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Abstract

In the growing field of K-12 engineering education, there is limited research that highlights the experiences of youth from historically marginalized communities within engineering learning environments. This study offers insights into the ways in which two groups of elementary school students constructed approaches for participating in the engineering design practice of collaborative reflective decision-making. Findings suggest that students conceptualized urban, engineering learning environments as spaces for risk management. This notion of managing risks informed their participation in collaborative decision-making, and the ways in which they viewed themselves as doers of engineering. Implications for this study include the continued need for the development of methodologies and frameworks that provide opportunities to uncover these potential risks, and design supports for student participation in engineering design practices.

"I'm a ten because I'm a good student. I'm a good listener. I follow directions, and I do what I'm supposed to do." – Cynthia, 4th grade engineering student

Introduction

When five African American students from two different elementary schools discussed their views of themselves as "doers of engineering," their self-appraisals varied across a scale from 1-10. Despite this variation in self-evaluations, students' responses were similar to the response that Cynthia provided above. Self-appraisals were heavily informed by students' perceptions of their abilities to negotiate the perceived risks associated with participating in an engineering design practice referred to as *collaborative reflective decision-making* (Wendell, Wright, & Paugh, 2017). Specifically, students' views of their adeptness to enact the qualities of a doer of engineering were situated in their abilities, or inabilities, to successfully negotiate the intellectual and social risks associated with engaging in collaborative reflective decision-making within the context of their classroom. Collaborative reflective decision-making was envisioned as a combination of two disciplinary practices in the Next Generation Science Standards' (NGSS Lead States, 2013): (a) designing solutions and (b) engaging in argument from evidence. The practice required students to reflect on previously gathered information and/or ideas while making team design decisions. Unexpectedly, when presented with opportunities to evaluate their participation in collaborative reflective decision-making, the five elementary school students characterized their "engineering abilities" through a lens that emphasized displaying good behavior and following strict instructions for developing "right answers."

Highlighting the experiences of youth within urban classrooms, this research argues for the use of theoretical frameworks that provide opportunities to critically examine and frame the complexities of student engagement in engineering design practices, such as collaborative reflective decision-making. Specifically, this study looks to offer insights into the ways that a group of students within an urban context developed situated identities (Gee, 1999; Lave & Wenger, 1991; Leander, 2002) as doers of engineering. Empirical work examining students' engineering experiences within urban learning environments is limited (Denson, Avery, & Schell, 2010; Mehalik, Doppelt, & Schunn, 2008; Silk, Schunn, & Cary, 2009), and even more so at the elementary school level (Capobianco, Diefes-

Dux, Mena, & Weller, 2011; Capobianco, Ji, & French, 2015; Marulcu & Barnett, 2013). We contend that as engineering's visibility in elementary school contexts increases (Aguirre-Muñoz & Pantoya, 2016; Cunningham, 2009; Hegedus, Carlone, & Carter, 2014; Lottero-Perdue, Bodwitch, Kagan, Robinson-Cheek, Webb, Meller, & Nosek, 2016), it is imperative to empirically call attention to the experiences of youth from historically marginalized communities to acknowledge engineering's history of both marginalization and underrepresentation (Frehill, 2004; McGee & Martin, 2011; Moore, Madison-Colmore, & Smith, 2003; Tonso, 2006) and to proactively explore opportunities for addressing these patterns at the elementary school level (Cunningham & Lachapelle, 2014).

Situated within Spencer's (1995) *phenomenological variant of ecological systems theory* (PVEST) framework, this research provides insights into a group of urban students' emergent engineering identities. In the context of this study, emergent engineering identities were conceptualized as the ways in which students viewed themselves, as well as their peers, as "doers of engineering" as it was realized within the specific contexts of their elementary classrooms. Succinctly, students described what kind of engineering students they were expected to be within social contexts and if they were able to meet these expectations. In the following sections, we present the theoretical framework and construct that guided this work and conceptualized the practice of collaborative reflective decision-making within this framework. Next, we present and analyze data from student interviews and classroom observations to unpack students' perceptions of their participation in collaborative reflective decision-making and their experiences with negotiating the challenges associated with this engineering design practice. Finally, we conclude with a discussion of the importance of utilizing alternate theoretical frameworks for providing insights into students' experiences.

PVEST and Emergent Engineering Identities

For this study, our sociocultural perspective deployed Spencer's (1995) phenomenological variant of ecological systems theory (PVEST framework (see Table 1) by specifically foregrounding the tenet of students' emergent engineering identities. Generally, PVEST is a framework that "builds a bridge between identity and context" (Swanson, Spencer, Harpalani, & Spencer, 2002, p. 75), whereby an individual's self-appraisal and meaning making are analyzed by also accounting for the contextual contributors. "Thus, an individual's perceptions about settings and their experiences in them matter" (Spencer, 2006, p. 697). As a tenet within the larger PVEST framework, emergent identities are defined as the ways in which individuals view themselves within various contexts of growth and development (Lee, Spencer, & Harpalani, 2003). This situated notion of identity was utilized to inform the construct of emergent engineering identities, which explored how elementary school students viewed themselves, as well as their peers, as doers of engineering within the contexts of their specific classrooms. Calling upon PVEST, in general, and the tenet of emergent identities, we foregrounded the belief that all humans are burdened by varying levels of vulnerabilities, or risks, that impacts their growth and development. We argue that the physical and imagined realities of being a student within urban contexts (Emdin, 2010; Martin & Larnell, 2014) impacted students' developing views of themselves as doers of engineering. Although all students experience varying levels of vulnerability within school contexts, we insist that deficit perceptions of "urbanness" (Watson, 2011) position students from urban contexts in spaces of increased intellectual and social vulnerabilities and risks. For instance, teachers, both pre-service and in-service, have been found to share concerns around personal safety, student abilities, cultural conflicts, and language barriers when faced with the task of working within urban contexts (Hampton, Peng, & Ann, 2008; Knoblauch & Hoy, 2008; Lynn, Bacon, Totten, Bridges, & Jennings, 2010; Siwatu, 2011). In this research, we contend that to understand students' development and engagement in disciplinary practices in engineering design that we must examine their experiences through lenses that recognize the imposed expectations of students within urban communities.

