"What the problem really was . . .": A preliminary exploration of youth problem definition in everyday contexts.

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Introduction

Throughout the history, one consistent theme is the interplay between technology and society. In persistent cyclical iteration, members of a society require new tools to meet new challenges, having been brought to these challenges by tools in the first place (see [1]). For example, the more advanced cell phone technology becomes, there is a higher demand for innovative features [2]. It stands to reason then that the technology serves a role greater than just a tool, as it is also an actor in the social space [1], [3]. Thus, technology has the potential, when paired with human designers and users, to make significant change and impact in current society [4]. Who are the human designers? With whom does this powerful role lay? Currently, engineers act as one of the main definers and designers of technology [5], [6]. Engineers serve in roles that not only technically design and manufacture technologies, but also define what problems are worth investment [7], [8]. This demonstrates both problems and opportunity for change: What does it mean that technological power rests with a group that historically and continually struggles with issues of injustice, inequity and exclusion [9], [10]? What does that mean for the types of problems being defined? How might problem definition be re-envisioned to be more inclusive?

Considering these questions means both acknowledging the lack of diversity in the engineering workforce and exploring ways to make trajectories into engineering more accessible and to make engineering culture more inclusive. Unfortunately, many White women, people of color, people who live in poverty and people whose identities intersect within these groups are kept from accessing engineering or persisting in the environment [6], [11]. This leads to lack of diverse perspectives in problem solving and the continuation of a perspective that is mainly Western, white, middle-class and male [6], [9], [11]–[15]. Further, the lack of access and inclusion begins much earlier than the college level. Traditionally, access to pre-college engineering education programming in classrooms could be described as limited and sporadic, with most such programs in extra-curricular or summer programming [16]–[19]. Such programs are important but depend on students being able to access them and may not be sustained over more than a few weeks’ time. Thus, issues of access and exclusion in engineering can begin in K-12 education: students without access to such programming have had less opportunity to develop an engineering identity, defined here as relating to, “…[students] earliest conceptions of engineering and potential career aspirations and how these conceptions and aspirations interrelate with their own later identity development as women and men, students, and prospective engineers” [20].

To begin to address these larger structural issues, scholars, practitioners, and policy makers generated standards that would demand attention to inclusive and robust science education, including engineering and technology concepts and practices. The inclusion of engineering in the Next Generation Science Standards (NGSS) was motivated by increasing access and interest, from the hope that, “[p]roviding students a foundation in engineering design allows them to better engage in and aspire to solve the major societal and environmental challenges they will face in the decades ahead” [21]. Adding and emphasizing engineering within the NGSS represents a unified and consistent effort to introduce engineering design equitably to students earlier in their educational trajectories, given the need for diverse perspectives in the problem-solving process. At the same time, however, the creation and
adoption of the Next Generation Science Standards (NGSS) has increased the urgency and volume of the discussion around engineering education at the K-12 level because so little is known about how to teach engineering concepts and practices to youth from a range of backgrounds and experiences.

Although potentially daunting, the newness of engineering design within the NGSS represents a unique opportunity not only to consider how to teach aspects of engineering design well, but also to experiment with using facets of engineering design to disrupt and resist inequitable and exclusionary notions of who can and cannot be engineers. Significant work on engineering and STEM identity has demonstrated the relationship between youths’ identification with the representations, knowledge, and goals of engineering and their sense that engineering is a field within their reach [16], [22]–[26]. Further, scholars in the field of science education have analyzed the everyday practices of young people as a way of merging the formal with the informal, and making classroom spaces more inclusive and meaningful for all learners [22], [27]–[29]. As Nasir and colleagues note, “often, people can competently perform complex cognitive tasks outside of school, but may not display these skills on school-type tasks” [30]. We maintain that it behooves researchers to conduct inquiry around the informal or every-day engineering practices of young people in the service of increasing accessibility of engineering content and practices. This focus of inquiry can begin to create counternarratives [31] to traditional deficit models of students learning engineering.

