Seeing Engineering Everywhere

Culturally Relevant Engineering Activities with Rural and Appalachian Youth

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***Abstract*—Broadening participation in engineering is an issue of national importance. Particularly in rural areas, otherwise capable students do not have the opportunity to envision themselves pursuing a career in engineering. To begin closing this gap, we present findings from a qualitative research study investigating the perceptions of engineering work held by rural and Appalachian youth. Fifth grade students participated in this research study as part of a university-wide program to broaden participation in higher education. Results indicate that students in this study describe engineering work primarily as involving fixing or inventing. Present in both of the two descriptions was an emphasis on technical artifacts in engineering work. This research contributes to an understanding of possible relevant approaches to engineering interventions with this demographic.**

Keywords—broadening participation; K-12; engineering outreach

I. Introduction

A. Problem Statement and Research Question

Despite national emphasis on integration of engineering into K-12 education [1] and the adoption by many states of the Next Generation Science Standards that include engineering standards [2], common misconceptions still remain for students considering careers in engineering [3]. Particularly for less privileged students in rural areas without access to purchased engineering education curricula such as Project Lead the Way [4], these misconceptions have little chance of resolving on their own. Furthermore, research has shown that students' interest in STEM often occurs before entering middle school [5] yet rural students often have none to little exposure to engineering [6], thus limiting their opportunities to develop an interest [7]. The need for cultural relevancy in pedagogical approaches [8] in the elementary years in these regions is clear. However, to recognize what constitutes a culturally relevant approach to introducing engineering to rural youth, it is important to develop an appreciation of how these students view engineering work. This critical step towards building an understanding of how these students perceive engineering will ultimately help inform culturally relevant approaches to broadening participation for these students. To this end, we answer the research question: How do fifth graders from predominately rural schools in Virginia describe what engineers do?

To address the research question, this study utilizes portions of the "Draw an Engineer Test" (DAET) instrument [9] as a method to help determine how rural students view engineering work. Several studies have utilized this instrument in an attempt to gain an understanding of student perceptions of engineering [10]–[13]. Research has looked at differences across gender [9], [10] and focused on girls [12] and African American students [13], but there is little research focusing specifically on perceptions of rural youth who are also underrepresented in engineering degrees and careers.

B. Research Frameworks

This study will utilize the Future Possible Selves (FPS) Framework [14] and culturally relevant pedagogy [8] as theoretical lenses through which to explore rural youths' perceptions of engineering work. FPS has been previously applied to research centered around career choice in rural Appalachia [15]. Individuals imagine these possible future selves based on their current "sociocultural and historical context and from the models, images, and symbols provided by the media and by the individual's immediate social experiences" [14, p. 954]. Considering the constraints on possible future selves becomes particularly important in engineering where students often need a role model and see engineers portrayed as stereotypes in the media [16]. Furthermore, envisioning a future self is closely tied to achieving that future self [15]. This study focuses on how rural students describe engineering work in consideration of FPS in part to help establish what constitutes culturally relevant approaches to teaching when engaging with this demographic. Culturally relevant pedagogy is engaging and motivating because it considers the unique experiences and cultural history of the learner [17]. These two frameworks come together in our study as we consider how culturally relevant approaches are not only better for learning but also for broadening participation in engineering by linking the local influences on career choices.

II. Research Design

A. Context

This study took place at a public university in the southeastern United States. Through a university-sponsored program, 5th grade students, many of whom are from the Appalachian region, traveled to the University for a day of engagement in higher education. The goal of the program was for the visiting students to have a positive and affirming experience in higher education to broaden participation in postsecondary education by these rural areas. We took this opportunity to introduce students to engineering through an

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intervention in which students gain entry into the engineering world through hands-on activities, involving tools and everyday objects. Research in FPS and K-12 students has shown that formal interventions can positively influence students' intentions to pursue engineering [15]. With the help of undergraduate student engineering facilitators, elementary school students took apart everyday objects, explored their function and intention in design, and put them back together. Rather than introduce students to engineering through activities that require specialized technology, the cultural relevancy of this activity was enhanced by using objects and tools that these students encountered in their everyday lives in an activity authentic for rural youth. Fixing objects and determining what is broken also incorporates problem solving explicit in the engineering design process and helps students see engineering in everyday life. In addition to the fixing activity, students were shown a short video developed by another university through a research project funded by the National Science Foundation. The video highlights different types of engineering careers, and students were prompted to share aloud what they learned about engineering.

