

## **”Maybe If I Put My Mind To It”: 5th Graders’ Receptivity to Pursuing Engineering Careers (Fundamental)**

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## Abstract

As educators strive to broaden representation in engineering, it is important to take into account how youth perceive themselves in relation to engineering careers. Youth as young as ten years of age are assessing the appeal and achievability of engineering as a career. This study explores preadolescents’ perceptions of the desirability of engineering careers and the self-assessed characteristics which impact students’ interest in engineering. In particular, this work unpacks what attracts elementary students to engineering careers and what these students believe it takes to be an engineer. Drawing from a set of 56 student interviews, this work addresses the research question *In what ways are elementary school students thinking about careers in engineering?* Existing research indicates that students’ interest in engineering careers declines as students enter middle school; this study contributes to understanding influences on students’ interests when they are on the cusp of deciding whether to pursue engineering study and careers.

As part of a study of a university-led engineering education outreach program in elementary classrooms, 5<sup>th</sup> grade students participated in 15- to 30-minute semi-structured interviews near the end of the academic year. Participants represented four classrooms in two suburban schools in the northeastern United States that had each engaged in 16-18 weeks of hands-on engineering activities led by undergraduate engineering students. Interviews focused on the students’ experiences with engineering and the engineering intervention, students’ role models, and students’ career aspirations. We utilized open coding to analyze the interviews and identified the keywords and themes that students used to describe why an engineering career would be appealing or unappealing and possible or impossible for them. Two themes characterized the interview data; these students’ receptivity to pursuing engineering careers appeared to be mediated by conceptions of engineering careers as involving *skill* (in idea generation or in creation of technology) or *desire* (the will to do engineering).

This paper utilizes interview data to attend to students’ perspectives and expand our understanding of barriers and gateways to student interest in engineering study and careers. It identifies a group of students, not previously identified in the literature, who see engineering as a possible career, but not as a compelling aspiration. It also discusses the implications of the findings for teaching engineering with an eye on the messages conveyed about the nature of engineering practices, the characteristics of engineers, and how students’ interests intersect with engineering careers.

## Introduction

Engineering education has become a part of science instruction as early as elementary school in the United States. Engineering educators and the Next Generation Science Standards hold goals of engaging children in engineering practices, informing children about the nature of engineering work, and ensuring that youth have the option to select future engineering study and careers [1]. Research studies indicate that children are increasingly well-informed about the nature of engineering work as a result of a growing number of K-12 engineering curricula [2]–[4] and that

elementary students in the United States are increasingly participating in engineering education [5], yet little is known about what young children perceive as moderating a pathway to an engineering career. This work aims to address that gap by listening to children describe what makes an engineering career possible, impossible, attractive, or unattractive.

This work draws from a set of 56 interviews with fifth-grade students participating in an engineering education outreach program. We address the question *In what ways are elementary school students thinking about careers in engineering?* This study contributes to the understanding of the ways in which preadolescent youth think about themselves in relation to engineering careers and which factors they consider when selecting or rejecting engineering careers. In particular, this study builds understanding of the personal characteristics fifth-grade students believe are necessary to pursue an engineering career. This work has implications for teaching engineering with an eye on the messages conveyed about the nature of engineering practices, the characteristics of engineers, and how students' interests intersect with engineering careers.

Youths' attraction to engineering study and careers begins as early as elementary school [6], [7] and engineering educators strive to support and build this interest through authentic, appealing learning experiences. Elementary school-aged youths' rejection of engineering study and careers is less studied, but research in engineering and science education indicates that children as young as age ten evaluate the possibility of participating in various careers [8]–[11]; for some upper elementary and middle-school-aged children, engineering careers seem impossible or unimaginable. Together, these studies suggest that many fifth-grade students are forming durable opinions about pursuing an engineering career.