In an effort to begin to interrupt the deficit perspectives that are often associated with students within urban schools, we utilized the construct of emergent engineering identities to uncover the vulnerabilities and risks students associated with their participation in collaborative reflective decision-making. Furthermore, focusing on emergent engineering identities provided opportunities to hear directly from elementary school students about the risks they perceived and their approaches for managing these risks. Framing students' participation as strategies for managing risks provides an alternate view of student engagement in engineering design practices. The next section looks to further conceptualize collaborative reflective decision-making through a lens of risk management.

Table 1. Tenets of the phenomenological variant of ecological systems theory (PVEST) (Swanson et al., 2002, p. 76)

PVEST Tenet	Description of PVEST Tenet	Translation to the current study
Net Vulnerability Level	Consists of the context and characteristics that can potentially pose a challenge during one's development at any life stage. A risk contributor is a factor that may predispose an individual for adverse outcomes during a particular developmental stage.	Conceptualized as the intellectual and behavioral stigmas that are often associated with students within urban contexts.
Net Stress (Engagement)	Refers to the actual experiences of a situation or context that challenges the individual's well being. These are the challenges that one actually encounters and are juxtaposed against any available support(s).	Conceptualized as the risks that students associated with their participation in collaborative reflective decision-making.
Reactive Coping Strategies	Problem-solving strategies that an individual employs to deal with stress and dissonance. Reactive coping responses can lead to either an adaptive or maladaptive solution.	Conceptualized as the practices or approaches that students co-constructed in response to the risks associated with participating in collaborative reflective decision-making.
Emergent Identities: Stable Coping Responses	As an individual employs various coping strategies, self-appraisal develops. The strategies that produce desirable results are replicated. Accordingly, these become stable coping responses, and, coupled together, they yield emergent identities.	Translated through the idea of emergent engineering identities, or the ways students conceptualized what it meant to be a doer of engineering within their classroom.
Life-Stage Coping Outcome	Identity lays the foundation for future perceptions, self-appraisals, and behavior, yielding adverse or productive life-stage, specific coping outcomes.	Translated as students' future perceptions, self-appraisals, and behaviors as engineering students. Examining elementary students' life-stage coping outcomes were not within the scope of this study.

Conceptualizing Collaborative Reflective Decision-Making through a Lens of Risk Management

Engineers are often described as professional decision-makers (Chen &Wassenaar, 2003; Hazelrigg, 1998), thus drawing attention to the importance of effectively and efficiently making sound decisions throughout the engineering design process. Design decisions within professional engineering contexts typically carry high consequences, potentially impacting the success of a design solution, the engineer herself or himself, the business affiliated with the engineer(s), and the society at large (Gandy, Jager, Bertsche, & Jensen, 2007; Jankovic, Stal-Le Cardinal, & Bocquet, 2010). The complexities associated with generating optimal engineering design solutions involve prioritizing a variety of information that is available to the design team, including, but not limited to, social goals, scientific understandings and applications, ecological impacts, and financial considerations and implications. Thus, the research presented here recognized and positioned decision-making as a vital disciplinary practice within the engineering design process.

Collaborative reflective decision-making was envisioned as the practice of collectively reflecting on previously gathered information and/or generated ideas in order to make in-the-moment, intentional, and informed design decisions within the contexts of engineering design activities (Wendell, Wright, & Paugh, 2017). The presumption is that this in-the-moment reflective practice of making design decisions based on "evidence" that a given design or idea would work would minimize a design team's dependence on trial-and-error methodologies, and foster an efficient and effective design experience. In this research, disciplinary norms for effectively participating in this kind of learning environment required students to carefully navigate through the process of critiquing the ideas of teammates, arguing points through the use of tangible evidence, defending potential design choices and ideas, and negotiating multiple individual ideas within a design team (Jordan & McDaniel, 2014). For instance, elementary school doers of engineering were expected to verbally articulate ideas and/or solutions within a design team, evaluate the pros and cons of each potential solution, and intentionally select a solution based on the previous analyses of their various options (Wendell, Wright, & Paugh, 2017).

Although students were expected to participate in these disciplinary practices associated with collaborative reflective decision-making, this study acknowledges that these practices could potentially position students in vulnerable spaces, especially those students attending schools within urban communities. Emdin (2016), a noted urban education scholar, points out that "students who populate urban schools are generally beholden to a pedagogy of poverty that rewards them for being docile and punishes them for being overly vocal and expressive" (p. 66). Emdin's observations call attention to the didactic and teacher-controlled instruction prevalent within urban school contexts (Ferguson, 2000; Rivera-Maulucci, 2010; Thadani, Cook, Griffis, Wise, & Blakey, 2010) that also emphasizes students' maintenance of "appropriate behavior" to succeed. Thus, the research presented here recognized the potential for students in urban communities to encounter various risks when participating in collaborative reflective decision-making, where instances of critique, argumentation, debate, and negotiation are encouraged within classrooms that typically reward students for contrasting practices of compliance and docility.

