

## **Draw an Engineer: A Critical Examination of Efforts to Shift How Elementary-Aged Students Perceive Engineers**

**Taylor Lightner, Virginia Polytechnic Institute and State University**

Taylor Lightner is a 2nd year Ph.D. student in Engineering Education at Virginia Tech. She received her B.S. in Industrial Engineering at Clemson University. She currently participates in the Disaster Resilience and Risk Management Program and New Horizon Scholars. Her current research interest includes broadening participation, interdisciplinary interactions, and socio-technical communication boundaries.

**Dr. Monica E Cardella, Purdue University-Main Campus, West Lafayette (College of Engineering)**

Monica E. Cardella is a Professor of Engineering Education at Purdue University.

**Natali Huggins,**

Natali Huggins is a PhD student in the Higher Education program at Virginia Tech. She holds a master's in public administration from the National Experimental University of Táchira in Venezuela. She has several years of experience in higher education administration and internal audit in Venezuela. Her research interests include diversity and inclusion in graduate education, particularly international and Latinx graduate students' persistence and development. She is interested in supporting students in their transition and adaptability to higher education in the United States.

**Cynthia Hampton, Virginia Tech**

Cynthia Hampton is a doctoral candidate in the Department of Engineering Education at Virginia Tech. While at Virginia Tech, Cynthia has directed summer bridge programs, led peer support initiatives for underrepresented groups, and served on various commissions, committees, and research groups focused on student support, organizational change, graduate student policy, and culturally responsive evaluation. Her research interests include organizational behavior and change as it pertains to engineering education and broadening participation, faculty change agents, and complex system dynamics. Her research investigates narrative inquiry of faculty who use their agency to engage in broadening participation in engineering activities. Cynthia received her B.S. in Biological Systems Engineering from Kansas State University and will receive her M.S. in Management Systems Engineering from Virginia Tech in 2019.

**Dr. Walter C. Lee, Virginia Polytechnic Institute and State University**

Dr. Walter Lee is an assistant professor in the Department of Engineering Education and the assistant director for research in the Center for the Enhancement of Engineering Diversity (CEED), both at Virginia Tech. His research interests include co-curricular support, student success and retention, and diversity. Lee received his Ph.D in engineering education from Virginia Tech, his M.S. in industrial & systems engineering from Virginia Tech, and his B.S. in industrial engineering from Clemson University.

**Dr. David B Knight, Virginia Polytechnic Institute and State University**

David B. Knight is an Associate Professor and Assistant Department Head of Graduate Programs in the Department of Engineering Education at Virginia Tech. He is also Director of Research of the Academy for Global Engineering at Virginia Tech, and is affiliate faculty with the Higher Education Program. His research tends to be at the macro-scale, focused on a systems-level perspective of how engineering education can become more effective, efficient, and inclusive, tends to be data-driven by leveraging large-scale institutional, state, or national data sets, and considers the intersection between policy and organizational contexts. He has B.S., M.S., and M.U.E.P. degrees from the University of Virginia and a Ph.D. in Higher Education from Pennsylvania State University.

# **WIP: Draw an Engineer: A Critical Examination of Efforts to Shift How Elementary-Aged Children Perceive Engineers**

## **Abstract**

Diversifying science, technology, engineering, and mathematics (STEM) disciplines is a national imperative. One approach to doing so is expanding opportunities for children from underrepresented groups to connect their interests to STEM topics at a young age. This approach is often achieved through programs such as the Summer Engineering Experiences for Kids (SEEK) program. SEEK is a three-week summer program organized by the National Society of Black Engineers (NSBE) to expose children to hands-on, team-based engineering design projects. The purpose of this work-in-progress paper is to discuss the data analysis process used to examine shifts in children's perceptions of engineers as a result of participating in the program. Children's perceptions were captured using prompts asking them to either (1) draw themselves as an engineer or (2) draw an engineer. Each SEEK participant received one of the two prompts. In this paper, we considered the inclusion of Critical Race Theory concepts to extend the qualitative analysis of participants' drawings. While this paper focuses on our efforts to expand our codebook using CRT, the larger project aims to connect research to practice by providing insight on children's perceptions of engineering and the types of engineering messages that might be present in informal programs and school environments. This work also highlights how practitioners might create an inclusive environment for elementary-aged children during this critical time.