Studies of elementary students predominantly have focused on youths' awareness of the job tasks of professional engineers [2], [12]. It is reasonable to believe that knowing what kinds of work engineers do could initiate interest in engineering careers. However, knowledge of the nature of engineering job tasks is not the only element moderating youths' imagined or desired future careers. Research suggests that when preadolescents select possible future careers, they consider the nature of a career, the opinions of their parents, role models for a career, and also their own interests and capabilities [9], [13]–[15]. Understanding preadolescents' perceptions of the characteristics needed to become a professional engineer can help us understand what these students might find appealing or unappealing about pursuing a career in engineering. This work focuses on elementary students and their statements about alignment of their interests and capabilities with the characteristics of professional engineers and engineering, or what elementary students say it takes to be an engineer. This work contributes to understanding what makes engineering careers attractive or unattractive to elementary school-aged youth by adding students' voices – as heard through interviews – to the research conversation.

## **Methods**

This work is part of a larger study of an intervention designed to engage elementary students in hands-on engineering design challenges. In the intervention, pairs of undergraduate engineering students collaborated with classroom teachers to design and facilitate 16 to 18 weekly, hour-long engineering projects throughout the school year. As part of the larger study, the research team

interviewed all consenting fifth-grade students (n=56) at the end of the intervention. Participants represented four classrooms in two suburban schools in the northeastern United States. 27 students in this sample attended a Title 1 school in which 38% of students are economically disadvantaged and 29 students in this sample attended a non-Title 1 school in which 14% of students are economically disadvantaged. Participants’ parents identified participants’ gender and race or ethnicity on study intake forms. In this sample, 26 participants (46%) were female students and 30 (54%) were male students. Table 1, below, shows student race or ethnicity as identified by parents. The total number of responses (n=60) exceeds 56 because some respondents selected more than one category.

Table 1. Participants’ race or ethnicity

Race or Ethnicity	American Indian or Alaskan Native	Asian	Black or African American	Hispanic or Latinx	Native Hawaiian or Pacific Islander	White	Multiracial	Not listed	Prefer not to state
Number of Students	1	5	9	5	0	27	4	6	3
Percent of Students	1.8%	8.9%	16.1%	8.9%	0.0%	48.2%	7.1%	10.7%	5.4%

At the end of the intervention and the end of the school year, we conducted and videorecorded or audiorecorded semi-structured 15- to 30-minute interviews in which we asked students about their experiences in the intervention, their role models, and their career aspirations. The complete interview protocol consisted of groups of items which probed the constructs of *making personal connections with role models*, *attributes of role models*, *mechanisms of selecting role models*, *career aspirations*, *engineering knowledge*, and *engineering identity*. We refined the questions over several iterations based on analysis of responses. For this paper, we are focusing on students’ responses to the questions:

- Have you thought about what you want to do or be when you grow up? What kind of job would you like to have and why?
- Do you think you could be an engineer? Why or why not?

We utilized open coding to analyze the interviews [16]. For the questions “Have you thought about what you want to do or be?” and “What kind of job would you like to have and why?” we noted which students identified *engineer* as a primary choice, which students identified *engineer* as a secondary choice, and which students identified other career options. By *primary choice*, we mean that a student indicated that becoming an engineer was their first-choice career or one of their top choices. By *secondary choice*, we mean that a student indicated that becoming an engineer was a backup plan if their first plan didn’t come to fruition. Table 2, below, shows examples of our classification of student statements. For this table, we selected examples to represent a range of students’ responses.