We seek to expand work in this area by exploring youth engagement in one specific facet of engineering design as defined by the NGSS: Problem Definition and Delimitation [21]. Taking steps to understand how youth define and delimit problems in their everyday lives begins to reveal connection points between informal and formal spaces that can be leveraged to make engineering practice relevant to more students and situate it in real context. To examine problem definition and delimitation as a practice, we drew on Crismond & Adams’s (2012) Informed Design Teaching and Learning Matrix and the NGSS definitions of Problem Definition and Delimitation [32]. Positioned as the product of scholarship of integration, the Informed Design Teaching and Learning Matrix represents an effort to consolidate discussions of early and experienced engineering design practices into a more easily consumable structure for researchers and practitioners. The Matrix outlines seven patterns that contrast beginning designers with informed designers. Two patterns, Problem Solving vs. Problem Framing and Skipping vs. Doing Research related to the practice of problem definition, providing us with an analytical lens of. We began with Crismond & Adams’s patterns focused on problem framing and doing research because these patterns map onto the NGSS standards for problem definition: “…stating the problem to be solved as clearly as possible in terms of criteria for success, and constraints or limits” [21]. This involves framing and researching to set success criteria. The purpose of this paper is to use these definitions as an analytical lens through which to view youths’ everyday experiences.

Methodology: Narrative and Counter-Narrative

With this preliminary analysis, we are specifically concerned with how two young women’s work on engineering problem definition and delimitation helped them begin to think like, and see themselves as, future engineers. The guiding research question was: How do youth from backgrounds traditionally marginalized in engineering discuss and engage with problem definition in engineering-related tasks and in their own lives? This preliminary analysis focuses on sharing the narrative perspectives of two Latina youth, Adina and Marie (pseudonyms).
Narrative inquiry rests on the assumption that humans, of all ages, are storied individuals, and “[t]he study of narrative, therefore, is the study of the ways humans experience the world” [33]. Given this perspective, we privilege both Adina’s and Marie’s understandings of their experience as important and able to stand-alone. Further, given the issues of inequity within the field of engineering, we present Adina and Marie’s stories as a counter-narrative to deficit models Latina youth in STEM [31], [34], [35]. As such, their stories serve to be in active resistance to the ideas that Latina youth disproportionately struggle or are deficit to White students in understanding science and engineering [36]. Making the voices of youth from marginalized backgrounds heard is an important action to continue to disrupt inequitable discourses around students [37]. To support the continued use of this method, we present our findings emphasizing Adina and Marie’s own words, with our analysis serving as a guide to connect back to problem definition.

Methods: Data and Analysis

The data used in this preliminary analysis are part of a larger design study. The purpose of the larger study is to create data-driven community engineering experiences that address educator needs in the Next Generation Science Standards. This larger effort is guided by design-based research (DBR) methods (e.g., [38]) to examine and refine extracurricular program opportunities and K-12 curricular units of study over multiple iterations in the life of the project. As such, students’ understandings and experiences informed the design of future iterations of the programming. The data set for this analysis were drawn from work in the first iteration of the project, occurring after school and in summer school with youth in one neighborhood of an economically challenged Midwestern city. The researchers worked with Adina and Marie in the community-based engineering program, aimed at empowering youth to define and create data-driven solutions for problems in their city using civil engineering and social science research. While working with these two youth, the researchers documented sessions via video, photography, and youth-produced work. Adina and Marie also participated in long-form interviews and a focus group.

We used the Informed Design Matrix as a lens to make sense of Adina and Marie’s stories [32]. Semi-structured, long-form interviews with Adina and Marie were coded deductively for images of problem definition informed design practices. These codes can be found in Table 1. Inductive codes were also created to note the context in which problem definition was occurring, in line with hybrid thematic analysis [39]. Themes presented below are representative of this coding and are discussed using large passages of Adina and Marie’s stories.

Table 1. Deductive codes adapted from Crismond & Adams (2012).

<table>
<thead>
<tr>
<th>Matrix Code</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Problem Definition: Beginning</td>
<td>Treat design task as a well-defined, straightforward problem that they prematurely attempt to solve.</td>
</tr>
<tr>
<td>Problem Definition: Informed</td>
<td>Delay making design decisions in order to explore, comprehend and frame the problem better.</td>
</tr>
<tr>
<td>Research: Beginning</td>
<td>Skip doing research and instead pose or build solutions immediately.</td>
</tr>
<tr>
<td>Research: Informed</td>
<td>Do investigations and research to learn about the problem, how the system works, relevant cases, and prior solutions.</td>
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Findings
Throughout our work with Adina and Marie, we documented instances of the two girls using informed design practices, specifically relating to problem definition. The likelihood of using informed design practices, however, appeared to be shaped by their knowledge of the problem and of the players involved. In what follows, we present 3 patterns in Adina and Marie’s approaches to defining and delimiting different kinds of problems.

