Exploring Perceptions of Disciplines using Arts-Informed Methods

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Abstract

This complete evidence-based practice paper describes preliminary results on a methodology used in a general first-year engineering program to explore students' perceptions of engineering through the use of drawings. Data were analyzed using an arts-based open-coding approach. Initial results provide a representation of students preconceptions about the discipline in terms of human, technical, process-based, and holistic/global aspects, which provides further evidence that arts-based methods are effective in capturing student perceptions of the engineering discipline.

Introduction

Many engineering programs offer first-year engineering programs with foundational courses for newly matriculated students to ensure they are prepared for their future academic and personal careers. These programs may exist across all engineering degrees or be targeted towards specific disciplines. In addition to their broad population, these programs can focus on a wide variety of learning outcomes including engineering and professional skills, orientation to a particular program, degree, or university, and to understanding the engineering profession itself [1], [2]. Beyond possessing the "technical" skills required to be successful in an engineering program, a significant factor in whether a student progresses in their degree is their *engineering identity*. This identity encompasses what they believe "engineering" to be and whether they view themselves as belonging to that ideal, profession, or educational program [3]. These ideas of "identity" and "belonging" are important as students that engage with engineering activities, develop social networks [4], and feel accepted in that identity [5], [6] are more likely to persist in their engineering program. The ability to persist, and consequently to be retained in the program, can be challenging for underrepresented populations as their views on engineering, and that of the larger cultural perception, may not align. Students who perceive less belonging or fit are likely to leave the program or university [7]. Hence, understanding student perceptions of engineering is important to develop introductory first-year programs that can help align students' preconceptions of engineering with what the engineering discipline really is, while at the same time developing opportunities for all students to be engaged with the discipline. This is important because some students' viewpoints may be very "individualistic" and "intangible" [5]. As can be seen, students' preconceptions of the engineering discipline when they start their academic program is crucial. However, many students entering the program come with narrow preconceptions or limited knowledge about the profession. One challenge instructors face is how to facilitate students' thinking about their own perceptions of engineering in a meaningful way.

Several studies have focused on understanding students' perceptions of engineering [8]–[12] at different levels and under different contexts including a study focused on first-year engineering students [7], however, these studies have focused on directly asking the students what they think. Although we consider that to be valuable information, we decided to take an alternative approach. We propose an arts-based method to capture student perceptions of engineering by extending existing drawing techniques used in K-12 education [13], [14], to first-year engineering students. For this study, we asked first-year engineering students to draw a visual response to the prompt: “What is Engineering?”. We believe this particular arts-based approach to be more effective than surveys [3], [5], [7] as it allows for a larger range of responses than possible on a single form. Furthermore, our approach may be able to target a larger set of students than possible with interviews [6] given the significant time needed to transcribe, code, and analyze recorded information.

Students’ perceptions of the engineering discipline are important because they can affect both academic performance and engineering-related motivational beliefs (i.e. motivation to persist in engineering). These motivational beliefs, including identification with engineering as a profession, in turn predict students’ major and career goals in engineering [15]. Therefore, it is important to explore how students perceive the engineering discipline, specifically, first-year engineering students who are just beginning to understand what being an engineer means and what role they can play in the engineering field.

Introductory engineering courses offer a good place to explore students’ perceptions of the engineering discipline. These courses are usually the classes wherein students are first exposed to more specific engineering activities during the first year in an engineering program. Extensive research has suggested that during the first year, students make important persistence-related choices. In fact, certain studies have suggested that students’ motivation to persist in an engineering degree tends to decrease during the first year [16]. Thus, it is necessary the inclusion of first-year students’ perceptions of the engineering discipline for a better understanding of courses and programs educational effectiveness. In the following sections we provide the frameworks that guided our study, our methods including how we collected and analyzed the data, and our preliminary results. We provide implications of our findings.

Theoretical Framework

In order to understand how first-year engineering students perceive what the engineering field is, we used the framework developed by Lattuca and Stark’s [17] theory on the academic plan model. The authors developed the model as a way to provide context and a tool to define academic curricula due to the lack of a comprehensive definition of it. The model provides a comprehensive overview of educational environments and considers not only the internal factors that influence a particular curriculum or program, but also several external stakeholders that have an impact on them. This model has been used previously in research about courses, degree programs, colleges and even institutions as a whole [16]–[22]. The academic plan model recognizes the importance of multiple internal and external key stakeholders and their roles influencing decision-making processes. The academic plan model provides a holistic approach to how we analyze students’ perceptions of one of the most important external influences (i.e. perceptions of the engineering discipline) as seen by one of the most important internal actors in the educational environment (i.e. the learners).