Table 2. Sample quotes illustrating student career choices

Engineer as Primary Choice	Engineer as Secondary Choice	Other Career Choice
<p>I narrowed it down to two options: doctor or engineer, software engineer.</p> <p>I kind of wanted to be something like an engineer, almost like an inventor or something like that. Or a teacher.</p> <p>So I probably want to be an engineer.</p> <p>A professional soccer player and computer engineer.</p>	<p>I want to be a hockey player but if that doesn't work out, I want to be an engineer that builds buildings like the school, for example.</p> <p>First choice would be baseball player, but second would be a biological engineer.</p>	<p>I have always wanted to be a veterinarian.</p> <p>My two gold jobs are MLB (major league baseball) player or an anesthesiologist.</p> <p>A football player, like a sports player. Or a chef or something like that.</p> <p>I would like to be a dancer.</p>

Openly declaring interest in working as an engineer is one indicator of engineering career interest. We also wanted to know to what extent students could imagine engineering as a possible career, even if it was not their ideal career. To this end, we asked students, “Do you think you could be an engineer? Why or why not?” Utilizing thematic analysis [17], we grouped student responses in five clusters: *definite yes*, *qualified yes* (or “yes, but...”), *maybe*, *unsure* (or “I don’t know”), and *definite no*. For example, the student who said, “Yes. I’m determined [to be an engineer]” was coded as a *definite yes*, while the student who said “Probably, but I don’t know that I want to be [an engineer]” was coded as a *qualified yes*. We consider the *definite yes* responses to indicate that the student believes that an engineering career is possible for them; we consider the *definite no* responses to indicate that the student believes that an engineering career is not a possible future for them, and we group the *qualified yes*, *maybe*, and *unsure* responses as indicators that the student believes that an engineering career is not likely, but may still be an option for them. Table 3, below, shows examples representing a range of student responses and our categorization of those responses.

Table 3. Examples of students’ statements about the possibility of becoming an engineer

Engineering career is possible	Engineering career is not likely, yet is still an option			Engineering career is impossible
	Qualified yes	Maybe	Unsure	Definite no
<p>Mhmm. Because I can build stuff.</p> <p>Probably. Because I have loads of ideas.</p> <p>Yes. I built something, it was like an art thing, and I built it.</p> <p>Yes. I’m determined. I want to.</p>	<p>I’d say yes, but like, I like engineering, don’t get me wrong, I like it, but I don’t really think I’m gonna wanna do it when I’m older.</p> <p>Probably but I don’t know that I want to be.</p> <p>Yes, but also no. Because it's not one of my real interests. But yes because I've been told that I can put things together and fix things easily.</p>	<p>Maybe, because I do use a creative side of my brain.</p> <p>At this age, probably not. But maybe in ten years, yeah.</p>	<p>I don’t know. I mean, if I got better at engineering, probably I’d want to be an engineer.</p> <p>I don’t know. I just think I’m not that good with remembering all of the coding of which part is which.</p>	<p>No, because I have horrible ideas.</p> <p>Not really. It’s just not in my interest.</p> <p>No. I don’t really like designing stuff and stuff like that but I like drawing and I can sketch things out. But just not - I don’t like modeling.</p>

Considering student responses to “Do you think you could be an engineer? Why or why not?” we identified the keywords [17] that students used to describe why an engineering career would be possible or impossible for them. To generate these keywords, we asked ourselves how student responses implicitly completed the statements “Yes, because engineering involves...” and “No, because engineering involves...” and listed the words explicitly stated in or implicitly suggested in students’ responses which completed these statements. For example, the student responses “Probably. Because I have loads of ideas” and “No, because I have horrible ideas” suggest that for these two students, engineering involves *ideas* (explicitly stated by the student) or *idea generation* (implicit). Finally, we used thematic analysis to search for patterns in student responses [17]; after identifying the keywords that students used to describe why an engineering career would be possible or impossible for them, we grouped these keywords into themes. We reviewed the keywords and the themes for good fit and coverage.

We believe that students’ explanations for why they could or could not be an engineer provide clues to what students believe it takes to be or become an engineer; that is, the elements that students named as pathways or barriers to becoming an engineer tell us about what these students believe is necessary to be or become an engineer. Table 4, below, shows examples of keywords and themes we identified from student responses. Table 5, further below, shows all of the keywords and themes we identified from student responses, grouped by appealing elements of and pathways to engineering careers and unappealing elements of and barriers to engineering careers.