B. *Data Collection*

Participants included 60 students in the fifth grade from schools in rural regions. Four participant responses were omitted because the response was illegible or incomplete. Demographic data such as sex and race was not collected as a comparison across demographics was not the intent of this research.

Before the activity, each of these students was given a printed copy of the "Draw an Engineer Test" and a set of colored pencils. The instrument contains five questions [9]:

- "In your own words, what is engineering?"
- "What does an engineer do?"
- "Draw a picture of an engineer at work."
- "Do you know any engineers?"
- "If yes, then who are they?"

The DAET fit the context as a natural reflection activity for our intervention. Students in this study were asked "What does an engineer do?" and "Draw a picture of an engineer at work." The reason for limiting the amount of questions asked had to do with the limited time allotted for the activity and maintaining the purpose of the day (i.e. we wanted students to have fun, not fill out paperwork). In lieu of the remaining questions, after the activity, students were asked "Write something you learned about engineering work that you didn't know before." This is not part of the DAET but was included to develop recommendations for implementing similar interventions in the future. Unfortunately, due to time constraints, many of the drawings were underdeveloped or missing. Additionally, most participants drew the materials for the activity that were in front of them on the table. For these reasons, the drawings were ultimately excluded from formal analysis but were checked with written responses as described in the Research Quality section.

C. *Data Analysis*

Qualitative content analysis techniques were used to analyze the student responses to the first question, "What does an engineer do?" In this method of analysis, we took specific steps to draw inferences from text [18]. Following the steps outlined by White and Marsh [19] and informed by the explanation of content analysis in Weber [18], our analysis began by defining separations in the data [19], and we determined the sample and data collection units were individual student responses to the question. The unit of analysis was phrases within those individual responses in alignment with our research question [19].

Our coding process consisted of three major steps. In step 1, we read through all text responses and marked student responses with the guiding research question in mind [19]. In step 2, cycles of open coding through conventional content analysis [20] were used to develop a mix of descriptive and in-vivo codes [21]. In step 3, we developed a set of reduced codes and operationalized definitions which we used in second cycle coding. The result of these code reductions was three major characterizations of engineering work: (1) engineering as fixing, (2) engineering as inventing, and (3) technical artifacts in engineering work. With few exceptions, our data grouped into one of these three final codes as depicted in Table 1.

TABLE I. CODES AND OPERATIONALIZED DEFINITIONS

Final Codes	***Operationalized Definitions***
Engineering as Fixing	Engineers use tools to fix and repair technology.
Engineering as Inventing	Engineers design and create new things.
Technical Artifacts	Engineering work is characterized by building infrastructure and high technology.

The third major characterization to emerge was technical artifacts in engineering work. The mention of technical artifacts bridged the other two characterizations of engineering work because it was present in explanations of engineering as fixing and as inventing. Figure 1 illustrates this overlap.