## **Motivation**

Beyond the interests of the nation's economic and technological competitiveness, broadening participation in STEM is an essential issue of equity and social justice. Diversifying STEM is critically influenced through experiences that allow young people to engage in STEM for "a future for full participation in educational, economic, political, and social domains of life for youth from currently underrepresented groups in science, technology, engineering, and mathematics" (Tucker-Raymond et al. 2016 p. 1025). As we examine the participation of minoritized groups, it is important to consider learning experiences across the lifespan and the impact that pre-college experiences can have on decisions to participate in STEM in college, graduate school, and professional practice. Some research, for example, suggests that children's experiences with STEM prior to sixth grade can position them to either have or not have access to middle and high school courses that equip them for success in STEM undergraduate studies (e.g., Reynolds 1991; Singh, Granville & Dika 2002), with motivation and interest impacting mathematics and science achievement (Singh, Granville & Dika 2002; Eccles & Jacobs 1986). It is essential, then, to consider what opportunities elementary-aged children have to develop their beliefs, interests, and self-efficacy related to STEM.

To address the minoritization of underrepresented groups, including girls, many initiatives and interventions have been developed through STEM programs. For elementary-aged children, these types of programs often take shape as targeted out-of-school programs. Out-of-school settings represent critical opportunities for learning and broadening participation in STEM as children spend more than 80% of their waking hours in out-of-school settings (LIFE Center: Stevens, R., Bransford, J. & Stevens, A. 2005), and schools have been slow to implement STEM

education approaches that broaden participation (Tucker-Raymond et al. 2016). As we seek to understand how learning experiences in out-of-school settings might promote STEM participation, we recognize three broad categories of informal learning experiences: (i) everyday experiences, (ii) designed settings (such as science centers or zoos), and (iii) programs (NRC 2009).

In this paper, we focus on this third category: *programs*. According to the National Research Council, successful STEM programs: 1) engage children intellectually, socially, and emotionally; 2) respond to children's interests, experiences, and cultural practices; and 3) connect STEM learning across all settings (National Research Council, 2015). Research literature assessing the impact of summer engineering camps for elementary-aged children have highlighted children's attitudinal and STEM learning gains with as little as 40 contact hours (Bottomley, Lavelle, D'Amico & LaPorte, 2015; Nugent, Barker, Grandgenett, & Adamchuck, 2010). The specific program we are focusing on is the Summer Engineering Experiences for Kids (SEEK) program. Organized by the National Society of Black Engineers (NSBE), SEEK is a three-week summer program that engages children who have recently completed grades 3-5 in daily hands-on, team-based engineering design projects led by collegiate mentors and teachers. Since its inception in 2007, over 20,000 children have participated in SEEK. One core strategy that SEEK uses is the inclusion of *mentors* (i.e., the program staff) who share racial/ethnic backgrounds with the children who participate in the camps. In most cases, this means that the camp staff identifies as African-American, STEM undergraduates, and/or in-service teachers. However, in some regions of the country, a number of the children who participate in SEEK are Latinx; in these communities, the camp staff also include Latinx undergraduates and/or in-service teachers. A second strategy that SEEK uses is portraying people of color as engineers. In the summer of 2019, NSBE posters were created for the classrooms to present images of male and female African-American and Latinx engineers.