Addressing the Need for Continued Research on Argumentation in Elementary School Classrooms

The practices of argumentation and critique, foundational practices for engaging in collaborative reflective decision-making, have received increased attention within the science and engineering education communities. For instance, the National Research Council Framework (2012) contends, "students should argue for the explanations they construct, defend their interpretations of the associated data, and advocate for the designs they propose" (p. 73). Empirical research around these practices often highlights the ways in which these practices enhance students' conceptual understanding and scientific reasoning (Duschl & Osborne, 2002; Osborne, Erduran, & Simon, 2004), and role of social interaction in learning and thinking processes (Jiménez-Aleixandre & Erduran, 2008).

Previous science education research has often cited elementary school students' capabilities for developing quality scientific arguments. For instance, McNeill (2011) focused on how 5th grade students' abilities to engage in argumentation changed over the course of a school year. She found that teachers were able to positively impact students' developing stronger arguments through the use of instructional supports that built upon students' everyday resources. Ryu and Sandoval (2012) also found that an instructional focus on argumentation supported elementary students' improved abilities in constructing and evaluating arguments. This finding was most attributed to improvements in the development of several classroom norms that supported students' defining "good arguments." Finally, while examining learning progressions for scientific argumentation, Berland and McNeill (2010) suggest that the instructional context supports students' engagement in argumentation in complex ways. While the discussion of these three studies is not intended to serve as an exhaustive review of argumentation research in elementary science education (Cavagnetto, Hand, & Norton-Meier, 2010; Martin & Hand, 2009; Richmond & Striley, 1996; van Zee, Hammer, Bell, Roy, & Peter, 2005), collectively, they suggests potential supports for addressing some of the complexities for engaging elementary children in argumentation. In our research we applied these findings that instructional contexts and the development of classroom norms have implications for students' abilities in developing quality arguments. Further, by situating our work within a phenomenological variant of ecological systems theory, we feature the roles that the classroom contexts and norms play in students' development in collaborative reflective decision-making.

Building upon the increased focus on argumentation and critique in science education, our current work looks to explore the demands of argumentation and critique during collaborative reflective decision-making in elementary engineering contexts. Research on argumentation in engineering education is not as extensive as that in science education; however, previous studies in this area do provide important insights for our current research. Similar to the aforementioned reasons for highlighting argumentation in science education, Garcia and Mazzotti (2016) argue that approaching engineering education from an argumentation perspective has the potential for providing students with opportunities to develop disciplinary literacies. They argue that by enabling critical thinking and empowering decision-making, students are allowed to refine their abilities for presenting plausible justifications for selected solutions. However, earlier work called attention to difficulties in leveraging argumentation for engineering learning in undergraduate contexts. Kittleson and Southerland (2004) found that undergraduate engineering students rarely engaged in concept negotiation, "a form of collaborative interaction in which more than one participant actively contributes to the evolving conceptual content of the conversation" (p. 271). They identified several themes that played a role in how and when groups engaged in concept negotiation, including (a) assumptions about the purpose of group work, (b) views about effective groups, and (c) their epistemologies and ontologies. They conclude that it is important for researchers and educators to uncover these types of orientations when examining practices such as argumentation and critique within group interactions. In another study, Purzer (2011) hypothesized a significant relationship between undergraduate engineering students' achievement and how many "challenge-oriented discourse" (p. 670) actions they received from their peers. Challenge-oriented discourse actions included instances of disagreement, argumentation, and defending one's points. She found that students were more likely to show agreement and ask questions rather than challenge each other's ideas. Purzer argues that opportunities exist for creating additional learning opportunities if students are taught to engage in effective argumentation. These findings highlight a need for continuing research that looks to address the social challenges of engaging in argumentation within engineering design contexts. To address the issues highlighted in this review, the research questions that guide this work are: (a) How did students conceptualize what it meant to be doers of engineering within their specific classrooms? (b) How did students respond to perceived risks associated with engaging in collaborative reflective decision-making? (c) What are the risks that students associated with this practice?

Methods

Study Contexts and Sample

This study took place in two engineering classrooms within two different schools located in the southeastern part of the United States. For the privacy of the participating schools, teachers, and students, pseudonyms were utilized. The two schools, *Medgar Evers Elementary School* and *Fannie Lou Hamer Elementary School,* were considered schools with "urban characteristics" (Milner, 2012, p. 559) and located within the same school district. Here, "urban characteristics" are used to describe schools that are not located in large cities but nonetheless are experiencing increased challenges often associated with larger urban contexts. These challenges may include, but are not limited to, inadequate resources for authentically engaging students in engineering design or science inquiry or the lack of culturally and linguistically responsive approaches and assessments for effectively engaging diverse populations of students. The larger project included two classrooms from each school, for a total of four classrooms; however, only one classroom from each school was included in this smaller research study. Adhering to a case study methodology (Stake, 1995; Yin, 2011), one engineering design team from each participating classroom became the focus of this research. All work produced from two teams were collected, including engineered artifacts and design drawings from engineering classroom interactions. Specific details of each school, engineering classroom, and design team are provided below.

Description of Evers Elementary School

The student demographics at Evers Elementary were 68% African American, 21% white, 6% biracial, and 5% Hispanic and 76% of students received free or reduced lunch. The featured design team at Evers consisted of three 5th grade African American male students named Corey, Keith, and Toren. This team was selected as the case study for this classroom based on a recommendation from Ms. Simpson, the students' general classroom teacher and facilitator of the students' engineering experiences. Ms. Simpson recommended the selected team because we wanted a heterogeneous ability group to see how different members interacted with one another. Design teams at Evers Elementary participated in a total of 18 hours of engineering design activities that included three units from the Engineering is Elementary curricula (Museum of Science, Boston): (a) A slick solution: Cleaning an oil spill, (b) The best of bugs: Designing hand pollinators, and (c) Now you're cooking: Designing solar ovens. A vital component of collaborative reflective decision-making is the ability to engage in argument through the use of tangible evidence (Wendell, Wright, & Paugh, 2017). Lesson Three of each of these units provided students opportunities to collect the necessary evidence for engaging in collaborative reflective decision-making. Lesson Three is described as the lesson that details how scientific data inform engineering design (Museum of Science, Boston). For instance, the best of bugs unit provided students the opportunity to perform controlled experiments to identify effective materials for picking up and dropping off pollen. This process included testing and describing the properties of materials of objects, such as, erasers, marbles, pipe cleaners, tape, and pompoms. Neither the students, nor Ms. Simpson, had previous experience with engaging in engineering design activities. Due to the school's below average test scores in mathematics and reading, the majority of the children's day consisted of test preparation and enrichment activities within the areas of mathematics and reading. School personnel considered students' engagement in engineering design activities as a fun, hands-on opportunity for students. Students were not given grades for their participation in these activities.

