LOOK ACADEMIC PUBLISHERS
OPEN ACCESS

INTERNATIONAL JOURNAL OF ENVIRONMENTAL & SCIENCE EDUCATION
e-ISSN: 1306-3065
2018, Vol. 13, No. 7, 559-578

A Qualitative Study of Baseline Urban and Rural Middle Level Science Teacher and Student Views on Engineers and Engineering

Emily Paige Driessen [1*], Ashley Dunn [1], Kameisha Sallah [1], Jennifer Wilhelm [1], Merryn Cole [2]

[1] *University of Kentucky, USA*
[2] *University of Nevada, Las Vegas, USA*

* CORRESPONDENCE: emily.driessen@uky.edu

ABSTRACT

This qualitative study investigated how Urban and Rural middle level science teachers and their students understand engineering. Four teachers (two from an Urban school and two from a Rural school) and their respective student populations were examined. Our data included student Views of Nature of Engineering (VNOE) survey, the Draw an Engineer Test (DAET), and teacher and student interviews. The interviews showed all teachers believed there were differences between science and engineering. However, the majority of the teachers did not differentiate between the two subjects in their classrooms. Student interviews showed Urban students, overall, had more ideas of what engineering is than Rural students, and most students (Urban and Rural) tended to distinguish between science and engineering. The VNOE revealed more Urban students than Rural claimed engineering combines all subjects, while more Rural students than Urban described engineering as a subject that involves creating, designing, and inventing. The DAET showed the majority of both Urban and Rural students drew an engineer with an inferred action categorized into the making/fixing/working with hands category. Overall, students and teachers, from both populations, held incomplete understandings of engineers and engineering.

Keywords: qualitative research, middle school, STEM education, teacher knowledge

INTRODUCTION

There has recently been much focus on the importance of K-12 engineering education as it has been argued to be necessary in order to (1) prepare students for the prominence of science, engineering, and technology in their everyday life; (2) provide solutions for pressing and future problems; and (3) stop the further decline of the position of the United States in the global economy (NRC, 2012). One such effort to increase K-12 engineering education was put forth by the 26 Lead States: The Next Generation Science Standards (NGSS; NGSS Lead States, 2013) with the inclusion of engineering disciplinary core ideas, practices, and standards. Since the previous science standards in the United States (U.S.), the National Science Education Standards, had no standards or practices that specifically included engineering (NRC, 1996), we wondered what science teachers and their students understood about engineering and engineers at baseline. As the middle level (students approximately aged 11-14 years) has been identified as a crucial time for either inspiring or discouraging student interest and participation in mathematics and science as well as their interest in a career

Article History: Received 14 June 2018 ◆ Accepted 16 July 2018

© 2018 The Author(s). Open Access terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/) apply. The license permits unrestricted use, distribution, and reproduction in any medium, on the condition that users give exact credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if they made any changes.

in engineering (Brophy, Klein, Portsmore, & Rogers, 2008), we focused specifically on middle-school science teacher and student understanding.

We explored four research questions in this paper: (1) How do middle level science students view engineers and engineering?; (2) How do middle level science teachers view engineers and engineering?; (3) Do middle level Urban students understand engineering/engineers differently than middle level Rural students?; and (4) Do middle level science teachers hold different understandings of engineering/engineers than their students?

Research concerning engineering education is not new; it has been ongoing since the 1970's. An early study focused on improving collegiate engineers' problem-solving skills by offering a non-credit course where the students wrote their solutions to given problems on transparencies and presented their thinking to the class (Woods, 1975). Later studies focused on student interest in and views of engineers and engineering. Knight and Cunningham (2004) developed a Draw an Engineer Test (DAET), based upon the Draw a Scientist Test (DAST; Chambers, 1983; where students draw what they think a scientist does and looks like) in order to assess Grade 3-12 students' images of engineers. Findings included (1) most students labeled engineers as builders (30%), fixers (28%), and creators (17%); and (2) most drawn engineers had an indiscernible gender (49%) and, of those with a discernable gender, 39% of drawn engineers were female and 61% were male. Katz (2009) discussed low student interest in engineering when data showed 85% of 1,277 students, ages 8-17, were not interested in a career in engineering, 30% expressed desiring a more exciting career than engineering, 44% said they did not know much about engineering, and 21% felt they had an inadequate skill set to be an engineer. Fralick et al. (2009), compared how 1,600 middle school students view scientists and engineers, by using the DAET (Knight & Cunningham, 2004) and the DAST (Chambers, 1983). A checklist (Fralick et al., 2009) was used to categorize the student answers. The findings showed students frequently perceived scientists, if they had any perception at all, as conducting experiments indoors, and they perceived engineers as performing manual labor outdoors. A study conducted by Karatas, Micklos, and Bodner (2011) examined 20 sixth-grade students (10 each from two separate but similar schools) in a small Midwestern town through a series of interviews. Their results demonstrated 40% of students did not know who would be involved in the construction of a roller coaster, 70% of students suggested engineers would work on a space shuttle, and 50% of students reported engineers would work on a highway overpass. Kaya et al. (2017) modified the Views of Nature of Science Version-C (VNOSC; Lederman et al., 2002) to make the Views of Nature of Engineering (VNOE) questionnaire. They used the VNOE to assess pre-service teacher views on the Nature of Engineering before and after an engineering professional development (PD) program. While those studies are illuminating and the tools developed are helpful, engineering education research has yet to touch specifically on baseline middle level student understanding, baseline middle level teacher understanding, baseline Urban versus Rural student and teacher understanding, or baseline teacher versus student understanding of engineering. For those reasons, this study fills some of the gaps in engineering education research.

BACKGROUND

The Necessity and Inclusion of an Engineering Education for Middle Level Students

The International Technology Engineering Educators Association (ITEEA) stated that increased knowledge and comprehension of engineering will lead to an increased chance that students will choose engineering as their future career (ITEEA, 2007). Thus, students must be more aware of engineering if they are going to consider it as a career. Furthermore, students should be aware of their future career options as they relate to the coursework they should be taking in high school. Pearson and Miller (2012) stated, "Students who begin algebra in Grade 10 or later have virtually no chance of obtaining entry into a baccalaureate engineering program without extensive remedial work in mathematics," (p. 58). Thus, the lack of information about engineering and the necessary mathematics in school can adversely impact the future college career of a student. This is why it is important to start engineering education early (e.g. in middle or elementary school).

Increasing the chance that students choose engineering as a career is currently very important in the U.S. This was documented by Katz (2009) when it was noted there is a shortage of engineers. Then, in 2015, the U.S. Department of Labor (USDL, 2015) released a statement that projected a 3% increase in architecture and engineering jobs over the period of 2014-2024 making for an additional 67,200 available engineering and architecture positions.

In order to include engineering in K-12 students' education in the U.S., the NGSS incorporated engineering through three disciplinary core ideas (DCIs) and eight science and engineering practices. The engineering

DCIs include: (1) Defining and delimiting an engineering problem; (2) Developing possible solutions; and (3) Optimizing the design solution. The eight science and engineering practices include: (1) Asking questions (science) and defining problems (engineering); (2) Developing and using models; (3) Planning and carrying out investigations; (4) Analyzing and interpreting data; (5) Using mathematics and computational thinking; (6) Constructing explanations (science) and designing solutions (engineering); (7) Engaging in argument from evidence; and (8) Obtaining, evaluating, and communicating information (NGSS Lead States, 2013). According to the NGSS, each of these eight practices can be used for scientific inquiry or engineering design and should be included within students' education. The NGSS claims the goal of the learning activity is what defines the practice. If the goal is to answer a question, then students are doing science, but if the goal is to define and solve a problem, then the students are doing engineering (NGSS, 2013).

Engineering and the Engineering Design Process Defined

With engineering as the focus of this research, it is important to know how "engineering" is defined in the literature. This is a critical distinction since engineering is a complex field where there has been little consensus regarding what exactly defines the Nature of Engineering (NOE; Karatas, Micklos, & Bodner, 2011). Further studies show that there are many facets to this intricate field. **Table 1** illustrates the varying views and definitions of an engineer/engineering.

Table 1. Various definitions of Engineers or Engineering

Authors	Term	Definition
Alon, 2003	Engineer versus tinkerer	Engineers plan structures in advance and draw up blueprints. A tinkerer puts together odds and ends in different ways until they come together in a functional way.
Davis, M., 1991	Engineers	"Engineers hold safety, health and welfare of the public in high regard as they 'handle things'" (Davis, 1991, p. 152).
Karatas et al., 2011	Engineering	Engineering requires analytical thinking. Engineering aims to meet the needs of the population.
Smith and Truxal, 1986	Engineering	Engineering is used to solve problems through the use of previous knowledge and a system of investigation. Engineering involves design and the formation or maintenance of complex systems.
Nguyen, D., 1998	Engineering	"Engineering is a profession directed towards the application and advancement of skills based upon a body of distinctive knowledge in *mathematics*, *science* and *technology*" (Nguyen, 1998, p. 65).
Capobianco et al., 2011	Engineers	Engineers integrate skills and knowledge in order to come up with solutions to problems.
National Research Council Committee on Theoretical Foundations for Decision Making in Engineering Design, 2001	Scientist versus Engineer	"A scientist studies what is, whereas an engineer creates what never was" (National Research Council Committee on Theoretical Foundations for Decision Making in Engineering Design, 2001, p. 1).