Similarly, our work was informed by the theoretical framework developed by Capobianco et al. [13]. They used the Draw An Engineer Test (DAET) to identify how elementary school students perceived an engineer. In their work, they were able to identify the actions performed by an engineer, and the artifacts used by an engineer from the students’ perspectives. They were also able to categorize an engineer into 4 different groups: (1) mechanic, (2) laborer, (3) technician, and (4) designer. Although this work has been used previously in engineering education research and provides insightful data on kids' perceptions of an engineer, we are taking a different approach. We are interested in understanding not the perceptions about the person (i.e. the engineer), but about the discipline. Hence, we used Capobianco et al. (2011) work to inform our approach to data collection and analysis and to frame how we developed our codes based on the engineering discipline rather than on the engineer as an individual.

Methods

In this study, we used a qualitative research methods approach. Qualitative research is based on the examination of a phenomenon in order to have a deep understanding of it by using data collection methods that are not necessarily quantifiable [18]. We used an inductive analysis approach since we were immersed in the details of the data, inductively seeking findings, and continuously interacting between data and analysis [19]. We made this methodological decision because our goal was to better understand students' perceptions of what engineering is by the way they draw their response to the question.

A typical activity to help the students understand their perceptions of the engineering discipline is to ask them "What is engineering?" However, instructors have been frustrated by the lack of depth in students' responses. We used a different approach to explore students' perceptions of the engineering discipline by taking an arts-informed methodology; instead of writing down their perceptions or talking with a peer, students are first asked to draw the response to the question "What is engineering?" Arts-informed approaches have been used before [20]–[24] in engineering education and other disciplines. These visual methods have been used to capture complex constructs that are difficult to verbalize, and promote participants' self-awareness [24], encouraging participants free and authentic expressions about the phenomenon [20]. It has been suggested that these types of approaches can facilitate more meaningful conversations between instructors and students regarding their previous preconceptions of disciplines. We used these methods to investigate students' drawings to observe how they organized their thoughts and chose to represent their views.

Data Collection

Data were collected from approximately 150 students enrolled in a first-year foundations of engineering course. Students participated in this activity during the first class at the beginning of their first semester in engineering (Fall 2018) across 6 sections of the course that were taught by two instructors. The instructors asked the students to draw the response to the question "What is engineering?" and they had about 10 minutes to finish their drawings. Students in the course had not yet enrolled in any engineering major, hence they were all considered to be general engineering students. We considered it important to conduct the data collection on the first day of class before students were familiarized with the course, since one of the learning outcomes is to provide students with a better understanding of the engineering discipline and to help them make decisions on how to select an engineering major. One of the primary objectives of the first-year program is to help students develop a sense of identity within the field of engineering, as well as understand basic engineering knowledge and skills, which in turn will support them in their selection of an engineering major (among 15 different options) and ultimately in their persistence toward their selected degree. Hence, we wanted to understand their initial preconceptions about the field when coming into college.

Data Analysis

Data were analyzed using open coding of the drawings and the analysis was conducted by 2 different researchers. Following art-based visual methodologies [20], [24], the coders started by using an open-coding process that consisted of coding every aspect of the drawing for a subset of drawings. Then, some of those initial codes were discussed until both researchers reached an agreement when differences in perceptions of the codes were encountered. The second step in the analysis was to develop some themes based on the grouping of some of the codes according to the common characteristics that emerged from the data, this helped us create our codebook (Table 1). Once the research team agreed on an initial codebook, two researchers proceeded to code the entire dataset. Throughout the process, the coders were making notes and memos of interesting aspects they considered required further discussion and had several think-aloud meetings to allow for further analysis.