Table 4. Examples of keywords and themes in student responses to “Do you think you could be an engineer?”

	<b>Student Statements</b> <b>Affirmative responses to “Do you think you could be an engineer?”</b> <i>(Keywords identified after student response)</i>	<b>Student Statements</b> <b>Negative responses to “Do you think you could be an engineer?”</b> <i>(Keywords identified after student response)</i>
<b>Ideation</b> Engineering involves generating ideas, creativity, sketching, or designing	I’m <b>very creative</b> . <i>(creativity)</i>  I have <b>a lot of ideas</b> going through my head at all times. <i>(generating ideas)</i>  I like <b>drawing</b> and I can <b>sketch</b> things out. <i>(sketching)</i>  I tend to like <b>designing</b> . <i>(designing)</i>	I have <b>horrible ideas</b> . <i>(generating ideas)</i>  I think if I had like a set idea given to me, I could solve the problems with it, but <b>I don’t know if I could come up with something</b> . <i>(generating ideas)</i>  [I don’t have] the strength to... <b>keep thinking of more ideas</b> to keep starting and leaving behind and starting. <i>(generating ideas)</i>
<b>Realization</b> Engineering involves building, making, or fixing	I can <b>build</b> stuff. <i>(building)</i>  I like <b>making</b> something new that hasn’t been invented yet. <i>(making)</i>  I can <b>put things together</b> and <b>fix things</b> easily. <i>(building/assembling, fixing)</i>	I’m not that person who wants to <b>put together things</b> . <i>(building/assembling)</i>  I don’t really like <b>building</b> that much. <i>(building)</i>
<b>Desire</b> Engineering involves interest or will	Anyone can be an engineer, it doesn’t care what you look like, it doesn’t care what you’ve done in your life, <b>it just matters, do you want to put your mind to this now?</b> <i>(want/desire, effort/put my mind to it)</i>	<b>I’m not that person who wants to put together things</b> . <i>(want/desire)</i>  <b>Because it’s not one of my real interests</b> . <i>(interest)</i>

<p><b>If I wanted to</b> build stuff and make stuff that would help people, <b>then I would.</b> (<i>want/desire</i>)</p> <p><b>Yeah, if I put my mind to it.</b> (<i>effort/put my mind to it</i>)</p> <p>I guess <b>if I put my mind to it and if I wanted to.</b> (<i>effort/put my mind to it, want/desire.</i>)</p> <p><b>If I want to do it, I will do it.</b> (<i>want/desire</i>)</p>	<p>It's just not <b>my interest.</b> (<i>interest</i>)</p> <p><b>I could if I really wanted to, but I not really in this point of time I would want to.</b> But maybe in another time, maybe if I really put my mind to it I would want to. (<i>want/desire</i>)</p>
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Table 5. Keywords and themes in student responses suggesting appealing elements of and pathways to engineering careers and unappealing elements of and barriers to engineering careers

<b>Appealing Elements of and Pathways to Engineering Careers</b>	<b>Unappealing Elements of and Barriers to Engineering Careers</b>
<b>Themes listed in bold text</b> Keywords listed in plain text	<b>Themes listed in bold text</b> Keywords listed in plain text
<b>Skill: Ideation</b>	<b>Skill: Ideation</b>
Creativity, Designing, Figuring out, Generating ideas, Inventing, Sketching	Designing, Generating ideas
<b>Skill: Realization</b>	<b>Skill: Realization</b>
Building, Fixing things, Making, Making for people, Putting things together	Building, Coding, Putting things together
<b>Desire</b>	<b>Desire</b>
Determination, Desire/Want, Effort/Put my mind to it, Enjoyment, Interest*, Persistence	Desire/Want, Interest**, Persistence
* Indicates interest in helping people and changing the world	** Indicates general disinterest in engineering rather than a specific element of engineering
<b>Skill: General</b>	<b>Skill: General</b>
Art, General intelligence, knowledge, or skill, Solving problems	General intelligence, knowledge, or skill, Mathematics, Modeling
<b>Other</b>	<b>Other</b>
(No other themes emerged in the <i>appealing</i> category)	Being outside, Being official, Lots of work