After perusing many different definitions of an engineer/engineering, we constructed our own definition of engineering and engineers that will be used for this study:

> *Engineering is the design, maintenance, and improvement of ideas, systems, and products through the use of prior knowledge, mathematics, science, and technology; An engineer problem-solves and innovates to advance the community around them and fulfill a human need.*

These definitions will guide the interpretations of the results.

Another useful definition to have is that of the engineering design process (EDP). The EDP is an iterative process used by engineers to engage in problem solving. Similar to the scientific method, the EDP includes a series of steps that may be followed in the order as presented or in a less linear fashion. Though the number of steps can vary depending on the source or on the specificity of the use, an important aspect to the EDP is that it's a repetitious process. Engineering is Elementary (EIE, 2018) presents the EDP with five steps; Ask, Imagine, Plan, Create, and Improve. They present the EDP as a circle with no definite beginning or end point, emphasizing that it is an iterative process that may repeat or loop back on itself. NASA Education presents a similar EDP, adding one more step, Test or Experiment, between Create and Improve, describing that students also need to test and evaluate their solutions (National Aeronautics and Space Administration, 2017). Regardless of the number of steps included or the order shown, the EDP is a useful description of the flexible, continuous approach to problem solving used by engineers.

The NGSS presents the engineering design more simply as three steps: Defining and Delimiting the Engineering Problem, Developing Possible Solutions, and Optimizing the Design Solution. These three steps can work together in an iterative process to address engineering design in grade band appropriate ways. For instance, in Grades K-2 the "emphasis is on thinking through the needs or goals that need to be met, and which solutions best meet those needs and goals" (NGSS Lead States, **Appendix I**, p. 3). In grades 3-5 students build on the idea of defining a problem to add more rigor to identifying and testing solutions; the iterative aspect is also emphasized as students are asked to optimize solutions by testing and adjusting them more than once. Specific criteria and constraints are added to engineering problems and engineering design in the middle grades (grades 6-8) which helps students connect the problem to the "larger context within which the problem is defined, including limits to possible solutions" (NGSS Lead States, **Appendix I**, p. 4). The high school grade band (grades 9-12) continues to add complexity to engineering design, asking students "to use mathematics and/or computer simulations to test solutions under different conditions, prioritize criteria, consider trade-offs, and assess social and environmental impacts" (NGSS Lead States, **Appendix I**, p. 5). With these definitions, guidelines, and societal engineering needs in mind, our study investigated the perceptions middle level teachers and students held concerning engineers and engineering.

METHODOLOGY

Research Questions and Measures

This qualitative study investigated how Urban and Rural middle level science teachers and their students understand engineering. This research was conducted at two participating schools in Kentucky (one Urban and one Rural) through semi-structured student interviews (4 randomly selected; 2 boys and 2 girls, using the random-select option in Microsoft Excel, from each teacher), semi-structured teacher interviews (4 teachers total), and the Views of Nature of Engineering (VNOE; Kaya et al., 2017) survey and the Draw an Engineer Test (DAET; Knight & Cunningham, 2004) administered to all participating students. The teacher interviews included questions concerning differences (or not) between science and engineering, definitions of science and engineering, and professional development engineering experiences. The student interview questions involved differences (or not) between science and engineering and definitions of engineering. Follow-up probing questions were asked if needed.

The DAET was used to collect students' images of engineers. The VNOE was used to gauge students' understanding about engineers and engineering including their definitions of engineering, differentiation between engineering and other subjects, and thoughts of engineering as a career choice. Each data collection method was used to answer the research questions presented in this paper. See **Table 2** for a breakdown of the research questions, methods used to answer them, and coding methods to analyze the data.

Table 2. Research Questions and Methods

Question	Data Collection and Instrumentation	Coding Method
1. How do middle level science students view engineers and engineering?	Views of Nature of Engineering (VNOE) survey (all students), the Draw an Engineer Test (DAET; all students), and student interviews (4 boys and 4 girls from each of the four teachers' classes)	VNOE responses were categorized. A checklist was used to group student DAET responses into certain categories (Fralick, 2009). Student interviews were analyzed for recurring and dominant answers (specific words or phrases).
2. How do middle level science teachers view engineers and engineering?	Interviews	Teacher interviews were analyzed for recurring and dominant answers (specific words or phrases).
3. Do middle level Urban students understand engineering/engineers differently than middle level Rural students?	Interviews, VNOE (Kaya et al., 2017), and DAET (Knight & Cunningham, 2004)	The same methods used for research question 1 were used here.
4. Do middle level science teachers hold different understandings of engineering/engineers than their students?	Teacher and student interviews; VNOE	The methods used for research question 1 and 2 were used to answer this question.

Participants

Research subjects were seventh-grade students from two middle schools in Kentucky and their science teachers (2 from each school). Per the National Center for Education Statistics (2017) one school, based upon the location within a city with a population of more than 250,000 citizens, was labeled "big city," and the other school was labeled "distant town," as it was distantly located from the, "big city." Additionally, the "distant town," has a population less than 40,000 people (SuburbanStats, 2018). Those population criteria match those used by McCracken and Barcinas (1991) to label schools as Urban and Rural, respectively. Mirroring their definitions, the schools will be referred to throughout this paper as Urban rather than big city and Rural rather than distant town. The Urban school was one of 12 middle schools in its district while the Rural school was one of two middle schools in its district. Of note, the schools in this study were chosen for convenience as we had a previous relationship with the Urban school and the Rural school was conveniently located near one of the researchers. These schools were comparable in some respects, but they differ in others. The two schools were comparable as far as demographics (Urban: 77% Caucasian, 6.9% African American, 6.5% Asian, 5.7% Hispanic, and 3.1% multiracial; Rural: 84.5% Caucasian, 6.2% African American, 5% Asian, 5.5% Hispanic, and 3.2% multiracial) as well as by standardized science test scores (2013-2014 Kentucky Performance Rating for Educational Progress, K-PREP; see Table 3; Kentucky Department of Education, 2014). However, on the 2016-2017 K-PREP mathematics test, the Urban students performed much higher than the Rural students (see Table 4; Kentucky Department of Education, 2017). Also, the Rural school was a Title 1 school (the school had at least 40% of students enrolled from low-income families, and for that reason, it receives additional federal funding to help meet the needs of those students), but the Urban school was not (Kentucky Department of Education, 2017).

Table 3 shows the 2012-2014 middle level K-PREP science scores for the entire state of Kentucky, the Rural and Urban schools in this study, and the district of each participating school. **Table 3** shows comparable scores between the two schools (Urban had higher scores for 2012-2013, but Rural had higher scores for 2013-2014), and the delivery targets (annual goals set by each school) were similar for 2013-2014. Of note, according to two contacts in the division of accountability data and analysis for the Kentucky Department of Education, science has not been assessed from 2014-current in the elementary/middle levels due to changes in standards (the adoption of NGSS) and testing methods (Hill & Wickizer, personal communication, June 5, 2018). For that reason, only 2012-2014 science scores were available and included in **Table 3**.

Table 3. Urban and Rural Science – Percentage Proficient/Distinguished (On State Standardized Test) Annual Goals versus Actual Achievement (Kentucky Department of Education, 2014)

	2012-2013					2013-2014				
	School		District		State	School		District		State
	U	R	U	R		U	R	U	R	
Delivery Target	81.7	67.2	70.1	66.9	65.6	70.1	70.8	73.4	70.6	69.4
Actual Score	68.5	59.1	63.2	59.6	61.2	66.9	77.0	63.1	70.8	64.2
Met Target	No	No	No	No	No	No	Yes	No	Yes	No

Table 4. Urban and Rural Mathematics – Percentage Proficient/Distinguished (On State Standardized Test) Annual Goals versus Actual Achievement (Kentucky Department of Education, 2017)

	2014-2015					2015-2016					2016-2017				
	School		District		State	School		District		State	School		District		State
	U	R	U	R		U	R	U	R		U	R	U	R	
Delivery Target	67.5	NA	54.9	53.7	47.8	71.1	46.8	59.9	58.9	53.6	74.7	52.7	64.9	64.0	59.4
Actual Score	61.9	40.9	47.4	39.8	42.8	64.2	44.0	49.0	50.5	47.0	67.8	44.7	49.6	51.7	47.0
Met Target	No	NA	No	No	No	No	No	No	No	No	No	No	No	No	No

Table 4 shows the 2014-2017 middle level K-PREP Mathematics scores for the participating Urban and Rural schools, the district of each participating school, and the state of Kentucky. As can be seen in **Table 4**, the Urban school, on average, outperformed, in actual scores, the Rural school in mathematics for every year included in the table. For example, for the last year shown, 67.8% of participating Urban students were classified as proficient or distinguished in mathematics compared to 44.7% of participating Rural students. The Urban school, on average, also set higher annual goals (i.e. delivery targets). This is contrary to the actual scores and annual goals in science between the two schools where those were comparable.