Table 1. Codebook

Theme	**Codes**	**Definition**
Human	Brain	Refers to visuals that have a human representation. The picture includes people on it, or a representation of human things like collaboration, or emotions
	Change in Emotions	
	Collaboration/Teamwork	
	Includes People	
	Negative Emotions	
Technical	Bridge	Technical refers to the inclusion of things that represent the technical aspect of the engineering discipline. This theme includes students' representations of many different technical aspects from math and equations, to rockets and planes
	Buildings	
	Cars	
	Gears	
	Hand Tools	
	Math	
	Planes	
	Rockets	
	Use of Technology	
Process-Based	Outcomes	This theme refers to students' representations of a process rather than an individual thing. In involves sequential steps or the final goal represented by a clear expectation or achievement of solving a problem
	Processes	
Holistic & Global	Earth/Globe	In this theme students took a holistic approach to the discipline, usually in terms of attempting to solve the world problems, or there was a clear representation of holistic issues affecting the discipline
	Holistic Issues	

Limitations

The study has limitations related to the transferability of the findings. Since the sample represents less than 10% of first year engineering students enrolled in the program during that semester, it might not be representative of all first-year engineering students. In addition, the results should be considered with caution as the students' perceptions represent a specific institution with a specific student population. Other first-year engineering programs could have very different student perceptions of what engineering is. Another limitation is the fact that two of the researchers in this study were the professors teaching the participants in the study, which could have influenced how students responded to the exercise. Nevertheless, we consider this work valuable as an initial exploration of how, using a visual methods, art-based approach, we can understand what are the pre-conceptions that first-year engineering students have about engineering when entering college.

Measures of research quality

Limitations were mitigated by having a set of procedures to ensure the results were of acceptable quality. Firstly, multiple coders met and agreed on analysis suggested in qualitative inquiry [18], [25]. The coders met to discuss the early stages of data analysis. An agreement was reached after having discussions on initial differences in coding to increase the trustworthiness of the results. The confirmability of the results was strengthened further in two ways. The credibility of the findings were further ensured by a third researcher that acted as an external evaluator of the process, ensuring inter-rater reliability; and data analysis was discussed collaboratively and results were deliberated by all authors.

Results

While there was a degree of variation in how students chose to represent the field of engineering in terms of complexity and details (see Figure 1), our data provide a representation of engineering students' preconceptions of what engineering is when they start an engineering program. Our data are described in more detail by explaining each of our themes: technical, human, process-based, and holistic/global.

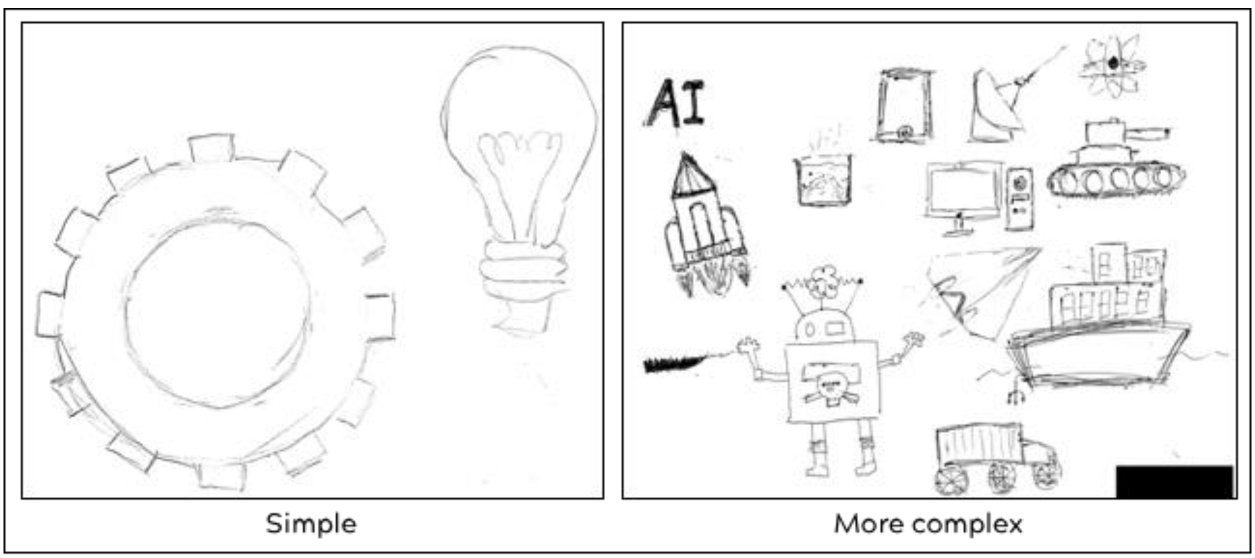

Figure 1.Comparison of the level of complexity of the draws

Table 2 contains the list with the codes that we identified along with the number/percentages of occurrences for each, and Table 3 contains a summary of the identified themes.