## **Purpose**

The purpose of this work-in-progress is to discuss how educators can use Critical Race Theory (CRT) to understand how conceptualizations of race link to engineers and STEM program practices. Though the concept of race is theoretical, the implications are concrete. The messages that children and youth are exposed to during years of socialization influence their attitudes about race, science, and math as well as their self-efficacy, choice of coursework, and future career plans (Knight & Cunningham 2004); and children begin to form negative attitudes about their abilities in math and science as early as second grade (Andre et al. 1997). To address our purpose, we focus on children's perceptions of engineering, which were captured using prompts asking them to either (1) draw themselves as an engineer or (2) draw an engineer. In the following section, we examine the development of a coding scheme grounded in CRT to articulate the ways race surfaces and is conveyed in their drawings.

## **Critical Race Methodology**

To address SEEK participants' perception of engineering, it is crucial to first understand what ideas children of color have about engineering, race, sex, and class. Critical race methodology uses transdisciplinary knowledge and methods to better understand the effects of racism, sexism, and classism on people of color (Solaranzo & Yosso, 2002). Furthermore, regarding education,

this methodology offers a unique perspective to understand the experiences of people of color at different points on their STEM pathways (Solaranzo & Yosso, 2002). It strategically uses multiple methods, often unconventional and creative, to draw on the knowledge of people of color who are traditionally excluded as an official part of academic research.

We considered the inclusion of Critical Race Theory concepts (i.e., color blindness, color imagery, counter-narrative, and critical race feminism). According to Delgado and Stefancic (2012), *color blindness* is a tendency to not consider the individual's race, avoid racial discourse, and assume the invisibility of racial inequality. *Color imagery* is the association of skin colors with certain traits presented in words, text, and images. *Counter-narrative* refers to the narratives that arise from the vantage point of those who have been historically marginalized. Furthermore, *critical race feminism* addresses issues of intersectionality between gender and race. These concepts informed our analysis in two ways: (1) to extend the qualitative analysis of participants' drawings that were collected to examine their perceptions of engineering; and (2) to characterize the posters and other imagery in the learning environment that may have influenced their perceptions. Our dual focus provided space to examine how children of color experience and respond to broadening participation efforts as well as those efforts themselves. Critical Race Theory concepts described are used as a coding scheme to analyze the children's drawings and the classroom posters.

## **Research Design**

Our research design is situated in a larger research project focused on evaluating SEEK's success at influencing STEM-related academic and career identity, conceptual knowledge, and interpersonal and intrapersonal skills (Cardella et al., 2019). To address this broad objective, we applied the logic of an input-environment-outcome framework to organize data collection and analysis. In addition to considering relationships between children's background characteristics and experiences within SEEK with their post-camp outcomes, the framework emphasizes the influence of organizational contexts on shaping children's learning experiences. We considered three major components of organizational context in comparing sites: 1) *Local structures, policies, and practices* – e.g., the influence of the host school, supporting local industry partnerships, access to resources; 2) *SEEK programs, structures and policies* – e.g., NSBE-provided curricula, site development procedures, participant selection policies, and 3) *Mentor/Teachers' Culture* – e.g., beliefs about engineering education, training programs. This work-in-progress paper will focus on expanding a codebook to analyze children's drawings of engineers that were completed both at the start and end of the three-week camp.

## **Context and Participants**

There were 14 SEEK sites across the United States during the time of data collection. At each site, the program staff engage in a week of training and preparation before the camp begins. During the week before the SEEK camp begins, SEEK mentors prepare their activities and their rooms for their SEEK campers. Mentors display copies of the NSBE mission statement and the SEEK mission statement in each classroom, often writing these statements out on the

chalkboard/whiteboard or writing them on poster board that is then displayed in the classroom.<sup>1</sup> This year SEEK mentors were also provided with posters related to: what is engineering; different engineering disciplines; SEEK team roles<sup>2</sup>; the SEEK design process<sup>3</sup>; and the standard and metric measurement systems. The first three of these posters included images of Black and Latinx engineers/children. The SEEK mentors were also provided with smaller posters that featured successful African American men and women and their engineering backgrounds (Leeker et al. 2019). Additionally, as part of the SEEK camp experience, the children and their SEEK mentors co-constructed additional posters for their classrooms, such as team chants and lists of camp expectations.