RESULTS

We begin this section with the teacher interviews followed by the student interview data, student VNOE assessment discoveries, and DAETs. The teacher interviews (see **Table 5**) highlight teacher science and engineering knowledge, teacher thoughts on the differences between science and engineering, teacher experience with engineering professional development (PD), and teacher practices on the differentiation between engineering and science in the classroom. Student interviews concerned student knowledge of engineering and the difference between engineering and science. Student highlighted VNOE questions focus on engineering knowledge, how engineering is different from other subjects, the engineering design process, and previous thoughts about working as an engineer. Student DAETs focus on gender of drawn engineers and the inferred actions of each drawn engineer.

Teacher Interviews

Teacher interviews were conducted during the teachers' free time, which included planning hours and after school hours. These interviews lasted anywhere from around 10 to 30 minutes. The most illuminating responses came from the following questions: (1) What kinds of professional development have you received regarding engineering, if any?; (2) What do you know about science?; (3) What do you know about engineering?; (4) What is the difference, if any, between science and engineering?; and (5) Do you differentiate between science and engineering for your students? See **Table 5** for each of the four teachers' responses to questions 1, 2, and 3. Teacher responses to questions 4 and 5 are explained in the narrative.

All teachers reported having previously received professional development (PD) for teaching engineering. However, one of the Rural teachers noted she had only received approximately 10 minutes of PD directly related to engineering, and this was in the form of building a car. The male Rural teacher noted he received extensive PD training in teaching engineering for the last five years. The two Urban teachers participated in a PD program with a focus on chemistry and an engineering component tied throughout. However, Urban teacher 2 noted this was additional PD she, "sought out," for herself.

Table 5. Rural and Urban Teacher Interview Excerpts

	Rural School Teacher 1 (Male)	***Rural School Teacher 2 (Female)***	***Urban School Teacher 1 (Female)***	***Urban School Teacher 2 (Female)***
What kinds of professional development (PD) have you received regarding engineering (E), if any?	I've done that (headed a cadre about NGSS) for five years. We explored E, different things we could do with our students… and how to actually incorporate E into our classroom.	The only E thing we did was maybe build a car. That was the only type of E PD I've had, and that was like 10 minutes of the whole PD.	All of the project-based learning professional developments that we have done where we developed our own units. There was the Engineer's panel and all that they brought in. We've had some trainings this year on cross-cutting concepts and bringing in, like, modeling and patterns and all that.	Last year, I think that we had a PD where it was a kind of county wide thing, but it was, of course, optional, if you wanted to come, where we talked about the E standards and how we can best implement those.
What do you know about science (S)?	S is understanding. It's learning. It's making sense of the world. S is what allows us to grow as a society.	I believe S is things we do in our everyday lives. We have to know how things work…You have to be able to observe. You have to be able to use your senses…	Well, everything is S. Everything has energy, and everything that you do takes forces. Every single thing that we do is S.	I see S in everything.
What do you know about engineering (E)?	E, you basically have a problem; you try to solve it. If it doesn't succeed the first time...you go back and you do it 'til you can solve that problem.	I think it is having a problem and solving it in a creative way such as building or something like that.	We make models… I say okay now it's your turn and have them build something. Sometimes they create it just based on what they know and for our house. They are building a thermal house from a, and all the houses are going to look the same they will all be covered the same way. What they are E is the type of insulation that goes in.	Architects design it and the engineers are who are in charge of all of the products and putting it together. Engineers... are problem solvers.

The teacher interviews showed that all teachers thought engineering was different from science and gave similar reasoning. For example, Rural school teacher 1 stated "Engineering is the application of science." This was a very similar response to the statement given by Rural school teacher 2: "I think you can't have engineering without science, but I think that there are some applications in science without engineering." Urban school teacher 1's response was slightly different as it noted the close relationship between engineering and science. Specifically, Urban school teacher 1 said, "I think they are very closely related, but I think science is more everyday around you… I think of engineering as more of the planning/building/design." While Urban school teacher 1 responded slightly differently than Rural teachers 1 and 2, Urban school teacher 2 responded similarly to the former 2 teachers with the following: "I think, like, science is a broad area of knowledge, and engineering is using that knowledge to apply and make changes to the world around you."

Even though all of teachers personally differentiate between science and engineering, only one of the teachers (Rural Teacher 2) reported differentiating between science and engineering within their classrooms. Specifically, when asked the question: *"Do you differentiate between science and engineering while teaching your students?"* the other three teachers reported they do not necessarily differentiate between the two in practice. For example, Rural teacher 1 responded, "Not really… because they flow into each other." Echoing this statement are those made by Urban teachers 1 and 2. Specifically, Urban teacher 1 stated, "I don't specifically," while Urban teacher 2 expressed, "I try not to because I don't want them to necessarily think that they're two separate entities." The one teacher who did express differentiating between the two to their students stated, "I do differentiate. I tell them it's a blurred line and that it's all interconnected" (Rural Teacher 2).

In summation, the main teacher interview findings showed, overall, (1) teachers have had a wide range (5 minutes to five years) of engineering education professional development (see **Table 5**); (2) 3 of the 4 teachers defined engineers as problem-solvers (see **Table 5**); (3) All teachers thought engineering was different from science in some aspect; (4) and 3 of the 4 teachers did not differentiate between science and engineering within their classrooms.

Student Interviews

In order to gauge students' perspectives beyond the VNOE and DAET, we chose to interview two girls and two boys from each of the respective teachers' classrooms (all were randomly selected). The students were prompted with specific questions and phrases that concerned student knowledge of engineering, science, and the difference between engineering and science. See Table 6 for the highlighted student interview questions and excerpted answers. Student interviews were conducted during the students' regular school day. All interviews were filmed and transcribed.

Table 6. Urban and Rural Student Interview Excerpts

		What is Engineering (E)? / What do you know about E?	**What is the difference between Engineering (E) and Science (S)?**
Urban	1	So my sister's husband is an environmental engineer …what he does is he tests the water, test the air for pollution… keeps Toyota in check so they don't pollute so much.	E you do… more hands on than S because…E isn't really like a class. S you can have a class and you can learn more. E is more like a kind of job.
	2	To solve problems and like if I need to get something I can like build something in order to get it.	S is like trying to figure out everything E is building things.
	3	Umm, you build things.	S involves E and E involves S.
	4	When you build something, you'll need, like, blueprints, materials, and stuff.	No response.
	5	you make something for any purpose really, but, like, it's you're building something and designing something…	S is not as hands on because, again, it's the technique…kind of way you build something and the reasoning, you know, the big idea behind how you're going to build something.
	6	You build things.	S is where you figure out what's going on like cold water and hot water mixed together if it would make warm water, and E would be like you build something and see if it works.
	7	Like building buildings and bridges and stuff, and just basically any landscaping stuff.	E is more like ideas and building it, and S is the knowledge to know what's going to work and stuff.
	8	A design process where you have an idea and you make a blueprint and then you do a model… And your ideas come to life…	E is when you have an idea and there is still S behind it. But it is more blueprints and ideas coming to life. I think S is a fact and you cannot change it.
Rural	1	I don't know, not really a whole lot, I can't think of any specific machines…	Um. I don't really know actually. I think there is a difference.
	2	Don't they work with like technology?	Like S is more…Well, not really… because E has to do with S. They are both like experiments kind of. I don't know. It's like both having to do with experiments and stuff.
	3	I don't really know a lot.	S is more like…one of the labs we did where we… it's called elephant toothpaste and it had this foamy stuff and you combine chemicals and E I don't think you combine a lot of chemicals and do chemistry and all that.
	4	I don't really know anything about E.	Kind of yeah because E they do more of like making some things and seeing if they'll like work and if they don't like finding the problem and fixing it. And S is the ways you get it to work. The energy behind it and the ways you make it balance.
	5	I've not heard of it a lot but…, I don't know, not really.	S is… well, E is… like you've gotta do stuff… I don't know. But… in S is like where you can learn stuff like…about something and everything.
	6	I don't know if I'm correct, I think of everything really.	S and E are pretty close… You can't just build something without knowing a little bit of S. Like bridges. We just learned that there are little gaps between the metal-- it's because when things heat up they expand so that if there wasn't those gaps they would expand and break the bridge…
	7	Nothing.	When I think of S it's like chemicals and stuff, when I think of E I think of like bridges. And I guess you kind of need like S to uh build a bridge… I guess.
	8	All I know is… [The student hesitated and then did not respond]	Um, no. Not much of a difference… there's a lot of E involved in S. If I said there was one difference it would be that uh S uh revolves um around um like the um more in depth uh of how like everything like um on a molecular level how it works and E is more just like the basics of power.