Table 2. Coding Results

Code	**Theme**	**Total Count**	**Percent**
Includes People	Human	77	50.7%
Cars	Technical	40	26.3%
Gears	Technical	35	23.0%
Outcomes	Process-Based	33	21.7%
Processes	Process-Based	32	21.1%
Use of Technology	Technical	30	19.7%
Buildings	Technical	29	19.1%
Bridge	Technical	25	16.4%
Hand Tools	Technical	24	15.8%
Collaboration/Teamwork	Human	23	15.1%
Planes	Technical	19	12.5%
Positive Emotions	Human	17	11.2%
Rockets	Technical	17	11.2%
Earth/Globe	Holistic & Global	15	9.9%
Math	Technical	14	9.2%
Change in Emotions	Human	7	4.6%
Brain	Human	6	3.9%
Negative Emotions	Human	4	2.6%
Holistic Issues	Holistic & Global	4	2.6%

Table 3. Summary of coding themes

Theme	**Total Count**	**Percent**
Technical	117	77.0%
Human	84	55.3%
Process-based	42	27.6%
Holistic & Global	16	10.5%

When evaluated on an individual coding basis we noticed that students chose to represent people most commonly, either as engineers or as stakeholders. The next highest code, cars, only had approximately half of the responses to those depicting people. Interestingly, when evaluated on a theme-level, we found that over 75% of students represented some technical aspect of engineering in their drawings, such as cars, gears, computers, bridges, etc. while only 55% drew something representing the human dimension of engineering. Following, we provide some examples for each theme.

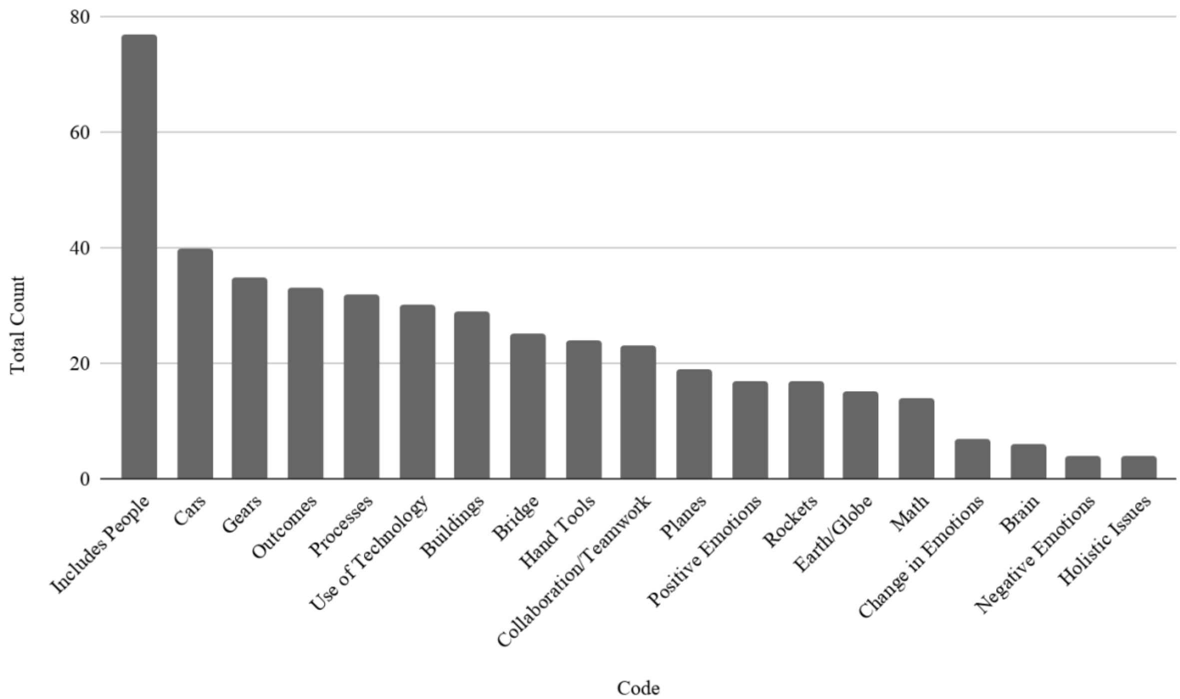

Figure 2. Coding frequency from student drawings

Human

As previously mentioned, people were the most commonly represented code. Most drawings included people, however, the most salient aspect was that in many cases students presented the engineering profession as the work that is developed by engineers. For example, in figure 3 we can see how students show that the engineers are the ones able to build cities and are involved with major aspects of society like transportation, resources, and can improve the lives of people.