Description of Fannie Lou Hamer Elementary STEM School

The student demographic at Hamer Elementary were 74% African American, 15% white, 6% biracial, and 5% Hispanic, and 81% of students received free or reduced lunch. The featured design team at Hamer consisted of three 4th grade female students named Abigail, Cynthia, and Jata. Abigail was a white female student, and Cynthia and Jata were African American female students. Although Abigail served as an integral member of this design team, she was not included in the collection of interview data. At the time of the interview data collection, Abigail had transferred schools and was unavailable for participation. This team was selected as the Hamer Elementary case due to the recommendation of Ms. Humphrey, Hamer's technology specialist and facilitator of the students' engineering experiences. Similar to the student design team at Evers Elementary, this design team was recommended because we wanted a heterogeneous ability group to see how different members interacted with one another. The design team at Hamer participated in a total of 12 hours of engineering design activities specific to this project that included two units from the Engineering is Elementary curricula (Museum of Science, Boston): (a) Water, water, everywhere: Designing water filters and (b) The best of bugs: Designing hand pollinators. Hamer students were provided the same opportunities to engage in data collection to inform their engineering designs, as described in the Evers Elementary description above. At the time of the study, Hamer was a school that was in transition and attempting to change its culture. Mathematics and reading scores were well below the state and national average, and the school was recently reconstituted as a mathematics and science magnet school. With this reconstitution came modest increases in student participation in engineering design activities within the school's engineering design laboratory. Despite the once a week engineering experiences, the school was heavily focused on improving its test scores through increased enrichment activities and test-taking preparations.

Data Collection and Analysis

Data sources for the study included semi-structured interviews and classroom observations of team interactions during engineering design activities. Study participants took part in face-to-face interviews lasting no longer than 30 minutes. Each interview was video recorded and transcribed for later analysis. During the interviews, students shared insights into their approaches for working within the design team and coming to team consensus on design decisions, as well as their assessments of being doers of engineering. Data included video recordings of 12 hours of engineering team interaction at Hamer Elementary and 18 hours of engineering team interaction at Evers Elementary, transcripts of these interactions, and field notes generated during each interaction.

Interview data for this study were analyzed using interpretive phenomenological analysis (Larkin, Watts, & Clifton, 2006; Quinn & Clare, 2008; Smith, 2004) to make sense of how students characterized what it meant to be a doer of engineering within their classrooms, their abilities or inabilities to enact these characteristics, and their approaches for engaging in collaborative reflective decision-making. Interpretive phenomenological analysis as a qualitative framework for data collection provided opportunities to understand the students' lived experiences – that of a student within an urban engineering classroom – and how they made meaning of these experiences. Using a thematic analysis approach (Marshall & Rossman, 2015), the research team utilized three categories derived from the PVEST framework (see Table 1) in analyzing data: (a) reactive coping strategies, (b) stress engagements, and (c) emergent identities. Reactive coping strategies, or the strategies that students employed to resolve dissonance-producing situations in response to perceived challenges for engaging in collaborative reflective decision-making, were identified through examining students' interview responses. Each student provided details into how their design team approached collaborative reflective decision-making and the research team analyzed for any emerging patterns across these responses. In addition, video recording and transcripts of design team interactions were analyzed to identify instances in which teams engaged in collaborative reflective decision-making, or the critique, argumentation, and negotiation of ideas to produce a single design solution for the team. These data were secondarily utilized to examine instances of team decision-making and coordinate with students' descriptions of their approaches for engaging in collaborative reflective decision-making from their interviews.

Student interview data were utilized to analyze the final two categories of stress engagement and emergent identities. Stress engagements, or the specific challenges students associated with engaging in collaborative reflective decision-making, were identified as students discussed the approaches they utilized for engaging in the disciplinary practice. Adhering to a PVEST framework, we expected to identify and connect students' perceived challenges for engaging in collaborative reflective decision-making with their reactive coping strategies. As students talked about the approaches they utilized for engaging in the disciplinary practice, they also described the experiences that led them to utilize these approaches. These described experiences were coded as "challenges for engaging in collaborative reflective decision-making." Finally, student interview data were also utilized to analyze students' emergent identities, or the ways that students viewed themselves as doers of engineering, and to identify the similarities and variations in the experiences of different students. The next section opens by highlighting these data, and addresses the question of how students conceptualized what it meant to doers of engineering within their specific classrooms.

Findings

Examining Students' Emergent Engineering Identities

This section looks to build upon PVEST's fourth tenet, emergent identities (see Table 1), to unpack and characterize students' emergent engineering identities. Emergent engineering identities were conceptualized as the ways in which students viewed themselves, and their classroom peers, as doers of engineering. To explore students' emergent engineering identities, students were presented with the question, *"if you had to place yourself on a scale of 1-10, 1 being the lowest and 10 being the highest, where you would place yourself in regards to engineering and why?"* As communicated in the opening paragraph of this manuscript, students' self-appraisals as doers of engineering varied and included scores ranging from 5-10 (see Table 2). We contend that the variations in students' self-appraisals were informed by their evaluation of being able to maintain "appropriate behavior" during engineering class.