In **Table 6**, student responses were edited for relevance and space. Further questions, probing or otherwise were also asked. However, not all of these were especially revealing or necessary for the purposes here.

During the student interviews, there was an obvious difference between the two populations. The Rural students had much more trouble producing responses to the question "What is the difference between science and engineering?" This was demonstrated by vague Rural student responses such as "Um. I don't really know actually… I think there is a difference," or, "science is...well, engineering is... like you've gotta do stuff... I don't know. But... in science is like where you can learn stuff like. About something and everything," while the Urban student group gave much clearer explanations of their thinking. For example, one Urban student stated, "science is like trying to figure out everything; engineering is building things." Another Urban student explained, "Well, science is not as hands on because, again, it's the technique, like, the kind of way you build something and the reasoning, you know, the big idea behind how you're going to build something. Engineering is like building something, the technique of it, and, you know, what you use to do it and how you use those materials." This additionally exemplified the finding that of the students interviewed, all of the Urban school students noted differences between the two, whether they match our definitions of engineering/an engineer or not, while only 4 of the 8 Rural school students differentiated between the two as well and gave an explanation for why/how they are different (see **Table 6**).

In summation, the main finding from the student interviews was: there were differences between the interviewed Rural and Urban students as Rural students responded "I don't know" somewhere in their answer to both the question "What is the difference between science and engineering?" (3 of 8 Rural) and the question "What is engineering/What do you know about engineering," (5 of 8 Rural), while 0 of 8 of the interviewed Urban students stated "I don't know" in response to either question (see **Table 6**).

Student VNOE Surveys

The VNOE survey was given to all consenting students and was administered within students' regularly scheduled science class. Urban students took the survey using technology such as computers, iPads, and laptops while Rural students took the survey on paper due to technology limitations within the school. After these were collected and reviewed, five questions from the VNOE were highlighted: (1) What is an engineer? What does an engineer do?; (2) How is engineering different from other subjects?; (3) What type of job or jobs do you think you might want to do when you grow up?; (4) Have you ever thought about being an engineer?; and (5) Have you ever heard of the engineering design process? After these questions were examined, the answers were coded and categorized by two of the researchers. The researchers then compared categories and results. Certain categories (see **Figure 1** and **2**) were selected. After that, 3 researchers separately coded all student answers into the agreed upon categories. These results were then compared. Interrater reliability was first established between 75 – 90% during first round of coding, but after discussion interrater reliability was 99% for all question responses. The highest frequency responses from the VNOE assessments are included in **Figures 1**, **2**, **3**, and **4**, for the first two questions and the last two questions respectively.

Figure 1 illustrates the top ten highest response categories to the questions "What is an engineer? / What does an engineer do?" Since some responses fit into more than one category, they were coded into all of the categories they fit. A little more than half of the Rural (54.64%) and the Urban (57.02%) students submitted a response that was categorized into the highest frequency category of make/build. A slightly smaller portion of the students (47.42% of Rural students and 43.80% of Urban students) wrote an answer that was categorized into the second most popular category of invent/design/create.

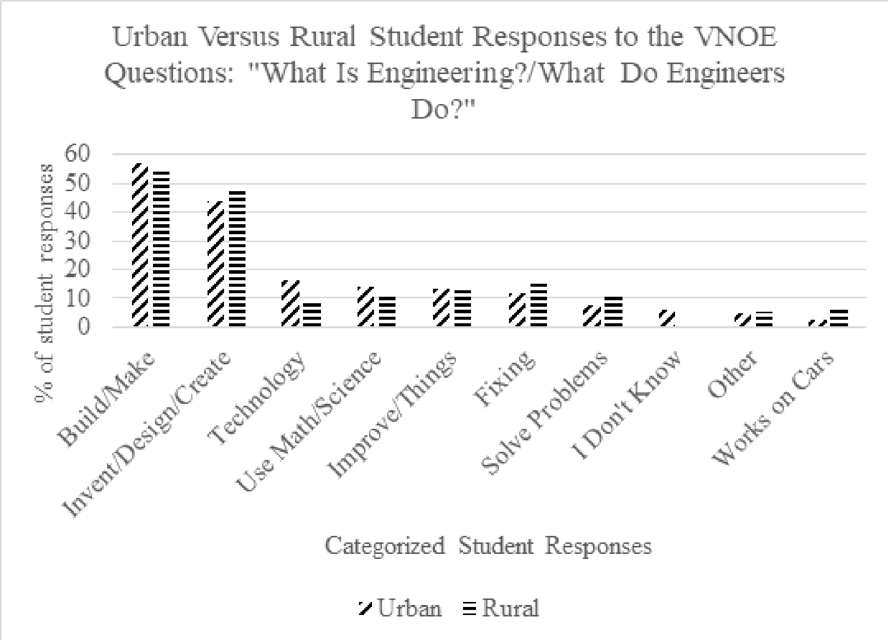

Figure 1. Categorized student responses to the question, "What is engineering? What do engineers do?"

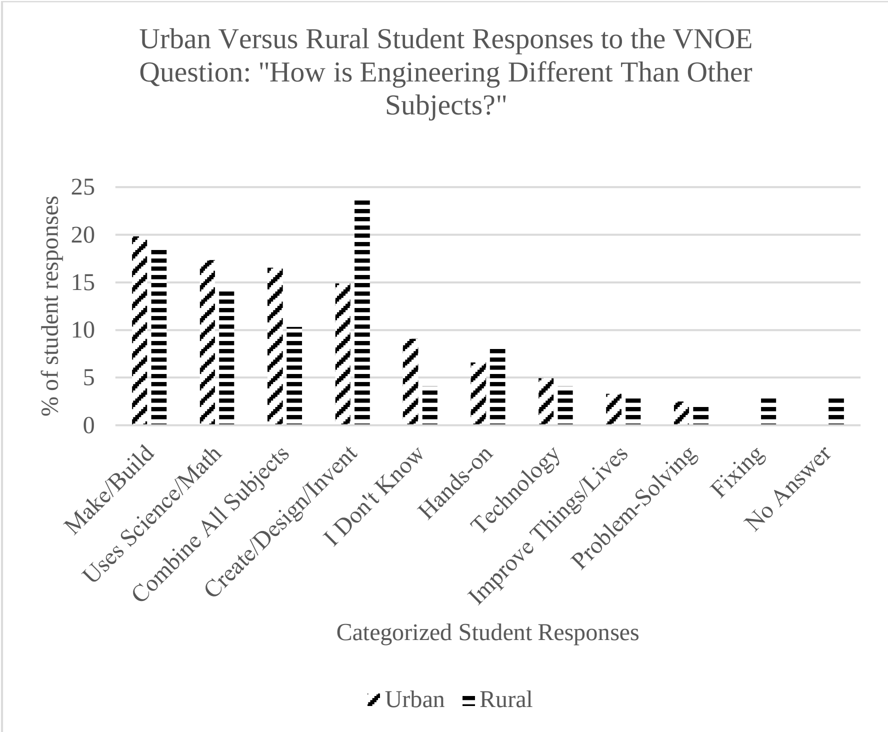

Figure 2. Categorized student responses to the question," How is engineering different from other subjects?"

In terms of student VNOE responses concerning the question "How is engineering different than other subjects" (see **Figure 2**), there were two main differences between the Urban and Rural populations: (1) more Rural students (23.71%) than Urban (14.88%) reported answers categorized as create/design/invent as the difference between engineering and other subjects, and (2) more Urban students (16.53%) than Rural (10.31%) thought engineering was different than other subjects because it combines all subjects. Urban students responded with a slightly higher frequency to the make/build and uses science/math categories than Rural students. See **Figure 2** for other selected categories by population.

The responses to the VNOE survey question, "What type of job or jobs do you think you might want to do when you grow up?" were coded into categories. If a student listed only STEM job(s), or listed STEM and Non-