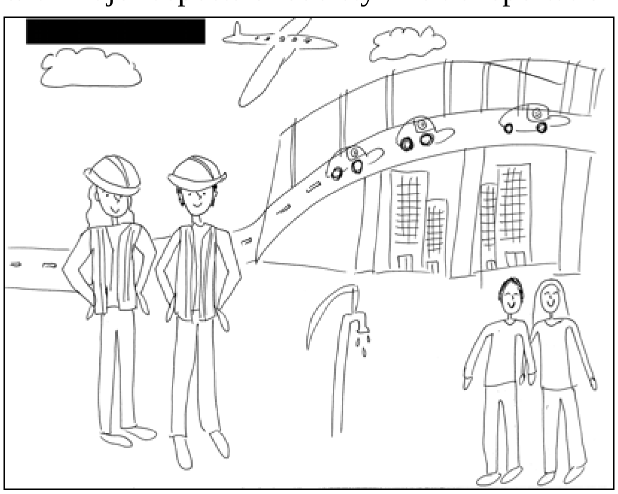

Figure 3. Representation of people

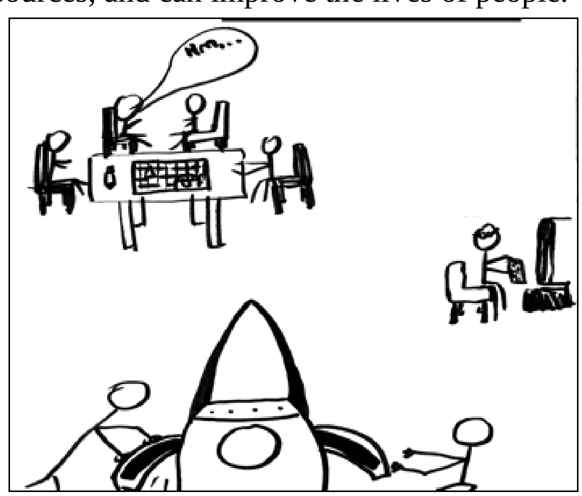

Figure 4. Representation of collaboration

Another common approach to showing people is to demonstrate how teamwork and collaboration are a key aspect of the engineering profession. Several participants included teamwork processes in their drawings as an approach to build something, to solve a problem, or simply seeing the engineering profession as a collaborative discipline. Finally, some students were able to include emotions in their data by drawing faces that demonstrated some type of emotion or change. For example, a sad face turned into a smiley face after a problem was solved using engineering.

Technical

The theme that collectively had more codes represented the technical aspects associated with the discipline. Several students related the engineering discipline to something technical represented by equations, a tool, a robot, gears, or some type of transportation (e.g. cars, planes, rockets). In some cases, the representation of the engineering discipline consisted in randomly placing all of these technical representations as can be seen in figure 5.

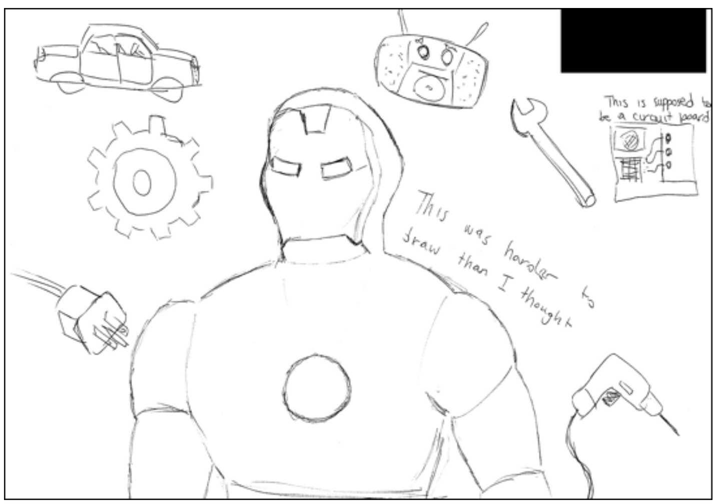

Figure 5. Representation of technical aspects

Process based

Students' representation of the engineering discipline also included a visualization of a process or an outcome. For some students, engineering was not presented as a static discipline, instead they considered it to be a dynamic one. Processes were presented as a way to solve a problem or as a way to build something step by step. This also included the representation of an outcome, that usually was also part of a process. For many students, responding to What is engineering? Involved making clear that the field needs to go through different stages when approaching an issue. We inferred from the data that this might speak to the complexities of engineering in terms of having multiple ways to solve a problem and the iterative characteristic of problem solving. Figures 6 and 7 represent a process and an outcome respectively in the same context (i.e. building a car).