## Results

We present three findings in answer to the question *In what ways are elementary school students thinking about careers in engineering?*

1. The fifth-grade youth in this sample are thinking about their future careers, including engineering.
2. A majority of students consider engineering to be a possible future career, though not currently their most desired future. While a small number of students have definite planned interest in pursuing an engineering career, many more believe they could be engineers. Additionally, a small number of students are turning away from engineering.

- Students' primary reasons for pursuing or turning away from engineering vary. Students named a variety of characteristics necessary to be or become engineers. Many students named individually variable constellations of characteristics they considered to be integral to engineering.

***Fifth-grade youth are thinking about future careers***

The ten- and eleven-year-old youth in this study have already started thinking about future careers. The vast majority of students in this sample (46/56) clearly stated a career interest. Six students were unsure about naming a future career and two students were not asked about future career plans. From the 54 students who were asked about future career plans, we identified seven students who listed *engineer* as a primary career choice and three who listed *engineer* as a secondary career choice. Figure 1, below, shows the distribution of primary and secondary career choices.

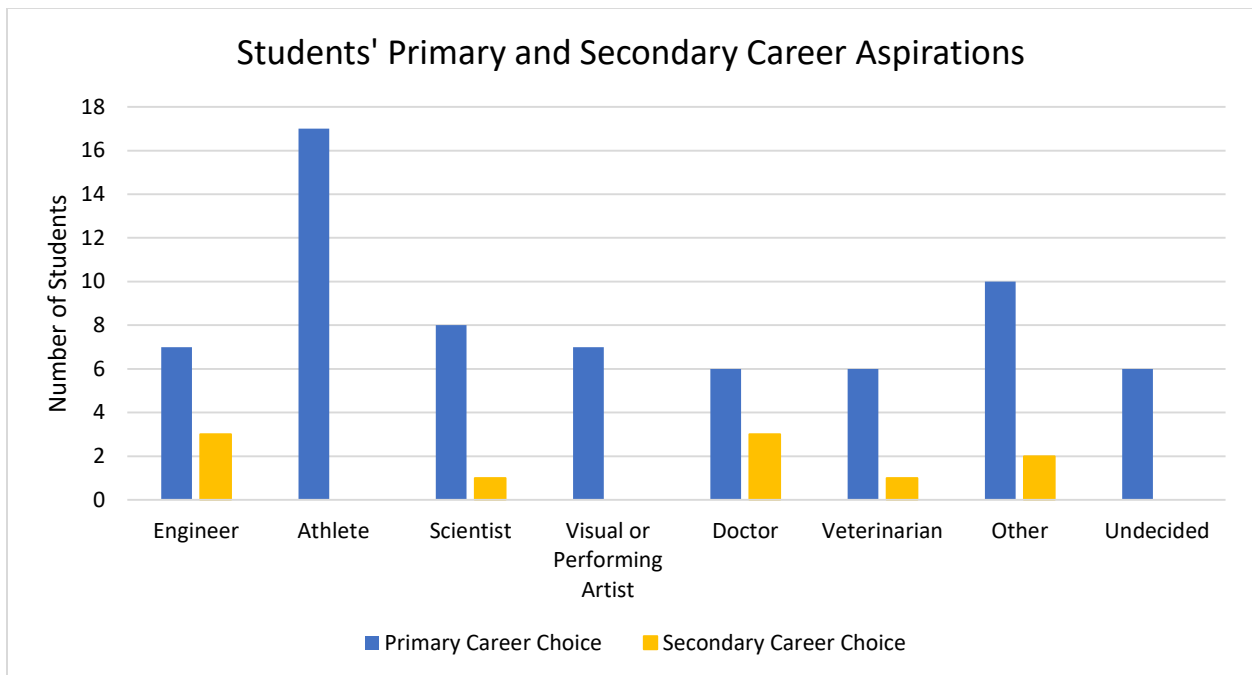


Figure 1. Careers desired by students.