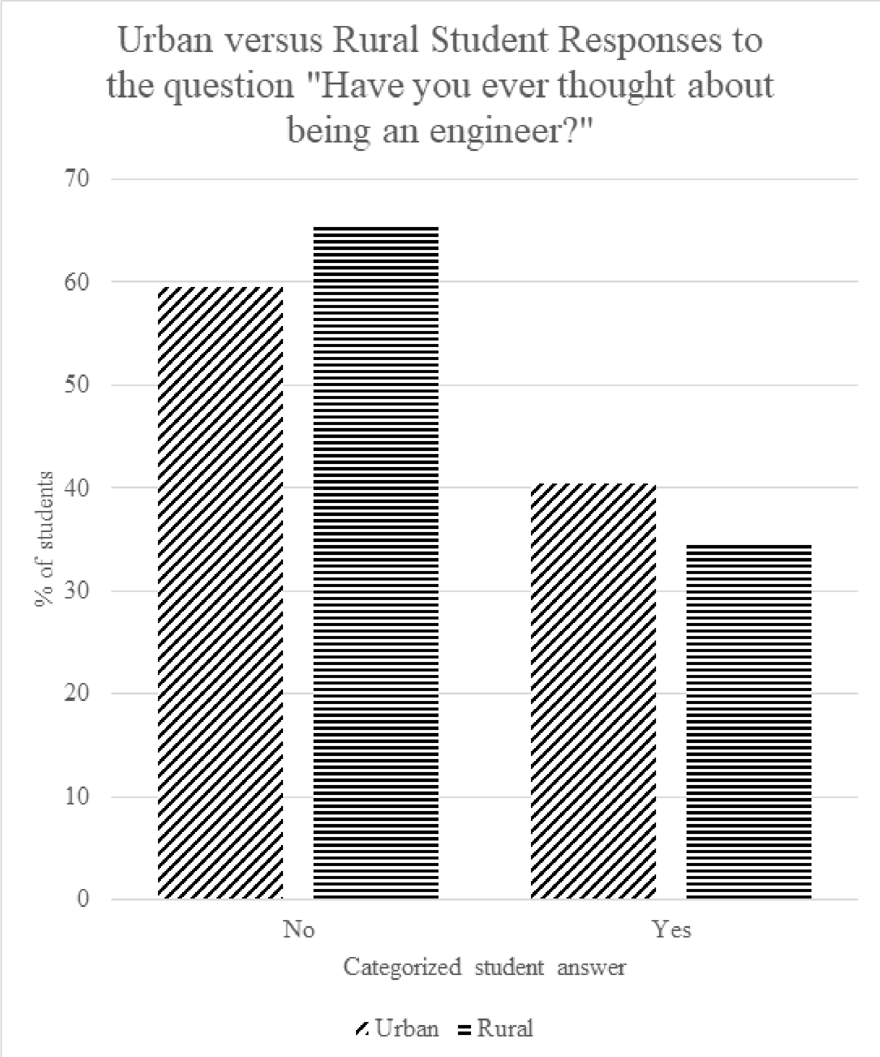

Figure 3. Categorized student responses to the question, "Have you ever thought about being an engineer?"

STEM jobs (e.g. ballerina and pediatrician) then this response was coded into the "STEM" category. If a student listed only Non-STEM job(s) then this response was coded into the "Non-STEM" category. If a student answered this question with, "I don't know," or, "undecided," then their answer was coded into the "Undecided" category. The number of times each category was represented for each group was divided by the total number of responses. The Urban student data showed 61.74% of students listed at least one STEM career, 37.39% listed only Non-STEM careers, and 0.87% reported they were undecided on a future career. The Rural student data showed 57% of students listed at least one STEM career, 39.79% chose only Non-STEM careers, and 3.23% noted they were undecided on a future career. Of the students who offered at least one STEM career of interest, working in the medical field (e.g. pediatrician, nurse, physical therapist, doctor) was the most popular for both the Rural (25.8%) and Urban (20%) students. The second most common STEM career chosen, for both Urban and Rural students, was engineering (17.39% and 11.81%, respectively). A minority of students in both groups saw themselves becoming an engineer in the future.

Figure 3 shows the majority of both student populations have not thought about being an engineer. Specifically, 59.50% of Urban students and 65.59% of Rural students have not thought about being an engineer. On the other hand, 40.50% and 34.41% of Urban and Rural students, respectively, reported they have thought about being an engineer. There were no major differences between the student population responses.

Figure 4 shows the majority of both student populations (Urban and Rural) have not heard of the engineering design process (EDP). Specifically, 78.51% of Urban students and 82.80% of Rural students have not heard of it.

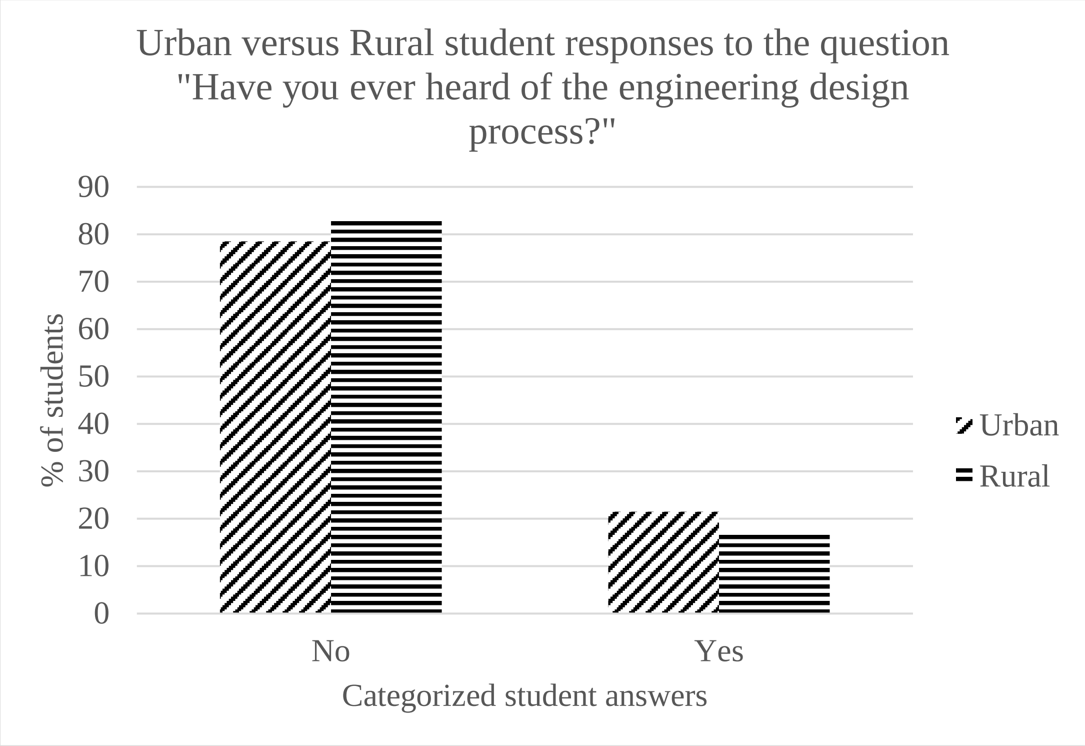

Figure 4. Categorized student responses to the question, "Have you ever heard of the engineering design process?"

DAET

Part of the regular VNOE survey for students included a prompt to draw an engineer. The DAET consisted of a piece of paper printed with the prompt: "draw a picture of an engineer"; a large empty square box in which to draw an engineer in, and a few lines following the prompt: explain the drawing. It is important to note a difference between the DAET ("draw a picture of an engineer") used in this research and the DAET ("draw a picture of an engineer at work") developed by Knight and Cunningham (2004). The DAET portion was then coded, using the checklist constructed by Fralick et al. (2009). Three researchers coded this data with an interrater reliability of 97%.

The DAET results consisted of 71 Rural and 73 Urban student responses. **Figure 5** shows examples of the type of drawings that students drew and how they were classified into the various categories of inferred actions. The top left image in **Figure 5** represents an example where we coded the inferred action of building/making/fixing due to the student's explanation stating "My dude is building a new bridge in NC." The drawn engineer was labeled as male since the student labeled their engineer as a, "dude," in the explanation of the drawing. The top right image in **Figure 5** represents a student example with a coded inferred action of driving machinery due to the student noting the engineer was, "a person driving a forklift." Due to the lack of pronouns used, this engineer was classified as unknown gender. The bottom left image in **Figure 5** represents a student example with a coded inferred action of designing/inventing by an engineer with an unknown gender where the student explained, "A person that sees a problem and comes up for a solution or answer." Finally, the bottom right image in **Figure 5** illustrates an engineer with no inferred action and unknown gender; the student wrote, "Engineers hold all the information they need to know in their heads. They have tools that help them create things. Anybody could be an engineer, so I drew one as an average person."