The participants are children who completed the 3rd, 4th and 5th grade, and the legal guardians of the children provided consent. We collected data during the first and third week of camp through assessments that were administered to all children who participated in SEEK. The Institutional Review Board approved all research protocols. In addition to collecting paper-and-pencil assessment data from all 14 SEEK sites, we also collected additional qualitative data (individual interviews with children, classroom observations, and photographs of the posters and other images presented in the classrooms) at four sites: Atlanta, Chicago, Detroit, and Washington, D.C. This analysis focuses on these four sites. These four sites were selected for the additional data collection based on two factors: (1) proximity to the research teams, and (2) camp make-up. Two of the sites were composed of all girls, and the other two sites were co-ed camps. Across the four sites, approximately 500 children completed the assessments in the first and third week and 52 children participated in interviews. We selected 27 participants' drawings purposely, 19 of which participated in interviews, to examine how children conveyed race in their drawings and their perceptions of engineers stated in interviews completed in the first week of camp.

### **Draw-An-Engineer Task: Data Collection**

The *Draw-an-Engineer Task* utilized in this study is an adaptation of earlier versions of the Draw-an-Engineer Test; which is an adaptation of the *Draw-a-Scientist Test* developed by Chambers in 1983, who examined children's stereotypic views of scientists through their drawings. Chambers claimed that when children drew images of scientists on blank paper, their drawings could provide researchers with specific attributes that children associated with scientists. The *Draw-an-Engineer Test* is used similarly to examine children's concepts and perceptions of engineers and engineering (Capobianco, Diefes-Dux, Mena, & Weller, 2011; Knight & Cunningham, 2004; Newley et al., 2017; Weber, Duncan, Dyehouse, Strobel, & Diefes-Dux, 2011). In engineering education studies, the *Draw-an-Engineer Test* has been primarily used for elementary school-aged children. Having images drawn by children is an unobtrusive technique that has been used in various settings as a means of assessment and information gathering. Such drawings have been used as an effective pre/post assessment to

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<sup>1</sup> The mission statement for NSBE is "to increase the number of culturally responsible Black Engineers who excel academically, succeed professionally and positively impact the community." The mission statement for SEEK is "to increase elementary school students' aptitude in math and science and their interest in pursuing STEM (science, technology, engineering, math) career fields, by having them engage in interactive, team-based engineering projects" (NSBE, n.d.).

<sup>2</sup> SEEK team roles included: Project Manager, Safety Manager, Materials Manager, Technical Manager, and Project Ambassador

<sup>3</sup> The SEEK design process is informed by empirical research, the Next Generation Science Standards and the Engineering is Elementary design process. It includes: Ask, Learn, Imagine, Model It, Create, Test and Improve as major design activities.

measure differences in children's perceptions and assessing their beliefs, misconceptions, and attitudes about the nature of science and engineering. More recently, the Draw-an-Engineer Test has also been modified to measure elementary school teachers' beliefs about what engineering teaching can look like in the Draw-an-Engineering-Teacher Test (Hammack & Vo 2019).

For this study, we refer to the instrument as the *Draw-an-Engineer Task* rather than *Test* because we believe that we are asking the children to complete an activity rather than that we are testing their knowledge of engineering. The *Draw-An-Engineer Task* was presented to the children on an 8.5 inches by 11 inches piece of paper. Children either received a version that asked them to "draw an engineer" or "draw yourself as an engineer." This alternative prompt, "draw yourself as an engineer," was inspired by similar wording used by Tucker-Raymond and his colleagues (2007) in a study where they asked children to draw themselves as a scientist. In our study, both versions of the task also prompted the children to add text below their drawings to describe their drawings. All identifying information associated with the drawings were removed before the analysis.

