, Lia, her aunt, for help, and Lia happens to be an agricultural engineer. Lia encourages Mariana to embark on a study that leads to the discovery that her plant does not have natural pollinators in its new home. Mariana uses this knowledge to engineer and test an efficient pollinating tool. This is indeed a good engineering design problem-solving scenario; however, there are several missed opportunities for making it a more authentic and culturally/socially relevant engineering design activity. First of all, we never learn anything else about who Mariana is and her country (the Dominican Republic) in this scenario. On the other hand, we appreciate the inclusion of a strong female role model like her aunt—who is an agricultural engineer. Through the storybook, we also briefly learn about Lia's work on invasive species (the papaya mealybug). However, Cunningham misses the opportunity to directly highlight the importance of having more women in STEM, and raising awareness about pervasive gender-based stereotypes and discrimination that hinders the participation of women in STEM-related fields. Similarly, this could have been an excellent entry point for learning more about the Dominican Republic's culture and economy. For example, readers could learn more about the tremendous ecological and financial damage invasive species and other pests can cause to countries like this one that has a vulnerable economy. Students could also learn more about other invasive species, such as the black leaf streak disease, also known as black Sigatoka disease that attacks fragile plants like bananas (Yonow et al. 2019). The storybook could have included practical examples of how governments prevent invasive species from entering their countries, such as not allowing passengers to bring in fresh fruit and vegetables. Another practical example could have been discussing the steps that Mariana and her aunt (agricultural engineer) took to ensure that the berry plant Mariana received from her Hawaiian friend was cleared of any potentially damaging invasive species or other pests. It is actually odd to start this storybook with a gifted plant coming from a state (Hawaii) that has suffered so much destruction from invasive species, yet no explanations are provided for how such a plant was cleared from invasive species and pests itself.

Educators and curriculum developers should not expect teachers and their students to make direct connections to gender, socioeconomic, and cultural issues in STEM just by including representative images and short assertions in storybooks or design problems. Furthermore, Gunckel and Tolbert (2018) point out that it is important to assist teachers and their students in problematizing the oversimplistic technocratic and utilitarian views of the engineering design process as portrayed in the NRC's NGSS Framework (2012). That is, the tendency to depict the engineering design process as a solve-all-problems tool without addressing the sociocultural and institutional factors that gave rise to the problem in the first place. Similarly, the utilitarian notion that all progress is beneficial for everyone portrays a false purity of science/STEM that negates countless acts of violence against culturally diverse individuals—and not to mention the planet (Conner 2005). We know that teachers welcome and appreciate explicit examples of culturally relevant pedagogy and curriculum (Rodriguez et al. 2005).

In the next section on Metacognition, we will revisit Mariana's story and her engineering design activity, but before that, we wish to highlight another example of how the sociocultural contexts in which some of the EiE activities highlighted in Cunningham's book are so unrealistic and unauthentic that they undermine one of the primary questions she and her team wish students to ask themselves: "What kind of problems do you want to solve when you grow up?" (p. 148). To explain this concern, we use Rodriguez's (under review) Pitfall #6, *the 180-Extreme Stereotype Reversal from How to Avoid Seven Common (but Seldom Discussed) STEM Curriculum Pitfalls*. This pitfall involves the movement from not including any traditionally underrepresented or minoritized (URM) student in the curriculum to portraying them in such extremely unrealistic scenarios that make those activities distracting and spurious. Consider this story and problem-solving scenario mention in Cunningham's text (p. 92) and described in more detail in the *Hop to It*, *Engineering Adventures* EiE curriculum. Therein, Jacob and India (whose ethnicities are not mentioned, but appeared to be Blatinos or African Americans—see Fig. 5.3, p. 94) are a pair of clever siblings, who somehow are traveling around the world by themselves (there is no context about their parents or how they are financing their travels). In the storybook, we see pictures of them enjoying skiing, scuba diving, and, of course, rock climbing by themselves. In the *Hop to It* adventure (https://www.eie.org/engineering-adventures/curriculum-units/hop-it), Jacob and India explain that during their trip to New Zealand, they discovered that a cane toad—an invasive species—somehow snuck into their backpack while they were visiting Australia. The curriculum includes a short video about cane toads and the damage they can cause, as well as a voice recording of Jacob and India urging their friends to help them build a trap to catch the cane toad. While we were pleased to see that this activity is more socially relevant and helps students gain knowledge and awareness about invasive species (as mentioned above), we were dismayed by the extreme 180° cultural stereotype reversal of the story and context. In our experience working in culturally diverse and underfunded schools, we do not believe that this story will "develop and motivate students' understanding of engineering's place in the world" (Curricular Design Principles of Inclusivity #1, Cunningham, p. 91). On the contrary, we believe students would be distracted by the unrealistic context. We argue that it is essential for curriculum developers, as well as for educators, to deeply reflect on the sociocultural contexts of the stories or scenarios in which they wish students to engage. In this way, they could strive to make these activities more culturally and socially relevant—and authentic.