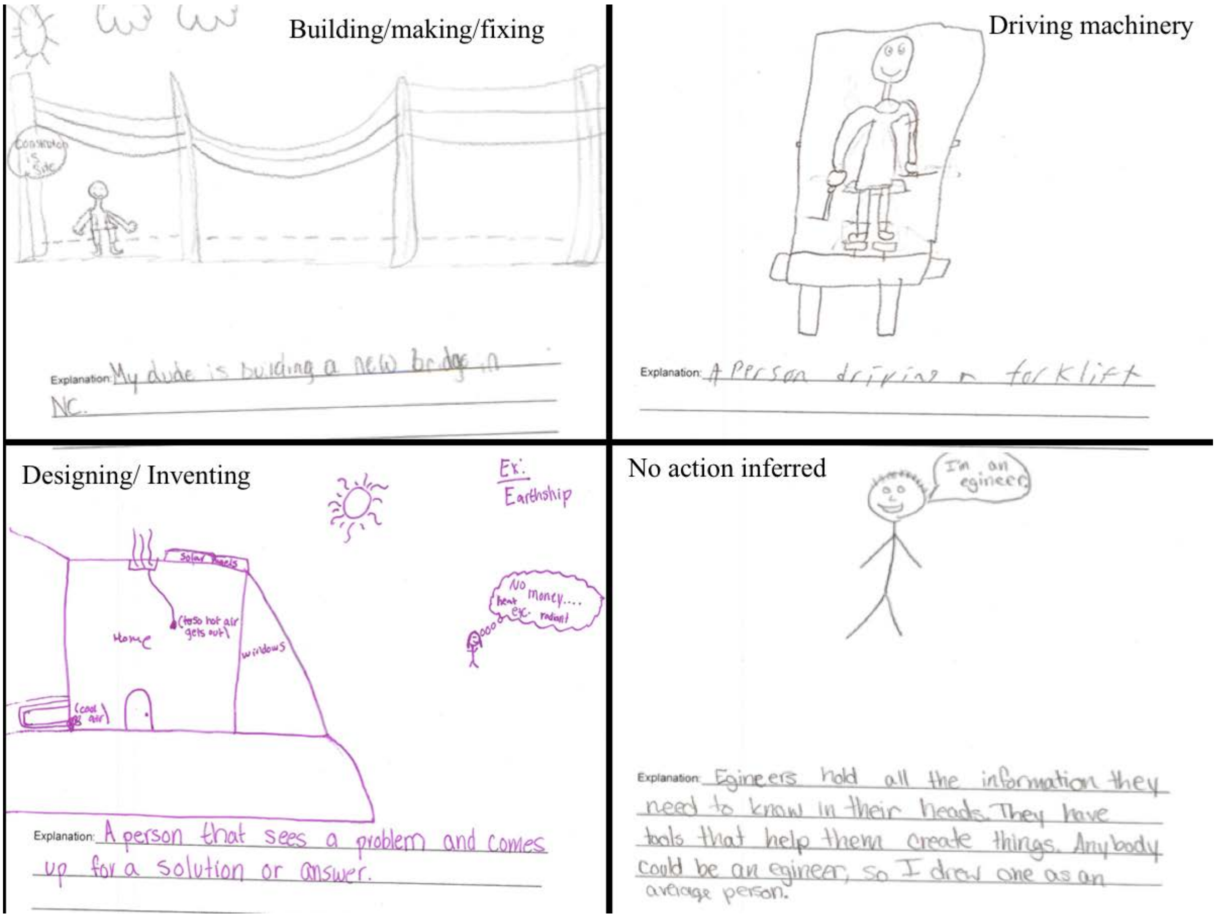

Figure 5. Examples of DAETs sorted into different inferred action categories.

Despite analyzing the DAET under many different lenses, the most telling data concerned the actions the students drew their engineers performing as well as the gender of the engineers drawn. These results can be found in **Figures 6** and **7**, respectively.

Figure 6 shows 51% of the Urban students and 45% of Rural students drew an engineer with an inferred action categorized into the making/fixing/working with hands category and the second highest action inferred for both populations was designing/inventing/creating products.

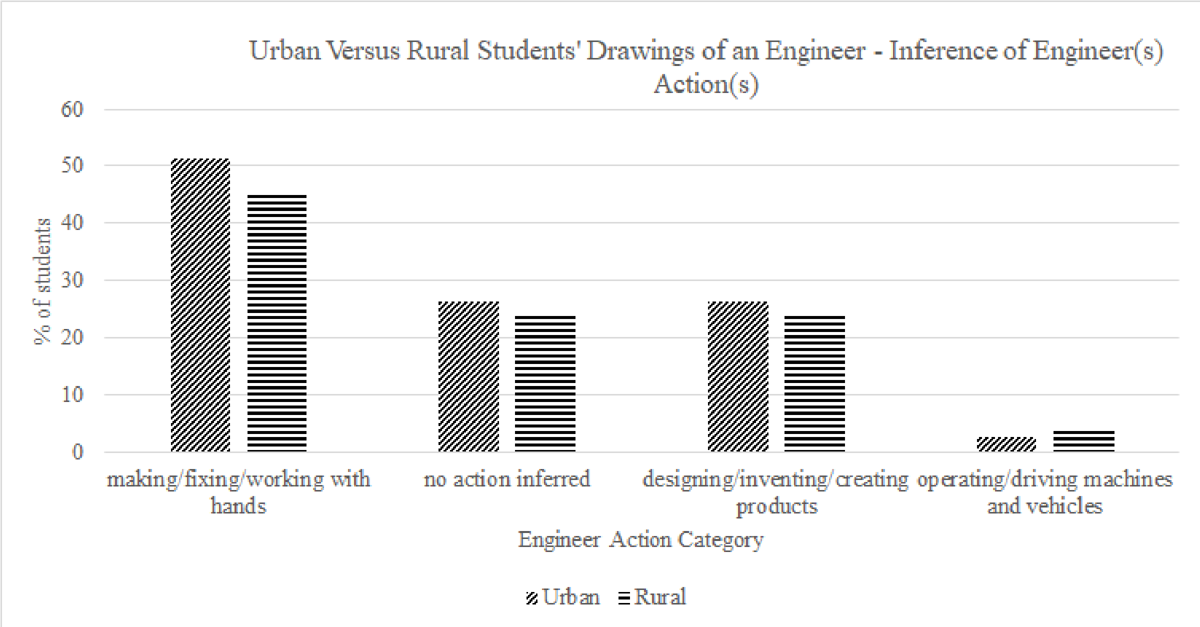

Figure 6. Engineer actions - from the DAET

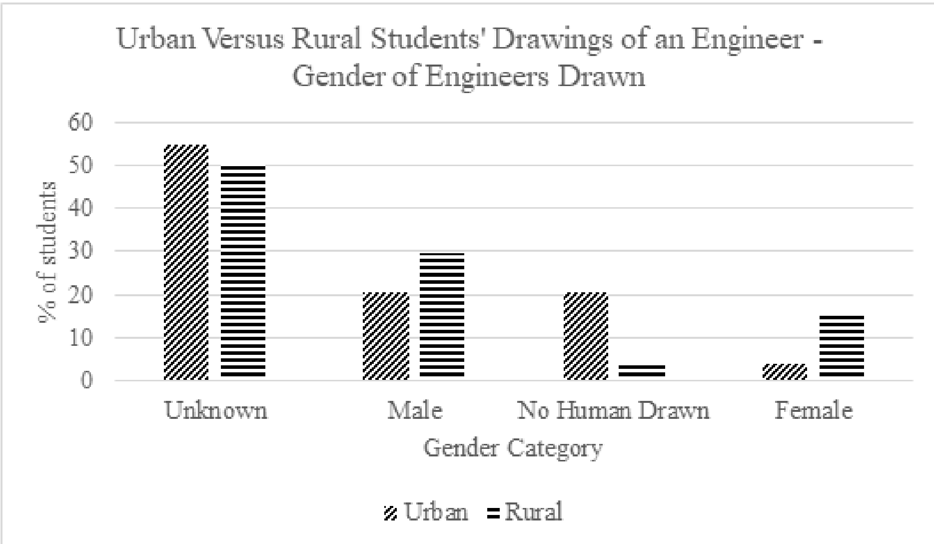

Figure 7. Genders of drawn engineers from the DAET.

It is important to note, the DAETs were analyzed without assumption. For example, as for the results in **Figure 7**, it was not assumed an engineer was male or female based on anything other than the descriptive pronouns of, "he/him/his," "she, her, hers," typically male/female names, or facial hair (indicating a male). For example, gender was not assumed to be male just because an engineer with short hair was drawn. It was also not assumed a drawn engineer was female just because of drawn long hair. This method of analysis led to 54.79% and 50.7% of drawn engineers with an unknown gender, 20.55% and 29.58% of drawn engineers with a male gender, 20.55% and 4.23% with no human drawn, and 4.11% and 15.49% of drawn engineers with a female gender, for Urban and Rural student populations, respectively. Of note, no human drawn means there was no engineer drawn at all; an example of this could consist of only a car being drawn.

DISCUSSION

In this study, we examined Urban and Rural middle level science teacher and student views of engineering and engineers. The findings of this study were derived from the teacher interviews, student interviews, student VNOE surveys, and student DAETs. This section begins with discussing how teachers in this study viewed engineering. It then transitions into examining student views of engineering. Finally, the discussion ends with a comparison of both student and teacher views to the NGSS engineering practices and disciplinary core ideas (DCIs).

Teacher Views of Engineering

The teachers interviewed in this study overwhelmingly viewed engineers as problem-solvers. This is in partial agreement with our definition of engineers and engineering; the teacher definitions were not complete due to missing crucial components such as innovation and the use of mathematics, science, and technology. However, teachers were not afforded the opportunities to fill out the VNOE or the DAET like their students and if given this opportunity, then we, most likely, would have seen more complete definitions.

This study also found that all of the teachers differentiated between engineering and science personally, however, even with those privately held beliefs, three of the four teachers reported they did not differentiate between science and engineering within their classrooms. According to the NGSS, the difference between engineering and science practices concerns the goal. Specifically, they noted the following: if the goal is to answer a question, then students are using science, but, if the goal is to define and solve a problem, then the students are practicing engineering (NGSS, 2013). When looking at the NGSS's definition of differentiation in practices between science and engineering, it is clear that the teacher's personal differentiation between engineering and science is supported by the NGSS. However, three of the four teachers noted they did not differentiate between engineering and science in front of their students, on purpose.