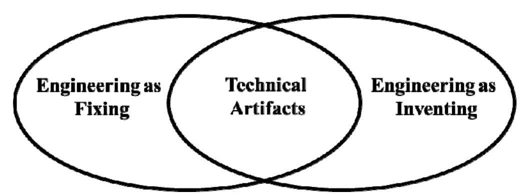

Fig. 1. Profiles of engineering work

D. *Research Quality*

We followed the guidelines for establishing trustworthiness in qualitative research outlined by Guba and Lincoln [22] and referenced by White and Marsh [19] in their procedures for content analysis. From [22], the four criteria for establishing trustworthiness are: credibility, transferability, dependability, and confirmability. The quantitative counterparts of these terms are commonly known as internal validity, generalizability (external validity), reliability, and objectivity respectively [22]. To establish credibility, triangulation among data sources and peer debriefing were used [22], [23]. Although only the first question was used in analysis, drawings were checked for consistency with the written codes. Additionally, drafts of this study were circulated among other researchers who provided feedback as peer debriefing. Triangulation among data sources can also contribute to dependability and confirmability of a qualitative inquiry [22]. A simple check for obvious errors in transcripts compared with the original hardcopy data also contributes to dependability (reliability) [23]. In this study, we have detailed the context in which the study has taken place and provided descriptions and examples of participant responses to contribute to transferability of responses [22]. In qualitative research, researchers provide enough detail that readers can determine how results might connect to their own situations [24].

III. Results

This research study sought to answer the question: How do fifth graders from predominately rural schools in Virginia describe what engineers do? Content analysis of rural fifth grade students' responses to the question, "What does an engineer do?", yielded two distinct profiles of engineering work: (1) engineering as fixing and (2) engineering as inventing. In both of these profiles was the consensus among the students that engineering work primarily involves technical artifacts, focusing on products such as robots, cars, buildings, and bridges.

A. Engineering as Fixing

Many participants chose to identify fixing as a primary aspect of engineering work in their responses. Fixing here did not mean engineering solutions that require "fixing" or updating such as repairing a problem in a broken engineering system. Instead, this theme refers to fixing as repair work that a mechanic might take on. This conflation of engineering and repair work fits a profile of engineering as fixing. For example, students responded to the prompt by writing,

> They fix different things and try to make them work. (Participant 25)

> Someone who helps fix things. (Participant 38)

Others highlighted tool use as an important aspect of engineering work. For instance, in talking about fixing and repair, one student stated,

> An engineer fixes things with the tools that they have. (Participant 36)

In addition to tool use, another aspect of the engineer as repairperson in student responses was the idea that engineers dismantle to fix. In two such explanations, students stated that engineers,

> Take stuff apart and build stuff and put stuff back together. (Participant 47)

Similarly, Participant 52 talked about how engineers are people who take apart vehicles. It is important to note that this portrayal of engineering as fixing was also frequently listed alongside descriptions of engineering as inventing. For example, a student stated,

> Someone who helps fix things. Also it can be someone who try to do new things. (Participant 38)

Participants 38 lists that engineers fix but that they also create. Many similar responses exist in the data.

B. Engineering as Inventing

Participants described inventing, designing, creating, or making something new as a primary component of engineering work. Included in this characterization were descriptions of engineering design processes such as predicting. These descriptions of engineers as designers fit a profile of engineering as inventing. One student simply stated,

> They invent stuff like light, cars, planes, and trains. (Participant 18).

There were also more nuanced descriptions of engineering that focused on creative processes. For example, students highlighted predicting and figuring as part of design in engineering work.

> An engineer is a person who creates things, codes things, and can predict things. (Participant 12)

In another example, Participant 21 explained that it is an engineer's job to determine the building materials for a project.

As was the case in descriptions of engineering as fixing, tool use appeared in descriptions of engineers as designers and inventors. One student described engineers as tool users and also idea generators. The student stated,

> An engineer builds things like robots. They have to use a lot of tools to help them build. Engineers can make ideas of things like computers, car models, and other things. (Participant 54)

C. Technical Artifacts

Across these characterizations was an emphasis on technical artifacts in engineering work (such as building infrastructure and vehicles). For instance, in one example combining fixing and high technology a student stated,

> An engineer fixes or builds things. They make things like robots, etc. (Participant 48)

Unsurprisingly, other students combined the description of engineering as inventing with technology. In answering the prompt, one student wrote that engineers create vehicles. The student stated,

> [Engineers] make mechanical designs for cars, airplanes, and even spacecraft. (Participant 50)

The focus on technical artifacts in engineering work was consistent among many participant responses portraying engineering as primarily fixing or inventing.