Table 2. Emergent engineering responses from the five participating elementary school students

Student Name	School	Response to emergent engineering question
Corey	Evers	Six or seven. I was being a little crazy with someone that I always get in trouble with and I think it's a bad thing to always to be around that person that get you in trouble. So, I learned my lesson and I stopped being around the people that makes me crazy and that's why I'm a good student now.
Cynthia	Hamer	Ten, because I'm a good student. I'm a good listener, I follow instructions, and I do what I'm supposed to do. And that's it.
Jata	Hamer	Five because I'm in the middle of it. I'm not really that bad, but I'm not really that good. Because I know – how to work together with people.
Keith	Evers	Seven to eight because sometimes I can be off task and sometimes I can – sometimes I have my moments, like paying attention for the whole class and doing good.
Toren	Evers	Ten. Well, because I've never really done anything to get kicked out of it [engineering class] or anything else or a teacher had to actually say something to me; tell me to get out the room.

Despite the variations in students' self-appraisals, the above data suggest consistency in students' conceptions of what constitutes a doer of engineering. Within and across the two engineering design teams, student responses focused on their ability, or inability, to "behave correctly" or following specific instructions. Absent from any of the above responses are specific engineering or engineering practice references. The similarities in student responses are consistent with Emdin's (2016) aforementioned observations where students within urban academic settings are often rewarded for their docility and compliance. Also visible from students' self-assessments (see Table 2) were the ways in which their emergent engineering identities developed during their engagement in engineering design activities, while also being re-evaluated by the ways in which they were able to adjust their behavior throughout the year. For instance, Corey and Keith (see Table 2) provided responses that articulated a fluid understanding of their self-appraisal that was connected with their abilities to alter their classroom behavior over the course of the academic year. Corey provided a narrative that described getting into trouble with a peer, learning his lesson at some juncture during the year, and believing that this was the reason that we was a *"good student now."* In a similar response, Keith also specified instances in which he considered himself to *"be off task"* and acknowledged these moments as contributing to his self-assessment of 7-8. Other students, specifically Toren and Cynthia, articulated more stable associations with their ability to abide by the emergent theme of "good behavior" and confidently viewed themselves as doers of engineering. Although they evaluated themselves as "10's," their assessments were connected to their abilities to avoid *"getting kicked out"* and being able to *"follow instructions"* instead of any specific engineering practice.

To further exemplify the relationship between students' emergent engineering identities and the idea of behaving appropriately in class, we present additional interview data from Evers Elementary. Students were asked to identify three classroom peers who they thought were smart engineering students. Student responses (see Table 3) provide additional support for the highlighted theme of doers of engineering being coupled with the assessment of one's behavior during engineering team interactions.

Table 3. Evers' student responses to naming smart engineering peers

Students' Name	Student Responses
Corey	Olivia, Toren, and Aaliyah, because they [Olivia and Aaliyah] both don't do anything, they just know not to be with people that get them in trouble. They just know straight right there, if you know somebody gone get you in trouble don't go with them. So, she [Olivia or Aaliyah] just go with girls that won't get her in trouble. Like, Olivia usually goes with Aaliyah and Aaliyah with Olivia. They just think the right way and they don't talk to each other like that…
Keith	I might say Aaliyah or Olivia because they don't – they don't really get in trouble like that.
Toren	Olivia, Corey, and Aaliyah.

Corey, Keith, and Toren all identified Aaliyah and Olivia as class exemplars of "smart engineering students" and described the girls' abilities to *"think the right way"* and avoid *"getting in trouble."* Coupled with student responses in Table 2, these responses suggests that students conceive doers of engineering as students who demonstrate the ability to avoid "getting into trouble" during team interactions. This ability to avoid getting into trouble included students' ability to follow teachers' strict instructions of rules and knowing how to talk to or work with specific teammates. PVEST describes emergent identities (see Table 1) as developing from students' deployment of reactive coping strategies (McGee & Spencer, 2013) that produce desirable results. From this perspective, the next section examines a reactive coping strategy that we believe contributed to students' emergent engineering identities within these two classrooms.

Situating the Approach of Combining Multiple Ideas as a Coping Reactive Coping Strategy

The goal of this section is to make sense of and characterize an unexpected approach for students' participation in collaborative reflective decision making that is referred to as "combining ideas." Specifically, we look to situate students' combining ideas approach within the PVEST tenet of reactive coping strategies (McGee & Spencer, 2013; Spencer, Dupree, & Hartman, 1997; Spencer, Noll, Stoltzfus, & Harpalani, 2001), or as a problem-solving strategy that students utilized to avoid "getting into trouble" while being asked to engage in collaborative reflective decision-making.

As the research team reviewed and analyzed data from two different elementary school engineering design teams, this approach of combining ideas emerged as a common approach across various design teams. The primary practice of combining ideas consisted of students incorporating several individual ideas within the team's final design solution without the interrogation or discussion of the pros and cons of these ideas. This approach contradicted the research team's expectations for student participation in collaborative reflective decision-making. To provide further context for what this approach looked like within a design team, an illustrative case is provided below. In this example, Abigail, Cynthia, and Jata are engaged in the water, water everywhere: designing water filter curriculum developed by the Engineering is Elementary team (Museum of Science, Boston). In this environmental engineering unit, students explored properties of potential water filter materials (e.g., gravel, cotton balls, cheesecloth), applied their knowledge of water, and planned and constructed team water filters.