The total number of career choices indicated by students exceeds 54, as some students selected more than one ideal career. For example, we coded the career goals of the student who said she “wanted to be something like an engineer, almost like an inventor...or a teacher” as both “engineer” and “other”. Seventeen students listed wanting to become professional athletes. The second tier of primary career interests (with six to ten respondents per category) included engineers, scientists, visual or performing artists, doctors, and veterinarians. Student responses to the question “Have you thought about what you want to do or be when you grow up?” suggest that at this point in their lives, seven students in this sample intend to become engineers and three students intend to become engineers if their first choice career doesn’t come to fruition. Students in our sample were more likely to name *athlete* or *engineer* and less likely to name *teacher* or *police officer* than students in similar studies [10], [11], [13]. Student responses demonstrate that



most fifth-graders (82%) in this sample are imagining specific future careers and some fifth-grade students (18%) are considering engineering careers.

***Students’ engineering career intentions and possibilities***

Definitively stating interest in working as an engineer is one indicator of engineering career interest. We also wanted to know to what extent students could imagine engineering as a possible future, even if it were not their most desired future. Student responses to the question “Do you think you could be an engineer? Why or why not?” indicate that just under half of the respondents believe they could become engineers, one-third believe they could but express some reservations, and just under one-fifth believe they could not become engineers. Table 6, below, shows the distribution of student responses by degree of possibility of becoming an engineer and by gender. Eleven students are excluded from this data table because they were not asked or did not respond to this question. Two of these eleven students indicated they intended to become engineers; while it is likely that they see an engineering career as possible for them, we did not hear them explicitly assert this possibility so we are conservatively excluding them from the table below.

Table 6. Students’ perceptions of the possibility of becoming an engineer

	<b>Engineering career is possible</b>	<b>Engineering career is not likely, yet is still an option</b>	<b>Engineering career is impossible</b>
Female (n=23)	11 (48%)	9 (39%)	3 (13%)
Male (n=22)	11 (50%)	6 (27%)	5 (23%)
Total (n=45)	22 (49%)	15 (33%)	8 (18%)

We interpret this distribution of responses to mean that many of these students, while they may not be aiming for an engineering career currently, are open to the possibility of pursuing engineering. Conversely, eight of the students in this sample appear to have turned away from engineering as a possible career.

***Students’ primary reasons for pursuing or turning away from engineering vary***

Of interest are the reasons students gave for engineering being a possible or impossible or appealing or unappealing future for them, and what these reasons suggest about the messages students are internalizing about what engineering involves. The students in this sample named a variety of factors necessary to become an engineer and few students named identical combinations of factors. Student responses to “Could you be an engineer?” ranged from “Mhmm. Because I can build stuff,” to “Maybe, because I do use a creative side of my brain,” to “No. I don’t really like designing stuff.” Students provided highly individualized responses, suggesting that each student may conceptualize engineering differently. While one student may think of engineering as involving building, another may think that engineering involves creativity, and a third may envision engineering as designing. What one student finds attractive, another student may find discouraging. Table 5, above, shows the range of keywords in student responses.

## ***Engineering involves will and skill***

Although student responses were quite individualized, we were able to group students' responses into themes of *skill* and *desire*. Students' responses suggested they believed they either did or did not have the *skills* to become engineers and they either did or did not have a *desire* to become engineers. We sub-divided the category of *skill* into two categories: *ideation*, or *skill in idea generation*, and *realization*, or *skill in the physical creation or repair of technology*. *Ideation* encompasses the student statements which suggested that engineers need skills in generating ideas, creativity, sketching, or designing. *Realization* includes student responses which suggested that engineers need skills in building, making, or fixing technology. While many students said they could (or couldn't) become engineers because they did (or didn't) have specific skills in ideation or realization, other students said that becoming an engineer relied on wanting to be, trying to be, or enjoying being an engineer. As three of these students said, they could become an engineer if they "put [their] mind to it." These students expressed a belief that becoming an engineer depends on having the will, interest, or *desire* to become an engineer. Skill and desire may intersect; for example, one student said she couldn't become an engineer because she is "not that person who wants to put together things"; "not that person who wants to" suggests *desire* and "put together things" suggests *skill*. Table 4, above, shows examples of student statements that we categorized as *ideation*, *realization*, or *desire*.