D. Summary

The patterns of engineering as fixing and engineering as inventing each characterize roughly half of the responses received in reference to the question, "What do engineers do?" Some also associated tool use with the interpretation of engineering work. Overlapping these two categories is the idea of the engineering profession as predominately involving technical artifacts and focused on producing technology products.

IV. Discussion

Developing an understanding of rural students' conceptions of engineering is an important step in determining culturally relevant teaching practices for engaging these students in engineering interventions. The ultimate goal of these interventions is to provide students with the opportunity to envision themselves doing engineering work. To this end, our study addressed the research question: How do fifth graders from predominately rural schools in Virginia describe what engineers do? Three major trends in the data were identified. These included: (1) the image of engineering as fixing with an emphasis on repair and tool usage, (2) the image of engineering as inventing including descriptions of engineers as creators, makers, and designers, and (3) the idea that engineering work primarily involves technical artifacts. This last theme bridges the two major depictions of engineering work and includes descriptions of artifacts such as cars, buildings, robots, and circuits. Broader implications of these themes are discussed below.

A. Engineering as Fixing

The first theme of engineering as fixing is rooted in descriptions of engineering work involving repair, working, and often tool use. Other research studies that used the DAET to measure student conceptions of engineering work found that participants held misconceptions involving fixing and tool use. For example, in their study of elementary school students in grades one through five, Capobianco et al. found categorizations of engineer as mechanic, laborer, and technician. Among other factors involving manual work, fixing was part of this conception of an engineer [10]. Tools and vehicles as the instruments and products of engineering work appeared in their study and our own. The original DAET instrument development also produced results from elementary students describing engineering as fixing (specifically fixing involving tools, buildings, and cars) [9].

According to FPS, potential imagined selves hinge on the sociocultural context [14]. Considering this context in the Appalachian region, there is a low amount of technical "white-collar" jobs [25] and many "blue-collar" jobs in the community emphasize hands-on work making fixing culturally relevant in this region. Thus, even though the description of engineering work as fixing and centered around repair represents a misconception, it should not be discounted as a continued avenue for engaging rural youth in engineering interventions because it represents a culturally relevant approach. It is also important to note that there is strong evidence that there is no one "Appalachia" or unifying Appalachian culture [26]. For this reason, it is important to consider these findings first and foremost in their local context.

B. Engineering as Inventing

The second theme of engineering as inventing comes from student descriptions of engineering work as involving making, creating, designing, or inventing. Again, the original study for the development of the DAET found participant depictions of engineering work that included aspects of designing [9]. However, the extent to which students identified these processes in their responses seemed notable in light of previous research that uses the DAET. Many students wrote about fixing and inventing in the same responses as exampled by Participants 38 and 49.

This depiction of engineering work is closer to an image of an engineer that "designs everything around us" [10, p. 321]. It is also a step towards alignment with the attributes of the "Engineer of 2020" that include "practical ingenuity" [27, p. 54] and "creativity" [27, p. 55]. Still, the description of engineering as inventing neglects communication and other social aspects of engineering. This idea is explored further through a discussion of the emphasis on the technical in student responses.

C. Technical Artifacts

Overlapping these two descriptions of engineering work is the consistent references to technical artifacts such as vehicles and electronics. In fact, with the anecdotal exception of one person who voiced that she believed engineers made things to help people, most student responses were rooted in the technical. This focus on technical artifacts was at the cost of a broader conception of engineering. The concept of "heterogeneous engineering" from Law [28, p. 111] emphasizes the linkage between the social and the technical. This more closely characterizes the reality of engineering work than the technical stereotype [16]. Moreover, emphasizing the social and humanitarian aspects of engineering opens the profession to a broader range of students imagining engineering work in their possible future selves. For this reason, the overemphasis on the technical in images of engineering work is a problematic conception.