### **Draw-an-Engineer Task: Data analysis**

Our initial coding scheme for this study was developed by combining the coding schemes used in three earlier studies (Newley et al., 2017; Carr & Diefes-Dux, 2012; Knight & Cunningham, 2004). The resulting coding scheme consisted of three major constructs. The first construct we analyzed was the *attributes* of the engineers found in the drawings and descriptions. We considered gender (e.g., female, male, unclear), whether the engineer was depicted as working alone or with others, and whether the child indicated the engineer was themselves. Two of these codes (i.e., gender unclear and whether the child indicated the engineer was themselves) were new for this study. Next, we looked at the *profession* of the engineer doing work. This construct included codes of a designer, technician, tradesman, mechanic, builder, driver, craftsman, factory worker, or an object/engine (if the child drew an object rather than a person). Lastly, we examined the *activities* that the engineer was involved in, which includes images of building/fixing, designing, drawings/blueprints, products of mechanical engineering, products of civil engineering, trains, laboratory work, engineering design process, SEEK class activities and using tools.

In addition to these codes, we used critical race methodologies to develop a second coding scheme to further analyze the ways that race, gender, and class were illuminated through these drawings. We used critical race methodologies to further examine what message children are provided about the intersection of engineering and race. This analysis will provide suggestions to expand the categories of the analysis of the *Draw-an-Engineer Task*. Furthermore, we propose ways to expand the categories of coding after using critical race theory as a lens. In Preliminary Findings sections, we will explain the development of emergent codes by taking a critical look at the ways race surfaces in the messages that are displayed to children and images conveyed by the children about who and what engineering entails.

### **SEEK Classrooms: Data Analysis**

To contextualize our analysis of the Draw-an-Engineer Task and understand the influence of the two primary strategies (i.e., hiring practices and intentional imagery) used by SEEK to influence

children’s perceptions, we also collected data about SEEK classrooms. To capture information about which posters were present in each classroom, we collected photographs of the classrooms using iPads and personal devices. The photographs collected were part of the high-level site description done by the research team during sites’ visit. The co-constructed materials, by mentors and the youth participants, and official messaging of SEEK (provided posters) provides insight into the alignment of messages conceived by children in this study. In the future, this analysis will provide helpful information for programming and curriculum design. To analyze the photographs of the classroom posters, we created a coding scheme based on Critical Race Theory concepts as color blindness, color imagery, counter-narrative and critical race feminism. Each poster displayed in the classroom was examined to determine the extent to which the posters presented or not a tendency, association, narrative, and intersectionality conveying race.

**Preliminary Findings - Attributes of Engineers**

This section begins with the new dimensions of the codebook that were developed to describe messages and conceptualizations of engineering from a critical race theory perspective. The codes were developed both through literature reviews and emerging themes in the analysis of the drawings, posters, and descriptions. We present three new codes that were developed to expand our coding of “attributes of engineers,” descriptions of the codes, and examples. We then present example drawings for each new code and examples of how we also saw this code evidenced in the classroom context (i.e. in posters or other classroom artifacts).

Table 1. Expanding Categories for Attributes of Engineer after applying CRT

Category	Description	Example
Color blindness	Children specifically said that they do not acknowledge race and people are all the same.	“My picture is showing a person walking in the street. I put this because anyone can be an engineer.”
White	Children specifically said the drawing is a White person or name a historical figure that is White	“Computer engineering is Steve jobs/Bill Gates in the office making a Microsoft computer.”
African American/Black	Children specifically said the drawing is a person of color or name a historical figure that is of color	“My picture shows a team of Black engineers using the design process to build a glider. They have done a test and now they are improving.”

Through our initial cycle of coding, researchers noticed several ways that race emerged in the attributes of engineers that were worth noting. One of the most common ways we noticed race was when children explicitly stated that anyone, regardless of race or gender, can be an engineer as shown in text from Figure 1. This theme is coded as a color blindness approach to diversity in engineering. Two drawings stated, “Anybody, everyone is an engineer.” Furthermore, in follow-up interviews, the children mentioned how race and gender do not matter when it comes to engineering because it is about your heart and mind.