Interestingly, even though 3 of the 4 teachers did not differentiate between engineering and science in class, of the students interviewed, all of the Urban students did note differences between engineering and science (whether they matched our engineering definitions or not), while half of the Rural students differentiated between the two. It is curious that the majority of the teachers were not quite in sync with the NGSS, by not distinguishing between science and engineering, but at least half of each respective student group still did differentiate between science and engineering. This is a novel finding and warrants further research if we are to understand where these discrepancies are coming from.

These incomplete definitions of engineering/engineers and contrasting views between the teachers and the NGSS on the differentiation between science and engineering could be due to a variety of factors. One such factor includes the recent adoption of the NGSS in 2014. This mandated science teachers in the adopting states and districts to teach engineering concepts, where science teachers were previously not required to teach standards which incorporated engineering. Another factor contributing to the naive understandings of engineering for teachers, could be the lack of engineering PD attained by teachers (as one teacher in this study alluded to). However, the reasons given for incomplete understandings of engineers and engineering, of teachers and students, have not been researched in the past.

Student Views of Engineering

While the teachers in this study defined engineering predominantly as problem solving, the students viewed engineers largely as makers/fixers/workers and designers/inventors/creators of products (per the DAET); makers/builders, creators/designers/inventors, and users of mathematics and science and combined subjects (per the VNOE); and primarily builders (per the student interviews). These student responses are consistent with previous research (Knight & Cunningham, 2004; Fralick et al., 2009) in terms of high percentages of students categorizing engineers as builders and fixers. In terms of our definition of engineering (i.e. engineering is the design, maintenance, and improvement of ideas, systems, and products through the use of prior knowledge, mathematics, science, and technology; An engineer problem-solves and innovates to advance the community around them and fulfill a human need.), some categories students missed include: systems thinking, maintenance, and advancement to fulfill a human need.

When analyzing the gender of the drawn engineer, engineers most commonly were labeled to have an unknown gender (58% and 75% for Urban and Rural students, respectively). This differs from the research conducted by Knight and Cunningham (2004) as they had a lower frequency of drawn engineers with an indiscernible gender (49%) and, of those with a discernable gender, 39% of drawn engineers were female and 61% were male. This is likely because the DAETs in this study were analyzed without assumption, and, as many students did not describe their engineer using pronouns such as, "he/him/his," "she, her, hers," all of those examples of drawn engineers were coded as gender: unknown; This is different than the way Knight and Cunningham (2004) coded the gender of the drawn engineers as they categorized an engineer as male if the drawing possessed short hair, square shoulders, or a necktie and as female if the drawing had long hair. We did not agree with this method as males can have long hair and women can wear neckties, have square shoulders, and have short hair. As for the known genders of the drawn engineers, 21% and 29% of drawn engineers were male, and 4% and 13% of drawn engineers were female, for Urban and Rural student populations, respectively. While there are differences between the frequencies of female and male engineers drawn between the Rural and Urban students, it cannot be concluded there is an actual difference, since such a large amount of each groups' drawn engineers have unknown genders. This is a limitation of the study and is further discussed in the limitations section.

As both populations of students, Rural and Urban, responded very similarly, overall, to both the VNOE and the DAET, it is important to consider the reasons underlying this. One possible reason for the similarities among the groups of students could be the actual NGSS standards themselves, as this is the main constant between the two schools (Next Generation Science Standards Lead States. (2013). This could be further investigated by measuring engineering understanding of NGSS trained students and science teachers and compare that to non-NGSS trained students and science teachers. Another hypothesis to explain the overall similarities between Rural and Urban student VNOE and DAET responses is that the Rural and Urban schools were not all that different.

While the VNOE and DAET responses from each of the student populations were very similar, it was obvious in the interviews that the Urban students were able to express more information about engineering than the Rural students were able to where Rural students responded, "I don't know" somewhere in their answer to both the question "What is the difference between science and engineering?" (3 of 8) and the question "What is engineering/What do you know about engineering," (5 of 8), while 0 of 8 of the interviewed Urban students stated, "I don't know" in response to either question. The reason for the Urban students outshining the Rural students in the interviews but not on the VNOE or DAET, is unknown. Perhaps this could be due to a small number of interviewed participants (N=8) making it possible for a non-representative sample of interviewed students. To correct this, in the future, we could interview more students to make sure the sample is representative of the population.

Teacher and Student Responses Compared to NGSS

When comparing the student and teacher findings to the NGSS engineering disciplinary core ideas (DCIs) and practices (NGSS Lead States, 2013), certain engineering DCIs and engineering practices were mentioned, and some were not mentioned at all. For example, the majority (75%) of the teachers (as mentioned in the teacher interviews), as well as Rural (11.34%) and Urban students (7.43%), as mentioned on the VNOE, suggested engineers solve problems. This matches the DCI: developing possible solutions. Developing possible solutions was the only DCI any of the teachers touched on, however, a few of the Rural and Urban students did touch on one other DCI: optimizing the design solution. For example, one Urban student wrote, on the VNOE, that "(engineering is) the process of designs being made for buildings, houses, etc. They (engineers) design buildings." Even though this DCI is touched upon by a few students from both populations, their explanations do not cover the entire engineering design process used when optimizing a design solution. As far as the science and engineering practices, Urban students discussed the use of models, and both student groups reported engineers plan, use mathematics and computational thinking, and construct explanations and design solutions.

Overall, teachers from both groups produced answers that resembled 1/3 of the DCIs (developing possible solutions), and described at least two of the science and engineering practices (designing solutions; developing and using models). Urban student answers hit on topics similar to 2/3 of the DCIs and 4/8 of the science and engineering practices, whereas, Rural students mentioned topics similar to 2/3 of the DCIs and 3/8 of the science and engineering practices. This shows students, from both populations, did not mention anything similar to the DCI: Defining and delimiting an engineering problem or the following science and engineering practices: Asking questions and defining problems; Planning and carrying out investigations; Analyzing and interpreting data; Engaging in argument from evidence; and Obtaining, evaluating, and communicating information, and teachers mentioned even less than their students. In order to make sure all of the engineering DCIs and science and engineering practices are understood by both teachers and students, further research, as to how to make this happen, must be done, especially since no research has explored the NGSS engineering DCIs or engineering and science practices touched on by students and their teachers before.

CONCLUSIONS AND SIGNIFICANCE

With the somewhat recent adoption and implementation of the NGSS (the first set of standards adopted by the state of Kentucky to include engineering) in K-12 schools, it is important to explore what science teachers and students at the middle level understand about engineering at baseline. Through the implementation and completion of teacher interviews, student interviews, and student assessments (VNOE & DAET), it was found: (1) the majority (~55%) of Rural and Urban students view engineers as constructors, builders, and makers; (2) The most common gender chosen for the student drawn engineer, aside from unknown gender, was male; (3) The majority (75%) of teachers define engineers as problem-solvers; (4) All teachers differentiate between science and engineering, personally, but 3 of the 4 do not differentiate between the two in their classrooms; (5) Although the majority of the teachers do not differentiate between science and engineering in their classrooms, the majority of their students do differentiate between the two; (6) Urban students and Rural students answered the five highlighted VNOE assessment questions very similarly with one slight difference in response to "How is engineering different than other subjects (see **Figure 3**), as 23.71% of Rural students reported answers categorized into create/design/invent, while only 14.88% of Urban students reported the same; (7) Urban and Rural DAET results were very similar; and (8) interviewed Urban students gave more explanatory responses than the interviewed Rural students (see **Table 7**).

The findings and conclusions documented in this paper demonstrate there is room for improvement in these studied middle level students and science teachers' understanding of engineers and engineering as the majority of them have incomplete/misinformed views. As students' images and stereotypes about engineers and engineering affect their perceptions of careers and whether they feel they can enter into those careers, it is important to understand the baseline views of middle level students and science teachers in order to gauge a possible need for intervention to produce students with fully formed views of engineering and engineers, so they possess all of the knowledge they need to be an engineer if so inclined. This is imperative since the middle level stage of schooling has been identified as a crucial time in education for motivating or losing student participation and interest in mathematics and science, and piquing their interest in a career as an engineer (Brophy, Klein, Portsmore, & Rogers, 2008). If this is gauged, monitored, and intervened upon in order to inspire students to become engineers, then this, ultimately, would give the U.S. labor force a chance to fill the projected increase in engineering positions and eliminate or reduce the engineer shortage.