D. Trends in Rural Students Profile of Engineering Work

Across the characterizations of engineering work in the data as discussed above, there was a focus on either products or processes. In the image of engineering as fixing, students described the processes of engineering as "working on" and "fixing." In the image of engineering as inventing, stated processes included "designing" and "making." In both cases, the product focus was usually technical engineering products and technology such as "cars" and "robots." Noticeably absent was the common image of engineers as train conductors which has been seen in previous studies [9].

V. Limitations

As a research inquiry rooted in the qualitative tradition, this study has limitations in making any generalizations. However, the purpose of this research is not to make conclusions about perceptions of rural youth everywhere, but to contribute to the conversation surrounding misconceptions of engineering work as presented in the discussion. Additionally, this work contributes to an understanding of rural students' conceptions of engineering, a necessary precursor to improving culturally relevant pedagogical approaches in future work.

Limitations of the research context are also important to consider. The data was collected through a university-wide program in which students from rural areas were invited to spend the day with faculty and students in a higher education setting. We were allotted a 45 minute time slot in which to collect data and complete our activity. For this reason, the decision to shorten the DAET test was made so more time could be spent on the activity. With an emphasis on time efficiency, sacrifices of richer data and demographic information were made. As mentioned previously, the purpose of the day (i.e. for students to have a positive experience) took appropriate precedence over data collection.

VI. Implications for Research and Practice

This study was motivated by the idea that no activity works across all situations, and an understanding of the local context is necessary to meaningfully design K-12 engineering interventions. Although fixing appears to be relevant in engaging rural students, anyone interested in using fixing with this demographic as an avenue to access engineering should be mindful of misconceptions and temper any activity with an explanation of the breadth of engineering work. After administering the DAET, we showed a short video on engineering, and we also had a discussion after the activity about engineering work. Based on the question, "Write something you learned about engineering that you did not know before.", this order of activities yielded positive results. It is important to note that we did not analyze the responses to this question, but they are still important to consider in the broader implications of this study. Many students said that they learned engineering was all around them or that engineers are involved in creative tasks from creating "shoes" to "hospital designs." Still, many students noted the same misconceptions as before or simply stated facets of the activity. For example, students referenced the toys and skateboards in front of them, tools, and taking things apart. For this reason, having a takeaway for participating students that reiterates the main ideas of the activity is our suggestion for improvement. Alignment with K-12 engineering standards may also improve the activity. However, research suggests that these standards can be applied in an "excessively expansive manner" [29]. If broad standards in engineering design are used, care should be taken to align them with classroom practice in a precise and intentional manner consistent with culturally relevant approaches.

Also from the reflection question that prompted students to tell us something they learned through our activity, at least one student had significant preconceived notions of an engineer as a designer from their grandfather who worked as an engineer. Another stated during the activity that their father works on cars at home. It may be that students without engineering role models are more likely to associate engineering with fixing (e.g. like a mechanic might do) than designing. This is consistent with the rural context and the FPS framework. If students do not have a role model of an engineer in their life, it would be harder for them to envision themselves as engineers. Still, adults who have vocations in which fixing and repair is a primary component may still serve as an engineering role model in a culturally relevant approach to engaging rural students in engineering.

The results from this study contribute to an understanding of how rural students perceive engineering work. Future research involving the DAET should carefully take into account the context in which the test is administered. In this study, drawings were not analyzed and students drew their immediate surroundings, even when the idea that there were no correct answers was emphasized. The notion that students have an unstable image of engineering is supported in the literature [30]. In our study, students appeared particularly susceptible to suggestion from their surroundings while spending time in the engineering building of the University. A potentially interesting question to explore is why students drew their immediate surroundings when asked to draw their personal conceptions of an engineer at work. These considerations will be important for future research that contributes to a better understanding of rural student perceptions of engineering. This valuable information about how students envision a future in engineering work can be used in developing culturally relevant activities to broaden participation in engineering.

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