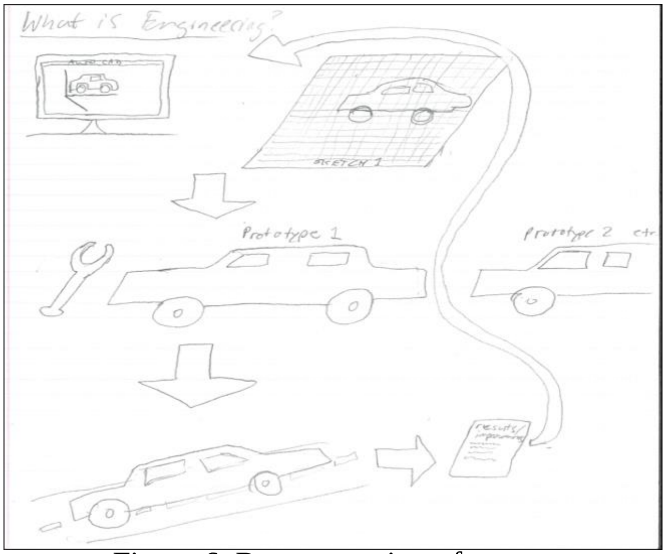

Figure 6. Representation of process

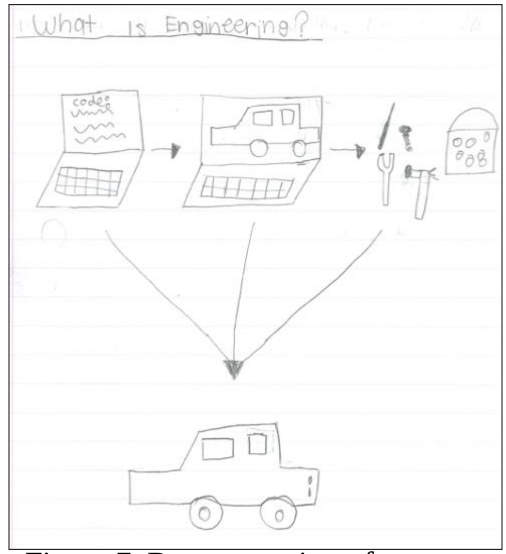

Figure 7. Representation of outcome

Holistic & Global

The last theme we found was related to how the students identified some aspects of the engineering discipline that had a holistic or global perspective. Several students included in their representation of the planet, and the impact that engineering has on it. Similarly, some students included some holistic descriptions when drawing their perceptions of the discipline (Figure 8). Figure 9 is also a good example of this theme, when describing engineering, the participant represented it by people working together towards a common goal, which we assume is to preserve the planet.