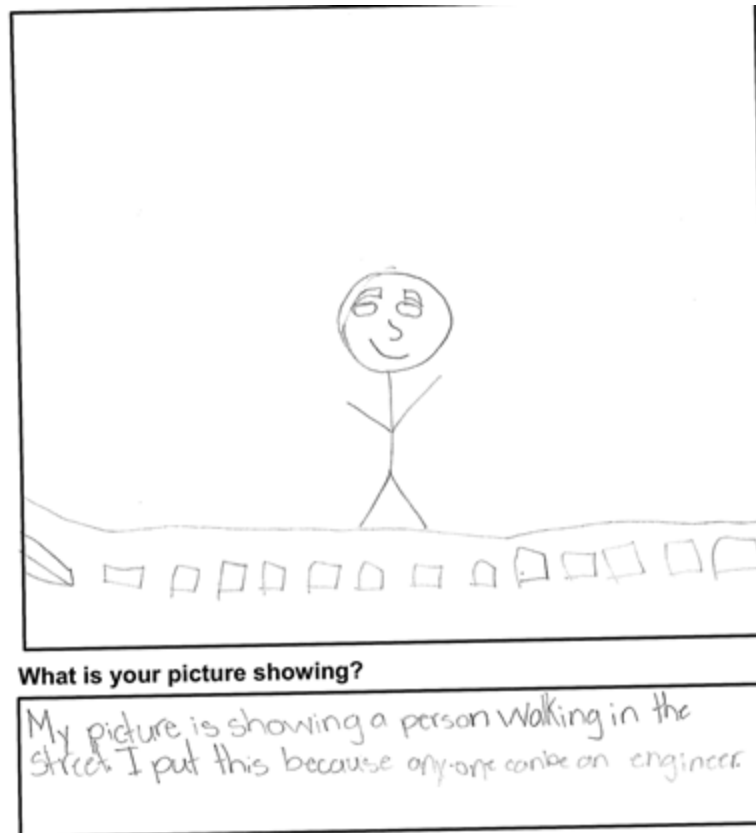


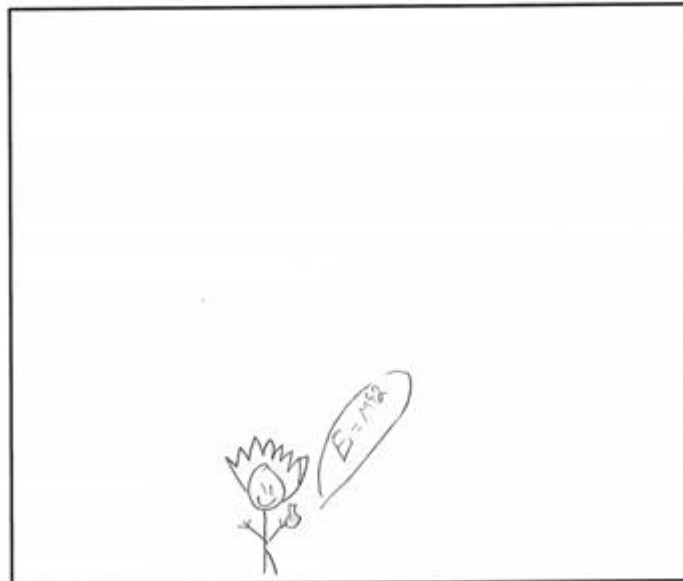
Figure 1. Transcription: My picture is showing a person walking in the street. I put this because anyone can be an engineer

In each camp, the mission of SEEK was displayed on the whiteboard or posters on the wall. As noted earlier in the paper, the SEEK mission is "To increase elementary school students' aptitude in math and science and their interest in pursuing STEM (science, technology, engineering, math) career fields, by having them engage in interactive, team-based engineering projects." Along with the children's drawings, this mission statement does not mention participants' race. Other images and messages in the classroom did not mention or show race, although this varied from site to site. Desai (2010) states, "the avoidance of racial terms not just in the discourse but in images reflects color blindness approaches." These drawings reveal how SEEK's visual culture approach can sometimes be color blind.