In the excerpt below, the three 4th graders were making decisions regarding the team's water filter design. Prior to the brief discussion documented below, each girl individually designed a solution, shared their individual design during a team discussion, and came together to decide on a single team design solution or to participate in collaborative reflective decision-making. This specific excerpt was selected because of the students' explicit reference to adhering to an approach that included "adding ideas together," or combining multiple ideas.

Excerpt 1. Illustrative case of a design team combining multiple ideas

1	Abigail	Well, can we draw something?
2	Jata	Okay, are we going to use my idea or are we going to add all ideas together?
3	Cynthia	Add all our ideas together//
4	Abigail	// Coffee filter. ((Begins drawing coffee filter on the team's whiteboard))
5	Cynthia	What is this? ((Referring to Abigail's drawing of a coffee filter))
6	Abigail	Coffee filter. [See Figure 1]
7	Cynthia	That's water.
8	Abigail	That ain't no water!

In the above excerpt, Jata (line 2) initiated a move for the team to make a decision on how to proceed with the team's design. She explicitly offered her teammates two potential methods for participating in collaborative reflective decision-making: (a) use the idea that she previously put forward to the team or (b) add all of their ideas together. Analyzing this exchange, we argue that Jata expressed confidence that her design would be an effective solution (e.g., are we going to use my idea?); however, she also felt the need to offer the team an additional option of *"adding all our ideas together"* (line 2). Following Jata's offer, Cynthia (line 3) verbally voted for the use of a combining ideas approach, while Abigail (line 4) physically validated the approach by initiating the drawing of her contribution towards the team's final design solution. Thus, the team's incorporation of this approach was solidified. This interaction continued with Cynthia's critique (lines 5 and 7) of the "appearance" of the coffee filter drawn by Abigail, as opposed to a debate regarding the potential benefits or disadvantages of including this material in the design of the water filter. Following the conclusion of this team's exchange, the team of girls continued the practice of combining ideas that included Cynthia's addition of cheesecloth and Jata's addition of cotton balls and a piece of screen to the team's final design (see Figure 1).

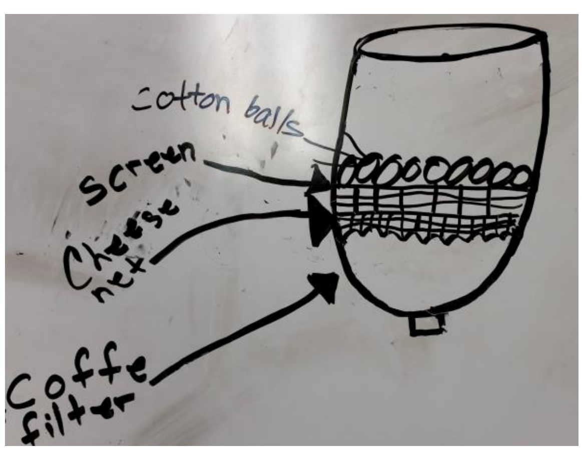

Figure 1. Drawing of the design team's water filter design

A combining ideas approach could have been recognized as collaborative reflective decision-making if teammates had debated and unpacked the pros and cons of the individual ideas with the purpose of developing an optimal design solution for the design challenge. However, this specific design team, as well as others observed throughout the study, utilized an approach where un-interrogated ideas were added within the team's final design. For instance, Cynthia questioned Abigail's drawing of a coffee filter by critiquing the aesthetics of the coffee filter and describing it as "water" (line 7). Due to previous teacher modeling of engaging in collaborative reflective decision-making and insights into developing an optimal solution, the expected approach for engaging in collaborative reflective decision-making would have included a discussion about the potential effectiveness for incorporating the coffee filter into the final design. From this perspective, a combining ideas approach would have been conducive for participating in collaborative reflective decision-making if teammates had debated the pros and cons for incorporating various design elements.

To situate a combining ideas approach as a reactive coping strategy (McGee & Spencer, 2013; Spencer et. al., 1997; Spencer et al., 2001), associated risks must also be identified and unpacked. During individual student interviews, Jata was asked why she offered her team the option of "adding all their ideas together" (line 2) instead of pushing for the adoption of her individual idea. Jata responded:

> Because, sometimes, I can get in arguments. Because you don't want Ms. Humphrey thinking you're in an argument with nobody. You get in an argument then it turns out to be a fight then you get suspended, and you get a whoopin' at home, you know?

Jata's response provided initial insights into the potential risks that students associated with participating in collaborative reflective decision-making. Here, Jata introduced the risk of being identified as participating in an argument when debating the pros and cons of individual ideas. With the risk of *Ms. Humphrey thinking you're in an argument,* Jata processed the potential for being reprimanded and the potential consequences that could follow, e.g., suspension from school and punishment at home. From Jata's insight, we argue that the approach of combining ideas served as a reactive coping strategy (McGee & Spencer, 2013; Spencer et al., 1997; Spencer et al., 2001) for many teams as they participated in collaborative reflective decision-making. Jata employed this approach as a problem-solving strategy for alleviating the potential for being reprimanded for the perception of engaging in negative behavior. The following section utilizes student interview data to highlight additional risks that students associated with collaborative reflective decision-making, while corroborating students' use of a combining ideas approach.

Identifying Perceived Risks Students Associated with Participating in Collaborative Reflective Decision-Making

The previous section argued that the students' approach to combining ideas should be positioned as a reactive coping strategy (McGee & Spencer, 2013; Spencer et al., 1997; Spencer et al., 2001). This characterization as a reactive coping strategy required the research team to also uncover the various risks that students were "reacting" to while participating in collaborative reflective decision-making. Lee and colleagues (2003) describe PVEST's second tenet, stress engagements (see Table 1), as the "actual experiences or situations that challenge an individual's well being" (p. 9). For this study, stress engagements were conceptualized as the specific risks that students associated with participating in a learning environment that promoted engagement in critique, argumentation, debate, and negotiation. The previous section introduced the risk of being reprimanded for the perception of engaging in detrimental behavior, while this section looks to identify additional risks students highlighted during student interviews.