Table 7, below, summarizes the frequency of keywords within themes derived from students' descriptions of what they found appealing or unappealing about engineering or what they envisioned as invitations or barriers to engineering. We did not observe any differences in responses that correlated with student gender. The set of appealing elements of engineering is broader than the set of unappealing elements of engineering. This finding of what students perceive as the key components of engineering, as well as which components provide or restrict access to engineering for them as individuals, has implications for how we as educators may wish to present the practices of engineering.

Table 7. Frequency of keywords and themes

<b>Appealing Elements of Engineering</b>	<b>Unappealing Elements of Engineering</b>
Skill: Ideation (12)	Skill: Ideation (4)
Skill: Realization (14)	Skill: Realization (2)
Skill: General (5)	Skill: General (3)
Desire (15)	Desire (13)
Other (0)	Other (3)

## **Limitations**

The students in the sample represent a suburban population which is not economically representative of the United States as a whole. Interview data suggest that it is likely that many of these students have parents or other family members who are engineers or scientists, which could influence these students' understandings of the nature of engineering careers and their own possibilities of becoming engineers. Familiarity with engineers and scientists may have contributed to the unusually large number of students who said they aspired to engineering, science, or medical careers.

Ten students in this sample considered an engineering career a first or second choice. We did not specifically ask all of these ten students why they were considering an engineering career; as such, only four provided reasons. These four students cited one of three reasons for pursuing engineering: wanting to help people, being interested in “mechanical stuff”, and peer recommendations. Our data about why students are drawn to engineering are limited and more information is needed about why elementary students aspire toward engineering careers.

## Discussion

This paper addresses the question *In what ways are elementary school students thinking about careers in engineering?* by exploring the ways in which students describe their career aspirations and the possibility of becoming an engineer. While many factors influence children’s career aspirations [9], [13], [19], this work focuses on aspects of engineering careers that these students identified in interviews as attractive or unattractive to them. Students’ responses to the question “Could you be an engineer?” suggest characteristics of engineers and engineering careers that are appealing, unappealing, attainable, or unattainable. Students identify a variety of factors which draw them toward or nudge them away from engineering careers; these factors generally fall into three categories: ideation skills, realization skills, or the desire to become an engineer. Aspects of engineering that are appealing or attainable to some students are unappealing or unattainable to other students.

In this sample of 56 fifth graders, there are students who want to become engineers, students who do not want to become engineers, students who can imagine themselves as engineers, and students who cannot imagine themselves as engineers. Of particular interest are the 37 students who, while they aren’t currently selecting an engineering future, have not ruled out this possibility. These students indicated they could be an engineer, suggesting that engineering is still a possible future for them. As providers of an engineering outreach intervention that is intended to support interest in engineering study and careers, we want to know what educators can do to keep engineering as a viable possible future for these students. Research indicates that interest in STEM (science, technology, engineering, and mathematics) careers declines as students enter middle school [18], [20]; these 37 fifth-graders are receptive to pursuing engineering and at the same time, are likely on the cusp of deciding whether to pursue engineering study and careers.