The second theme we noticed in the attributes is whiteness being the first image when they think about engineering. There were drawings of historical White men such as Albert Einstein, Thomas Edison, Abraham Lincoln, Steve Jobs, and Bill Gates (Figure 2). Children described their contributions as purely technical to help people communicate more efficiently. Furthermore, in follow-up interviews, children were asked to describe engineers, and they mentioned White tall men in suits or their White art teacher. Children most likely drew these images from cultural influences outside of SEEK's learning environment. Although SEEK does not have an explicit mention of race in its mission statement, NSBE's unique programming around Black engineers and recruitment of mentors provides a counter-narrative to the predominantly White male illustrations of engineering contributions. These findings are essential in understanding SEEK's influences on the cultural representations of engineers.



Please draw an engineer in the box below.



What is your picture showing?

Albert Einstein saying "E = M<sup>2</sup>"

Figure 2. Transcription: Albert Einstein saying " $E=M^2$ "

The final theme we noticed in the attributes of engineering are images and descriptions explicitly stating that their engineer was African American or Black (Figure 3). There were historical figures such as George Washington Carver and Mae Jemison. Most images included in the analysis revealed the intersectionality of their engineers being a Black/African American woman doing varied engineering related tasks. The children did not express that this would make doing engineering harder or easier, but it is an attribute they feel is important to reveal.

In most of the camps, including the single-sex (girls) camps, posters with messages about NSBE girls and women were displayed. According to O'Connor (1997) cited by Evans and Esposito (2010, p. 13), "academically resilient Black girls are socialized to have a strong sense of racial identification." Racial identification can be promoted between the classroom using different images and messages by showing African American girls the intersectionality of their race and their gender.



Figure 3. Transcription: My picture shows a team of black engineers using the design process to build a glider. They have done a test and now they are improving

Overall, children’s’ drawings and descriptions of gender and race provide insights into what the children consider engineering is and who an engineer can be. In future work, we plan to analyze how summer STEM programs, such as SEEK, influence the images and messages around attributes that engineers hold and narratives around what those current messages are by closely examining pre- and post-drawing differences.

### Limitations

Several limitations should be considered when interpreting these findings. First, the writing utensils available to children varied across sites. We originally intended for children to be able to access crayons and/or colored pencils as they created their drawings, but in actual implementation of the task, children only had access to pencils. Because of this, we found it challenging at times to determine whether children considered race/ethnicity in their drawings of engineers. In some cases, we made determinations based on accompanying text or hair styles, for example. Second, as in any project with multiple coders, there is the potential for different perceptions to enter into the coding process. We sought to minimize this limitation with extensive work to: develop the common code book; have coders work together in multiple rounds of consensus building; and engage in peer auditing with the entire research team. We also asked children to describe their drawings in words, which helped our interpretations. Finally, we decided to sample four sites for this paper. Our future work extends beyond these four, but readers should be careful in considering the transferability of the findings from these sites, which are located in metropolitan areas, to all of the SEEK sites. We anticipate that the coding

approach can be transferred to the other SEEK sites as well as other STEM programs, but that each site and the broader community context impact the ways that children illustrate their perceptions of engineering.

### **Future work and Conclusion**

In conclusion, this work-in-progress paper presents new codes that we developed using CRT concepts to examine the ways race surfaces and is conveyed in the child participants' engineering drawings. We identified new CRT codes that we suggest should be added to the existing coding schemes used to examine children's concepts and perceptions of engineers and engineering. This codebook will be used in our research as we examine the images present in learning environments and we will share it with the broader research community.

Future research aims to analyze and outline the connections between the participants perception of engineers, classroom posters, and the possible shifts in perceptions' after SEEK participation. As we continue the analysis of the Draw-an-Engineer Task responses, we will investigate the extent to which children include any of the classroom posters and other posters in their drawings. Additionally, we will investigate differences between pre- and post- SEEK responses, and investigate possible differences in response when the task was framed as “draw an engineer” vs. “draw yourself as an engineer.”

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