To explore students' perceptions for participating in collaborative reflective decision-making, students were presented the question, *"what kinds of things did you need to do in order to come up with one solution as opposed to having different ones?"* Student responses provided insights into the perceived risks for participation (PVEST tenet of stress engagement) and their responses to these risks (PVEST tenet of reactive coping strategies). For instance, Corey, a student at Evers Elementary, stated:

> Try to put it [ideas within the team] together. Because if you think one idea is good, that means you just have to put it together because it ain't gonna be right to just use one person's. So – so, if you like, we all have good ideas, and you could try to connect parts with each other and just try to like work with it because sometimes, sometimes, people get real mad when you don't use their ideas, and they just go off and just get real mad and just say they don't care. So, you should just put it together just to make no commotion, or not commotion, but – arguing.

Analyzing Corey's response, we initially highlight Corey's acknowledgement of the team's use of a combining ideas approach, e.g., *"you should just put it [ideas within the team] together."* Consistent with positioning this approach as a reactive coping strategy with Jata's team, we argue that Corey's team also utilized this approach in response to potential risks for participating in collaborative reflective decision-making. Two risks that emerged from Corey's response were the potential for (a) unfairness within the team when making collective design decisions and (b) marginalizing teammates from the decision-making process. Corey calls attention to his desire to avoid potential unfairness within the team as he stated, *"it ain't gonna be right to just use one person's ..."* Although the objective of participating in collaborative reflective decision-making is to generate an optimal design solution to the engineering design problem, Corey incorporated the additional objective of maintaining a positive team atmosphere by avoiding "commotion or arguing...." In addition, Corey recognized that this potential for "unfairness" while making team decisions could possibly marginalize his teammates' participation in the design process, as he stated, *"... sometimes people get real mad when you don't use their ideas. And they just go off...."* Corey identified the risk of maintaining a positive team environment within the design team and utilized the approach of combining ideas in response to these risks.

To further highlight the approach of combining ideas as a reactive coping strategy and the perceived risks for participating in collaborative reflective decision-making, we call attention to Toren's response when posed with the same question presented to Corey. Toren stated:

> Pretty much what we did, we can come up with our own ideas and then we talked together as a group and see if we can find one good; like the best idea we can out of all ideas combined. Well, some people think differently and you combine three different things and made something very good or something not good.

Analyzing Toren's response, we initially call attention to his acknowledgment of incorporating a combining ideas approach as he stated that they *"combined three different things."* Toren and his teammates were not confident in the development of an optimal solution by combining ideas, as evident by his concluding statement, *"made something very good or something not good."* The research team interpreted Toren's acknowledgment of combining ideas as reacting to the risk that was previously articulated by Corey; the risk of maintaining positive team relationships.

The previous two sections have highlighted an approach of combining ideas that student teams utilized for participating in collaborative reflective decision-making. This approach was positioned as a reactive coping strategy (McGee & Spencer, 2013; Spencer et al., 1997; Spencer et al., 2001) that students utilized to participate in critique, argumentation, and debate while also minimizing the risks that were associated with these practices. By combining ideas, students reduced the chances of being improperly reprimanded for arguing or fighting or marginalizing teammates.

Discussion

What it meant to be Doers of Engineering at Evers and Hamer Elementary

Focused on supporting students' engagement in collaborative reflective decision-making, the research team conceived the notion of "doers of engineering" to include students who effectively participated in the practices of critique, argumentation, and negotiation. Specifically, in these classrooms, we envisioned doers of engineering as students who utilized these discursive practices during the process of developing team design solutions. From this perspective, we did not define student "success" through a lens of the development of "right answers," but through a lens that valued the various ways in which teams developed productive processes for engaging in collective problem-solving. Previously described findings illustrate that students' developed contrasting conceptions of "doers of engineering" that revolved around their ability to avoid trouble. In these classrooms, from the student perspective, being a doer of engineering meant being able to collectively develop a team solution while also avoiding the potential risks of being reprimanded by the teacher or alienating teammates. Similar to findings from Kittleson and Southerland (2004), we argue that "it is important to recognize that it is not just contextual features such as objects and other group participants that shape knowledge, but also seemingly invisible factors such as assumptions and ideologies …" (p. 269). The issue for the current study is that these factors affected student engagement in collaborative reflective decision-making, and to consider the development of these invisible factors.

This study conceptualized emergent engineering identities as the ways in which students viewed themselves, as well as their peers, as doers of engineering as it was realized within the specific contexts of their engineering classrooms. While participating teachers, Ms. Humphrey and Ms. Simpson, continually modeled varied ways for engaging in collaborative reflective decision-making and encouraged team discussions during design phases, these engineering classrooms also lived within a larger school contexts that could have informed students' perceptions of "smart students." Evers and Hamer Elementary were both considered schools with "urban characteristics" (Milner, 2012), where students were often subjected to teaching acts that included giving directions, asking questions for right answers, settling disputes, and punishing noncompliance (Haberman, 2010). This is important to note because while students were provided opportunities to co-construct approaches for engaging in critique, argumentation, and negotiation, these opportunities were limited to a total of 18 hours at Evers and 12 at Hamer. We contend that as students went through a process of making sense what it meant to be a doer of engineering, their conceptions were also informed by previous experiences at Evers and Hamer that privileged compliance and docility.