Metacognition

Metacognition in sTc involves critical awareness about what, how, and why we teach a specific curriculum and/or what, how, and why we learn that curriculum in certain ways (Martinez 2006). This implies that teachers should encourage students to ask questions about their learning, such as: "What am I meant to be doing? What is the purpose of this task? Why am I doing it this way? What control do I have in how to proceed?" (Rodriguez 2015a, p. 6). Similarly, teachers need to also reflect on what, how, and why they teach a certain subject matter in a particular way, as well as the ways by which they allow students' voices and creativity to be represented in the teaching/learning enterprise. Throughout Cunningham's book, we find arguments in support of providing multiple opportunities for scaffolding, reflection, and motivation. Her Curricular Design Principles for Inclusivity #9, *Model and make explicit the practices of engineering* (p. 106), and #11, *Produce activities* *and lessons that are flexible to the needs and abilities of different kinds of learners* (p. 109), perhaps are the most salient regarding this topic.

After reviewing Cunningham's book, as well as various EiE curriculum lessons and activities, we are wondering if her book and the EiE program are mostly more about *modeling* how to conduct engineering practices and less about *doing* engineering. Although we are not claiming to have reviewed the entire and extensive EiE curriculum (we cannot afford it), we wish to point out in this section two examples that seem to work against promoting metacognition.

The first example allows us to revisit the storybook and EiE activity, *Mariana Becomes a Butterfly* (p. 93), described earlier. We find that this storybook and various images in the story provide all the information students need to build the best possible handheld pollinator without going through the engineering design process, even though this is not what the author intended: "And though the child in the book does the same challenge kids in class will do, we were careful not to show a definite solution in the book—we did not want to influence students' designs" (p. 93). Nevertheless, in this storybook, there are four pictures of Mariana holding what seems to be the best option for a pollinator since she is actually pollinating her plant with it, and it seems to be built with the most logical materials. That is, in this activity, students are given the following materials as choices for engineering and testing the pollen-dispensing component of their handheld pollinators: aluminum foil, pipe cleaner, and pom-poms. Although we do not wish to generalize, the school children with whom we have (and continue) to work would most likely select the pom-poms as their first choice for this activity right away. Also, they would most likely seek to skip all other steps of the design process because it might be already evident to them (from the storybook pictures and the story) what design would work best.

We argue that these types of activities do not promote the kind of creative and critical thinking Cunningham and her EiE team intend—and much less metacognition. Furthermore, we often find engineering design activities that passionately seek to promote creativity, only to offer a very limited variety of materials to be used by following a lockstep procedure. This represents Pitfall #4, *Be Creative (But Not Really)* (Rodriguez under review). Cunningham explains in her book that some of the feedback she has received from teachers includes "limiting materials that students might use, at least initially. Having students choose from specified materials (instead of using a wide array or whatever they bring to class) focuses them and their work" (p. 118). We fundamentally agree; however, in our research, we urge pre- and in-service teachers to be intellectually honest. That is, if the nature of the activity requires limiting materials, we encourage them to avoid stating that "students can use whatever they want and be as creative as they wish." It is perfectly fine, and congruent with the engineering design process, to include limited kinds of materials as a constraint, and we should just say so. Nevertheless, in most activities, we ask students to consider additional materials, as well as changes in procedures, and to share these with the class. Sometimes, some of these changes are quite possible, but most importantly, this approach enables students to share their own cultural knowledge and enact their sense of agency in constructing new knowledge (metacognition).

Reflexivity

The fourth and final component of sTc framework is reflexivity. This construct enables teachers and students to critically consider how their cultural backgrounds, socioeconomic status, beliefs, values, and education influence their teaching and learning (Rodriguez 1998; 2015a). In other words, all individuals should reflect on their own positionalities and critically analyze how these influence their teaching and learning and how these reflections impact their actions. To this end, one of the engineering habits of mind, promoted by Cunningham (2018) is "identifying criteria, constraints, and implications" (p. 80). Since criteria and constraints are bounded to an engineering problem, such a problem should include information about costs, time, and cultural norms which can be the context for an engineering design challenge. From this information, students can generate questions about the given problem and develop criteria that can be used as a guideline to evaluate their engineering designs. Additionally, Cunningham argues for the importance of reflection on "the impact and implications of the solutions in the real world" (p. 81). She adds that identifying possible negative and positive implications of an engineered product is necessary when describing a project's criteria and constraints.