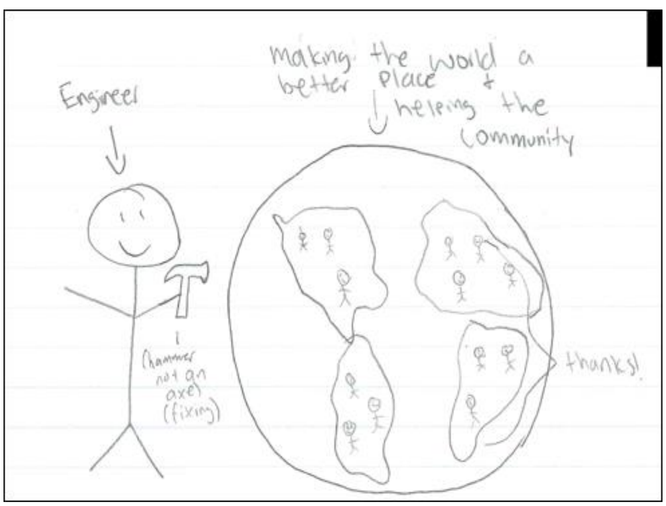

Figure 8. Representation of holistic

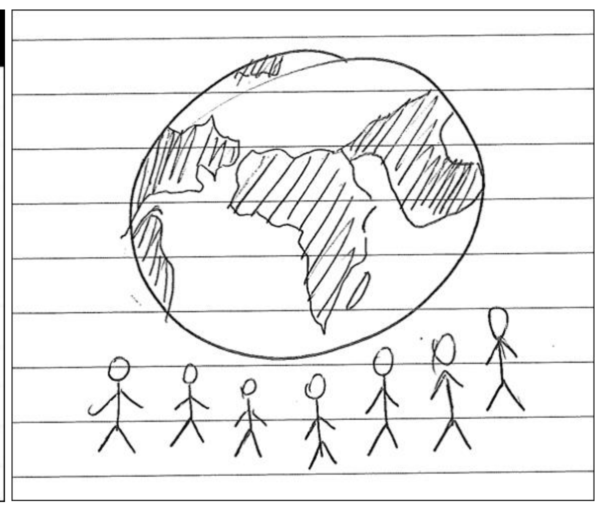

Figure 9. Representation of holistic/global

Discussion

Our findings confirm the model developed by Capobianco et al. [13] in which the authors presented an engineer, based on students' perceptions as a fixer, builder, someone that makes and uses vehicles, engines and tools ([13], p.304). This aligns with our *technical* theme where students were representing engineering by drawing tools, gears, vehicles, but also aligns with the rest of our themes since from a *human* perspective they were representing the field as one composed by people willing to build and fix, and also most of the draws that involved the *process-based* theme included the concept of engineers being in a process of fixing and building. Furthermore, different types of vehicles (cars, planes, boats) were commonly found on the drawings, aligning with previous work by Capobianco et al. [13].

Another aspect of Capobianco et al. [13] study that aligns with our results is that students perceive engineers as designers. We consider that our themes *human, technical, and process-based* all had some context where design was common across the data. For example, when drawing people (code: includes people), some students drew people on a table working with others creating a design, similarly when drawing some of the *technical* themes the buildings, cars, or a bridges they drew included part of the design process in the representation. Similarly, process and outcomes were often related to the design process.

One interesting finding from our study is that despite students mentioning in class that they wanted to do engineering because of a noble cause (e.g., bringing clean water to remote communities, developing a prosthetic device, finding alternative sources of energy) this was not salient in their drawings of the engineering discipline. Furthermore, despite students coming with an array of different interests in terms of the engineering majors they want to pursue, most of their draws of the engineering discipline had a very narrow focus in terms of disciplines, most focused on better-known disciplines such as civil, computer, and mechanical engineering (e.g., a bridge or a computer). This led us to be aware of how much we need to invest in showing them, through real examples, the broad scope of the engineering field and the multiple roles that an engineer can have in the workforce. This makes one of our projects to show them real engineers even more relevant [26]. This is a finding that was made visible to us by using arts-based methods that we feel would not have been as easy to discern using other, more traditional mechanisms.

Another finding that we anecdotally find interesting is that when first-year engineering students are asked “What is engineering?” at the beginning of their program, the response is often about a discipline that solves problems; however, through the drawings this was not explicitly depicted. In most of our data, the focus on solving problems came through a systematic process that included expected outcomes. Also, we were able to see other aspects of engineering that students consider that we had not seen before in their responses, such as working with others, connecting emotions to the discipline, engineering as a holistic field connected to the earth, and the perception that the discipline is relevant and important on solving the worlds’ problems.

Conclusions and Future Work

This study presented an alternative approach to understand students' perceptions of engineering by using visual methods, arts-based data collection methodology. Our results provide an overview of what students think engineering is at the beginning of their first semester in college. We were able to identify some aspects of their perceptions that we had not been able to identify before, after many years of asking them to verbally or through surveys express what engineering is. Some of the aspects that we could identify that were new included the perception that engineering is a collaborative discipline that requires interaction among people, and that for some of them, engineering should care about holistic issues and how the discipline fits into solving world problems. In addition, we were able to identify that students describe engineering with a very narrow perspective in terms of engineering disciplines and the multiple roles engineers can have.

We will expand this work in several ways. First, we already collected data at the end of the semester and we want to analyze the pre-and-post data to see if there were any major differences between students' perceptions after taking a foundation of engineering course. Similarly, we want to include several institutions in our study to be able to explore if we can identify any major cultural differences driven by institutional context. We also plan to include a second data stream to our research by including a narrative to their drawing so that we can triangulate the data and confirm our results.

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