How Students Responded to Perceived Risks Associated with Participating in Collaborative Reflective Decision-Making

Collaborative reflective decision-making was envisioned as a disciplinary practice where students would rely on instances of argumentation and critique in the efforts of making informed engineering design decisions. Although the research team identified positive beginnings of student engagement in this disciplinary practice (Wendell, Wright, & Paugh, 2017), students also exhibited apprehension about collectively engaging in these discursive practices. Specifically, students frequently utilized an approach that we refer to as "combining ideas" that included students combining several ideas within a team while limiting the discussion around the pros and cons of these ideas. We contend that the approach of combining ideas served as both a "facilitating and inhibitory role" (Kittleson & Southerland, 2004, p. 267) related to the teams' decision-making interactions. Conceptualized as a reactive coping strategy (McGee & Spencer, 2013; Spencer et al., 1997; Spencer et al., 2001), a combining ideas approach was co-constructed to provide students opportunities to engage in the decision-making process while minimizing the potential risks of being reprimanded by a teacher or marginalizing a teammate. Additionally, within classrooms where students perceived the importance of developing and producing "right answers," a combining ideas approach also served the purpose of distributing the potential for developing "wrong answers" throughout the design team.

From this perspective, the approach of combining ideas facilitated team decision-making interactions by reducing the social and intellectual risks that students associated with collaborative reflective decision-making. In contrast, a combining ideas approach also served an inhibitory role by minimizing students' use of argumentation and critique during the decision-making process. Believing that "reasoning and argumentation are needed to identify the best solution to a design problem" (NGSS Lead States, 2013, p. 13), we contend that a combining ideas approach was not very productive for students developing optimal design decisions. While Abigail, Cynthia, and Jata were able to provide a design solution for the water filter challenge (see Figure 1), they could not articulate some of the intricacies of the design, such as the physical properties of the cotton balls that could potentially contribute to a successful design. We contend that a discussion around the pros and cons of these materials, or engaging in collaborative reflective decision-making, could have positively contributed to students' final designs and contributed to their developing important disciplinary literacies (Garcia & Mazzotti, 2016). In conclusion, we would like to clarify that we are not arguing that a combining ideas approach would be the expectation within urban engineering classrooms. On the contrary, we contend that this approach was co-constructed by students in response to the specific risks that students perceived within these two classrooms. The larger contention is for the need to recognize that there may be perceived risks for engaging in engineering practices, and for researchers and educators to acknowledge as reactive coping strategies.

The Risks that Students Associated with Engaging in Collaborative Reflective Decision-Making

Analyzing students' participation in collaborative reflective decision-making through a phenomenological variant of the ecological systems theory lens presented the opportunity to identify potential vulnerabilities for engaging in group interactions. While students, in general, could face vulnerabilities with engaging in argumentation and critique, we contend that "the nature of the vulnerabilities that human individuals and human communities face are clearly differentiated by an array of societal positionings, particularly with regard to race, ethnicity, class, gender, sexual orientation, and constructions of ability" (Lee, 2017, p. 262). Specifically, we found that the intellectual and behavioral stigmas often associated with students attending schools within urban communities impacted the ways in which students conceptualized their participation in this disciplinary practice. Findings from student interviews suggested that students aimed to minimize the following risks: (a) being reprimanded for behavior deemed inappropriate by the classroom teacher, (b) marginalizing teammates from the decision-making process, and (c) having proposed design solutions evaluated as a "wrong answer." Despite these findings, we do not claim that these risks will appear within every engineering classroom in an urban school. However, we are calling attention to the need for engineering education researchers and educators, alike, to consider the role of context when examining student participation. This study by acknowledged the potential vulnerabilities and conceptualized students' interactions as reactive coping strategies.

Recommendations

A goal of this study was to explore elementary students' conceptions of "doers of engineering" in relation to their participation in a disciplinary practice referred to as collaborative reflective decision-making. These findings call attention to the importance of context when considering participation in engineering design practices, and the essential role that teachers play in supporting the development of productive learning environments. Although participating students maintained positive views of themselves as doers of engineering, their justifications for those views were absent of any references to engineering or engineering practices. Here, we recommend that engineering educators devote the necessary time for co-constructing a shared understanding of "success" and "competence" within their engineering classrooms.

The educator's role in developing these shared understandings, or disciplinary norms within their classrooms, is important in students' development. McClain and Cobb (2001) examined the teacher's role in renegotiating the sociomathematical norm of mathematical difference in a first grade classroom. Through the explicit solicitation of different solution processes during whole-class discussions, the teacher contributed to the class' development of criteria used to judge a variety of mathematical solutions. In another study, Andrews (2017) uncovered a teacher's role in developing norms around testing and failure within an elementary engineering classroom. The teacher's moves included continued references to a poster, or anchor chart, about the importance of testing early and often, and numerous questions asking students to share why they made the changes they made. Success and competence in varied elementary engineering contexts can look different than other disciplines (e.g., mathematics and language arts), and explicit discussions about these specific competencies could potentially contribute to different conceptions of "doers of engineering."

Additionally, we recommend that educators examine the potential for engaging students in engineering design practices, specifically argumentation and critique, in culturally sustaining ways (Alim & Paris, 2017). Culturally sustaining pedagogy "seeks to perpetuate and foster – to sustain – linguistic, literate, and cultural pluralism as part of schooling for positive social transformation" (p. 1). Such an approach would require educators to attune their attention to their students' heterogeneous linguistic and literacy practices, and recognize their potential for engaging students in engineering design practices. For instance, Wilson-Lopez, Mejia, Hasbun, and Kasun (2016) found that Latina/o funds of knowledge mapped onto the application of engineering design processes, and could be reconceptualized as cultural practices to be fostered and sustained within K-12 engineering classrooms. Additional research highlighting students' cultural engagement in argumentation (Hudicourt-Barnes, 2003) and critique (Wright, 2016) in science learning environments could inform the implementation of these practices within engineering classrooms.

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