We agree with these arguments in principle, but they are not enacted in the activities we reviewed in Cunningham's book and in the EiE curriculum. Take for example the popular TarPul challenge activity described in pp. 69–75 of her book and the accompanying EiE storybook, *Suman Crosses the Karnali River: A Geotechnical Engineering Story* (2007). In this engineering challenge, students are encouraged to assist a male geotechnical engineer (whose ethnicity is not disclosed) and a precocious Nepalese boy explore the best site to construct a TarPul bridge (i.e., a small cable cart mounted on a wire that people can pull themselves to move above a rapid flowing river, see Fig. 4.2., p. 70 of Cunningham's book or https://www.eie.org/sites/default/files/resource/file/sumancrossesthekarnaliriver.pdf).

Suman—the Nepalese boy—is worried about his ailing grandmother, and the possibility of not being able to take her to the village clinic (located across the river) due to the common rising of the river during the rainy season. He is also worried about having to miss school and having his village be cut off for periods of time. Buwu, a well-educated village elder and Suman's father, wishes to have the TarPul bridge built in the same location the villagers have always used to cross when the river is low. He says, "I want to honor our village traditions." He adds, "the bridge should be built where we have always crossed by thousands of years." The set up for this activity could be an excellent opportunity to model various aspects of sTc highlighted earlier. Namely, 1. the dialogic conversation: Promote an honest and direct dialogue to contrast the Anglo-Western, science-based recommendations with the elder's culturally and historically based point of view; 2. Authentic activity: Examine how engineers and scientists' work does not occur in a social vacuum, and that sociocultural, historical, and socioeconomic contexts are as important as material constraints; 3. Metacognition: Highlight how Suman is thinking about the nature of science, and about how what he is learning (about soil types, bridges, village politics) are also connected to persuasively communicating those insights to others. However, and most relevant for this section, this activity could have provided a very valuable opportunity to critically reflect on everyone's positionalities (reflexivity).

For instance, we could have started with some basic questions first to instigate discussion, such as: Why are the Anglo, male, David Mister (who supposedly invented the TarPul bridge) and the male (who might be Nepalese) geotechnical engineer at this village in the first place? Who invited them? Why is the TarPul bridge (which still is a dangerous type of bridge) being built instead of a regular suspension or more durable and reliable bridge? These important questions and sociocultural context are left out of the storybook and activities, and we argue they only serve to reify *Pitfall#1, the Savior Fetish* (see Rodriguez, under review). This common pitfall found in many engineering design activities perpetuates the colonial stereotype that people of color need to be “saved” by the wiser, compassionate, “White man” because they know better, and because the less educated, “primitive” villagers are in need of saving. While, most likely, this is not the premeditated message in these well-intentioned activities, this is really the predominant message being conveyed. This is where the role of a culturally competent and inclusive teacher is most critical because these kinds of activities could provide productive and socially transformative spaces. For example, in the EiE storybook, Buwu—Suman’s father and village elder—clearly argues that “Every time we tried to build a bridge at any other point of the river, it has been washed away. Every time we lose money and days of work.” Thus, it is not that these villagers do not know how to build bridges, it is more likely that they do not have the resources and manpower to build a sustainable bridge. A more culturally and socially relevant story would build on this important aspect. Similarly, it would be more realistic and socially relevant to draw attention to the economic disparities people living in rural communities often encounter. This is a common global issue, and the USA is not exempted from it. It is also prudent to allow students to consider the question: Why does the Nepalese government does not build a proper bridge in this village? The overall issue described in the storybook is a real issue affecting many Nepalese (e.g., see this video https://www.youtube.com/watch?v=bwGKy_dREpg). It is also appropriate to provide a more realistic scenario by which the villagers are already advocating for themselves and pressuring government authorities to build a safe and durable suspension bridge. Portraying peoples of color as passive (villagers) who silently accept their fate and do not advocate for themselves is a common trait of the Savior Fetish pitfall.

Using reflexivity as a guiding lens, the storybook and engineering design scenario could be turned instead into excellent entry points for students to explore their own positionalities. In other words, instead of just playing the omnipresent, safe, and presumed neutral role of voyeurs in Suman’s life, they could be posed with the question: What would you do if this was happening in your own neighborhood? If there was a river that often flooded and prevented you to go to school, or go to the doctor, or to the market? These questions could help students explore and acknowledge their positions of privilege, their sense of agency, as well as help them reflect on the potential role they could play someday in creating a more socially just world.