Table 7. Conclusions to the Research Questions

Research Question	Conclusion
1. How do middle level science students view engineers and engineering?	The majority (60%) of middle level science students, from both populations (Urban and Rural), see engineers as builders and makers. The most popular gender chosen by both student groups was male (when taking out unknown gender), so these students also view engineers, most commonly, as male.
2. How do middle level science teachers view engineers and engineering?	The majority (75%) of middle level science teachers view engineers as problem-solvers.
3. Do middle level Urban students understand engineering/engineers differently than middle level Rural students?	There were two main differences on the VNOE for the question, "How is engineering different than other subjects?" More Rural students reported create/design/invent responses, and more Urban students stated uses science/math and combines all subjects. All DAET responses were similar between groups. Interview responses showed Urban students giving more explanatory answers.
4. Do middle level science teachers hold different understandings of engineering/engineers than their students?	The majority (~55%) of middle level students from both populations saw engineers as builders and makers, but the majority (75%) of the middle level science teachers viewed engineers as problem-solvers.

LIMITATIONS

The DAET was specifically vague in order to elicit honest student drawings of engineers. However, this posed some challenges. For example, the DAET stated, "draw an engineer," and then had a few lines below the drawing space in which to explain the drawing. Many students drew a person doing nothing or a person with no obvious gender. For these reasons, 75.00% and 57.90% of Urban and Rural students, respectively, drew an engineer that was categorized to have an unknown gender. While we are not sure why there were so many engineers with indiscernible genders, we did find the frequency of this occurrence was much higher in this research than was found by Knight and Cunningham (2004). We postulate this difference could be because we discerned gender differently (no assumptions) than they did (gender of the drawn engineers was categorized as male if the drawing possessed short hair, square shoulders, or a necktie and as female if the drawing had long hair). With this in mind, we may be able to elicit more frequent drawn engineer responses with a known gender if we use the prompt Knight and Cunningham (2004) used (Draw an engineer at work). Another notion to explain this may be that the students just do not find gender to be an important characteristic to note when drawing an engineer. However, this would require further research in order to claim this. Regardless of why this happened, it is important to note the high frequency of drawn engineers with indiscernible genders became problematic when trying to compare the draw an engineer gender data to previous research. In the future, it would be beneficial to administer the DAET prior to, and separately from, the VNOE. After the students have drawn their engineer, they then would receive the VNOE. We suggest the VNOE then also have an additional set of questions concerning the DAET including: What is the gender of the engineer you drew?; What is the ethnicity of the engineer you drew?; and What is the age of the engineer you drew? This would provide more information, while keeping the bias small, than the DAET used in this research.

Another challenge presented itself when 26.39% and 23.94% of Urban and Rural students, respectively, drew an engineer in which no action could be inferred. This means about a quarter of both populations did not contribute to the data on inferred actions of engineers. This could be due to the fact the DAET used in this research stated, "draw an engineer," rather than "Draw a picture of an engineer at work," as Knight and Cunningham (2004) used. However, this was done on purpose to increase the similarity between the DAET and its predecessor: the draw a scientist test (DAST) (Chambers, 1983; i.e. match the DAST prompt: "draw a scientist" more closely). In the future, as the checklist (Fralick, 2009), used to analyze the DAET (Knight & Cunningham, 2004), includes a category to evaluate the inferred action of the drawn engineer, it may be beneficial to add a prompt after "Draw an engineer (used in this study)"/"Draw an engineer at work," (Knight & Cunningham, 2004) to "What actions do engineers perform?"

This study has a relatively small focus in certain areas as it looks only at two schools in Kentucky, four teachers total, and 16 interviewed students. To lessen this limitation, and to confirm the results of this study, the study can be extended to more student and teacher groups across the nation. It would also be helpful to increase the amount of students interviewed, so we can more confidently distinguish a difference between the Rural and Urban student interviews.

FUTURE DIRECTIONS

The data collected and analyzed in this study provided many similar results to previous research, but it also sparked some new questions. For example, why were the Urban and Rural VNOE responses very similar but their interview responses noticeably different? Why did the middle level science teachers define engineers differently than their students? Why do middle level science students see engineers as mostly makers/workers doers (in this research and past research)? These sparked questions require further research in an attempt to answer them as these answers could help us develop students and teachers with more informed views.

Disclosure Statement

No potential conflict of interest was reported by the authors.

Notes on Contributors

Emily Paige Driessen – University of Kentucky, USA.

Ashley Dunn – University of Kentucky, USA.

Kameisha Sallah – University of Kentucky, USA.

Jennifer Wilhelm – University of Kentucky, USA.

Merryn Cole – University of Nevada, Las Vegas, USA.

REFERENCES

Alon, U. (2003). Biological networks: the tinkerer as an engineer. *Science, 301*(5641), 1866-1867. https://doi.org/10.1126/science.1089072

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education*, *97*(3), 369-387. https://doi.org/10.1002/j.2168-9830.2008.tb00985.x

Capobianco, B., & Rupp, M., (2014) STEM Teachers' Planned and Enacted Attempts at Implementing Engineering Design-Based Instruction.

Chambers, D. W. (1983). Stereotypic images of the scientist: The Draw-a-Scientist Test. *Science education*, *67*(2), 255-265. https://doi.org/10.1002/sce.3730670213

Davis, M. (1991). Thinking like an engineer: The place of a code of ethics in the practice of a profession. *Philosophy & Public Affairs*, 150-167.

Engineering is Elementary. (2018). The engineering design process. Retrieved on April 18, 2018 from https://www.eie.org/overview/engineering-design-process

Fralick, B., Kearn, J., Thompson, S., & Lyons, J. (2009). How middle schoolers draw engineers and scientists. *Journal of Science Education and Technology, 18*(1), 60-73. https://doi.org/10.1007/s10956-008-9133-3

International Technology Engineering Educators Association (ITEEA) (2007). Standards for technological literacy: content for the study of technology. ITEA Press, Virginia.

Karatas, F., Micklos, A., & Bodner, G. (2011). Sixth-Grade Students' Views of Engineering and Images of Engineers. *Journal of Science Education and Technology, 20*(2), 123-135. https://doi.org/10.1007/s10956-010-9239-2

Katz, Jonathan. (2009). Engineering Low on Students Radar. Industry Week. Retrieved on January 12, 2018 from http://www.industryweek.com/public-policy/engineering-low-students-radar

Kaya, E., Newley, A., Deniz, H., Yesilyurt, E., & Newley, P. (2017). Introducing engineering design to a science teaching methods course through educational robotics and exploring changes in views of preservice elementary teachers. *Journal of College Science Teaching, 47*(2) 66-75. https://doi.org/10.2505/4/jcst17_047_02_66

Kentucky Department of Education. (2014). Kentucky Performance Rating for Educational Progress School Report Card. Retrieved on February 9, 2018 from https://education.ky.gov/Pages/default.aspx

Kentucky Department of Education. (2017). Kentucky Performance Rating for Educational Progress School Report Card. Retrieved February 9, 2018, from https://education.ky.gov/Pages/default.aspx

Knight, M., & Cunningham, C. (2004, June). Draw an Engineer Test (DAET): Development of a tool to investigate students' ideas about engineers and engineering. *Paper presented at the annual American Society for Engineering Education Conference & Exposition*, Salt Lake City, UT.

McCraken, J. D., & Barcinas, J. D. T. (1991). High school and student characteristics in rural and urban areas of Ohio. *Journal of Research in Rural Education, 7*(2), 29-40.

National Aeronautics and Space Administration. (2017, July 17). *Engineering Design Process*. Retrieved from https://www.nasa.gov/audience/foreducators/best/edp.html

National Center for Education Statistics. (2017). *Search for Public Schools*. Retrieved on February 13, 2018 from https://nces.ed.gov/

National Research Council (1996). *The National Science Education Standards*. Washington DC: National Academy Pres.

National Research Council (U.S.). Committee on a Conceptual Framework for New K-12 Science Education Standards. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, D.C.: National Academies Press.

National Research Council Committee on Theoretical Foundations for Decision Making in Engineering Design. (2001). *Theoretical foundations for decision making in engineering design*. National Academy Press.

Next Generation Science Standards Lead States. (2013). *Next generation science standards: For states, by states*. Washington, District of Columbia: National Academies Press.

Next Generation Science Standards. (2013). Read the Standards. Retrieved from http://www.nextgenscience.org

Nguyen, D. Q. (1998). The essential skills and attributes of an engineer: A comparative study of academics, industry personnel and engineering students. *Global J. Of Engng. Educ. 2*(1), 65-75.

Pearson Jr, W., & Miller, J. D. (2012). Pathways to an engineering career. *Peabody Journal of Education, 87*(1), 46-61. https://doi.org/10.1080/0161956X.2012.642270

Smith, K., & Truxal, J. G. (1986). The definition of engineering: Continuing misunderstandings. *Change, 18*(5), 7.

Suburbanstats. (2018). Current Clark County, Kentucky Population, Demographics and stats in 2017, 2018. Retrieved on May 24, 2018 from https://suburbanstats.org/population/how-many-people-live-in-kentucky

United States Department of Labor. (2015, December 17). 2015 Median Pay. Retrieved on October 01, 2017 from https://www.bls.gov/ooh/architecture-and-engineering/home.htm

Woods, D. R. (1975). Teaching Problem Solving Skills. *Engineering Education, 66*(3), 238-243.