We grouped students’ explanations for why they *could*, but probably *would not* become engineers into skill-based reasons and desire-based reasons; students said they didn’t have necessary skills in ideation or realization (e.g., “I don’t know. I mean, if I got better at engineering probably I’d want to be an engineer” and “I think if I had a set idea given to me, I could solve the problems with it, but I don’t know if I could come up with something”) and that they did not want to be engineers (e.g., “Because it’s not one of my real interests”). At times, engineering was competing with other interests; as one student said, “I want to be a biologist...I wouldn’t really hate to be an engineer, but I’d actually kind of rather be a biologist.” We do not advocate dissuading children from their interests; rather, engineering educators could work to convey the message that engineers have and work with multiple and varied interests. For example, educators could convey that someone interested in biology could also be an engineer

who designs for the benefit of animals or for the benefit of people who work with or study animals.

## **Conclusion and implications**

We start from the standpoint of wanting to ensure that youth can imagine a range of future selves and have experiences that facilitate creating the future selves they desire. We also wish to ensure diverse participation in engineering study and careers. To attract a wide range of students to engineering, it is imperative that a wide range of students can imagine themselves as engineers. This study identified a group of students, not previously identified in the literature, who see engineering as possible, but not as a priority. What can engineering educators do to draw these students to engineering? This may be answered, in part, by looking at the heterogeneity of the responses. The interviews in this study suggested that the students in this sample who think they could be engineers or might want to become engineers are not actively pursuing future engineering study or careers because they are not particularly interested in or do not enjoy engineering. Several students in this study said they could become an engineer if they wanted to, but that they did not want to become an engineer because they did not enjoy certain elements of engineering.

A possible pattern within our data suggests that students' primary reasons for selecting or ruling out engineering careers may be beliefs about intersections of their skills and interests with the skills and interests of engineers. Students who are receptive to engineering careers can identify overlap with their skills and interests with those of professional engineers (e.g. "I can put things together and fix things easily"), while students who are turning away from engineering identify conflict between their skills and interests and those of professional engineers (e.g. "I have horrible ideas"). It is of course, possible, that these results are an artifact of the interview format and that students' expressions of congruence or incongruence between their skills and interests and those of engineers are simply the result of students justifying their earlier statements that they could or could not become engineers. However, it is worth considering how engineering educators can help students see alignment between their individual skills and interests and engineering.

Additionally, we wish to emphasize that the vast majority of the students we interviewed quickly and decisively identified careers of interest to them. While some students identified engineering as desirable and/or possible, some students identified engineering as undesirable and/or impossible. This pattern suggests that youth as young as ten are making judgments about the desirability and feasibility of future careers. As such, we recommend that educators consider the engineering experiences and messages about engineering that we make available to elementary students. Several students in this study cited interest or skill in building or putting things together as reasons they could not become an engineer, suggesting that some students see engineering as for builders or makers, but not for them. Other students said they could not become engineers because they were not creative or didn't know how to ideate. Several students said they could become engineers but would not because they planned to pursue another career of interest. It is possible that all of these students might find engineering more appealing if they saw their own skills and interests reflected in engineering. For example, we note that six girls and one boy planned to become veterinarians; perhaps these students would be drawn toward engineering if

they were aware of ways to integrate their interest in veterinary medicine with engineering. Veterinary medicine was one of the top aspirations of girls in this study; future work on girls' interests and aspirations could illuminate interests which dovetail with engineering. This information could in turn help educators teach about a variety of engineering careers which might be especially appealing to girls or other members of groups underrepresented in engineering. While we are not advocating that every student should want to be an engineer, we do believe that every student should feel that it is possible to become an engineer. This work suggests that educators expand the messages that engineering education conveys to students about the nature of engineering and the nature of learning to become an engineer.

In addition, methodologically, this work has implications for how we evaluate engineering interventions in elementary school. To date, many surveys have focused on expressing interest in engineering as a primary career. However, at this age level, students' sense of career futures is variable and mediated by many other factors [13]–[15]. It may be more generative and reasonable to evaluate elementary students' openness to engineering rather than evaluating their future career plans, particularly if we also unpack how the experiences they are having with engineering are interacting with their own interests and sense of self.

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