In the same vein, it would be more believable (appropriate) if the villagers were considering the TarPul bridge as a temporary solution—something to be used only in case of emergencies. It would also be a more realistic and less colonial scenario if the White male, inventor of the TarPul bridge, and apparently his protegee, the geotechnical engineer visitors were the ones receiving expert knowledge about the various types of soil in the area from the elders—after all, the elders have been long time farmers with a great deal of traditional ecological knowledge passed down from generations. It is quite safe to assume that the villagers in this story, who have lived in the area for generations and have managed the turmoil of many floods during rainy seasons, are quite knowledgeable about erosion, soil types, soil compaction, and so on. Unfortunately, however, the story ends uncritically with the villagers being persuaded to build the TarPul bridge where the Western experts said it should be built in the first place.

It is relevant to add at this juncture that in a review of this popular EiE activity, we found two different and recent doctoral dissertations that used this TarPul bridge story and engineering design activity as main data gathering tools (Tank 2014; Rynearson 2016). However, neither one of these dissertations addresses the *Savior Fetish* pitfall discussed here. Instead, they simply widened this pitfall by allowing it to remain unchallenged. This and other common pitfalls in developing more culturally and socially relevant engineering design activities could be avoided if we were to include a *Dimension of Equity, Engagement, Diversity, and Social Justice* right along with the other three NGSS dimensions. In this way, the urgent need to address issues of social justice in STEM classrooms could be more productively and directly tackled, instead of relegating them to appendix documents and other add-ons to the NGSS (see Rodriguez 2015b for a critique of the NGSS). We cannot expect that everyone would readily identify and productively engage with the pitfalls discussed here without more purposely making issues of equity, diversity, and social justice more salient in major education reform documents and standards.

One last aspect we wish to highlight through the concept of reflexivity is the importance of being intellectually honest and portraying science and engineering practice as they are: Potentially flawed and imperfect human endeavors greatly affected by social, historical, and institutional factors. Unfortunately, throughout Cunningham's book—as in many other sources—there is a predisposition to romanticize science and engineering as innately *benevolent* and *pure* practices. For example, Cunningham states that her design principle for inclusivity is meant to "demonstrate how engineers help people, animals, the environment, or society" (p. 95). Of course, this is what we all hope for, but this is not congruent with our present reality. Many of the ailments that affect our troubled planet today have been indeed produced by advances in science and engineering (which ironically were "designed" to meet the "needs" of greedy "clients," such as international corporations and the billionaire class). It is essential for children to gather a more balanced understanding of the nature of science and engineer as human endeavors, and of the critical role that ethics plays in our development as caring and responsible human beings—responsible to our communities as well as to our local and global environments (Macfarlane et al. 2019).

Conclusion

Christine Cunningham's book *Engineering in STEM Education* and the *Engineering is Elementary* curriculum highlighted in her book provide a rich resource of activities and ideas for all those interested in integrating engineering practices in the science classroom. However, like many well-intended curriculum materials available for purchase in the current NGSS-spurred market, Cunningham's book and her EiE curriculum often fall short of their stated inclusivity goals. Given the urgent need to more effectively address issues of equity, diversity, and social justice in increasingly culturally diverse schools, it is imperative that we closely examine any research and/or curriculum claiming to "infuse engineering into your teaching, school, or district curriculum in age-appropriate, inclusive and engaging way" (p. 3) for two principal reasons. First, the demands from the most recent science education reform effort in the USA—the NGSS—like any other previous reform effort, generated a craze that translates into millions of tax dollars being spent in pursuit of the next "shiny bell" that would ring success for all and all of the time. Should we not then be more prudent about where limited funds are invested? Second, highly popular curriculum, related research, and even new standards like the NGSS often become very influential on teachers, policymakers, and researchers without in-depth analysis. For example, the NGSS—a complete set of new science standards—was proposed without conducting any kind of comprehensive research on the impact of the previous science standards on teachers' practice or students' learning in spite of being in existence for almost two decades (see Rodriguez 2015b for a detailed critique of the NGSS). In this essay, we provided another example of the influence of popular curriculum by citing two recent doctoral dissertations based on one of the Engineering is Elementary curriculum (the TarPul design activity) without recognizing how these types of well-intended activities reify colonial thinking and deficit stereotypes about the Other. It is likely that there are many more dissertations based on this type of curriculum that were written by future science educators and researchers who would (most likely unintentionally) continue to promote colonial thinking through their own work because we are not exposing them to critiques like the one presented here.

As scholars, it is our responsibility to review, critique, and advance knowledge, and Cunningham (2018) reminds us in her book "we cannot change the education landscape today without asking questions about how we can improve, how we can best serve all students" (p. 144).

It is our hope that the examples we provide in this essay build upon Cunningham's work by demonstrating how we can avoid common pitfalls, such as unintentionally promoting colonized thinking, romanticized notions of engineering as a pure human endeavor; and culturally and socially unauthentic scenarios.

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