Problem-defining in everyday life. In interviews, we asked both Adina and Marie to describe a recent problem they solved in their lives. The question did not prompt either respondent to explore an engineering problem; rather, they were asked to recount any situation they considered a problem but felt they solved successfully. Both girls answered this question by discussing disagreements between family members. Adina raised an issue between her younger cousins when she was caring for them:

“This weekend, [my] cousins were like fighting over the phone, so like, I took the phone from both of them and told them that they both had 15 minutes on the phone and that they had to keep alternating” – Adina (Interview 1)

In this statement, Adina articulated the solution she posed for her fighting cousins: alternating shared use of the phone. We then explored how Adina reached that solution with her cousins. When asked what information she needed to solve the problem, she responded:

“What the problem really was…because one of them wanted to play the game by themselves, one of them wanted to play a different game by themselves, and they were fighting because they wanted to play at the same time… They argue a lot, about a lot…so I had to like focus on what the main problem was, which was, at the moment, it was the phone. So, I had to see like…how they could each have for the game, or how long the game would take for them to finish at least like 4 or 5 levels…and then pass it on to the next person...” – Adina (Interview 1, emphasis added).

In this response, we see Adina engaged in practices of informed designers. She acknowledged that she had to explore, “what the problem really was” before she could reach a solution. Further, Adina sought to understand not just that her cousins wanted to use the phone, but also what aspects of the phone they were concerned about (the game) and how that aspect could work for each user (time to finish 4 or 5 levels). In this, she “delayed making design decisions in order to explore, comprehend and frame the problem better,” exhibiting informed design practice in her everyday problem solving [32]. In this everyday context that Adina relayed, she engaged in problem definition in as a way considered more thoughtful or informed by the discipline of design, mirroring practices we hope to encourage in formal K-12 engineering settings.

Problem-solving as community-based. Adina and Marie were also asked about whose opinions mattered in problem solving. Marie discussed several problems she solved recently, from a family dispute, to raising her grades. On this every-day problem solving, she noted:

“I mean, it’s good when there are a lot of different opinions of one thing because that…like that gives you more questions…there’s going to be even more…like, how do
I say it…it will give you more…more reasons why to understand or to understand somebody else’s view or point of view or observation or any other word that exists for that. It’s more important to have different people’s view and hear them…” – Marie (Interview 1, emphasis added).

In this statement, Marie articulated the importance of having multiple points of view when solving a problem. She goes on to explain that multiple viewpoints might raise more questions. In this, we note that Marie was discussing “doing investigations and research to learn about the problem” through connecting questions raised to understanding. Further, we see her emphasizing a need to, “build an understanding of users” before jumping to a solution [32]. To build this understanding, she discusses “hearing” the user. We see this as emphasizing authentic understandings of each persons’ viewpoint, rather than a superficial diversity of thought.

Responding to a question about the after-school program about why we considered researching different locations, she echoed this sentiment. Marie stated:

“If it’s like a thing, like our research, then it’s like better to have other people's opinions because I could have like an opinion, I could say this, or I could disagree with that…but then like, what if I’m wrong? We need somebody else to give their opinion. (Marie, Interview 1)

Here again we see Marie emphasize the need for different perspectives in problem solving. She expanded on this idea by emphasizing that her own thoughts on a problem may be skewed. This may be remedied by gathering more information (other’s opinions) to “enhance background knowledge” of the problem at hand [32]. In her interview, Marie discussed a desire to more fully understand a problem before attempting to create a solution. Both Marie and Adina demonstrated sophisticated ways of defining and understanding problems in everyday contexts.

The importance of context. In Adina and Marie’s discussions and work, we began to notice the importance of context [30], [40]. By this, we mean that Marie and Adina engaged with or discussed problem definition differently depending on the environment and the task at hand. To further illustrate this idea, we examined Adina’s work in the after-school program alongside discussions of other problem-solving spaces. At the time of working with us in the afterschool program, Adina was an avid participant in her school’s robotics program, helping code the robots. When talking about problem solving in robotics, Adina described different problem-solving behavior than with the example of her cousins. When the team’s robot was not functioning correctly, she describes:

“Our shooter wasn’t connecting. So, it wouldn’t shoot the balls. But we could collect them. So, we saw that the issue wasn’t with the collecting of the balls, but with the shooting and the holders for the shooters…We started testing…we started to move the motors around to test it where it was, to see if that helped any…trial and error” – Adina (Interview 1, emphasis added)

In this context, Adina describes her teammate’s and her behavior in terms that more align with beginning designers. They, “[t]reat design task as a well-defined, straight forward problem that
they prematurely attempt to solve” [32]. When asked about whose opinions are important in either of these two problems, Adina responded:

“It depends on the problem. Like, for robotics, it’s not really an opinion. It’s a fact that if the robot doesn’t shoot, we won’t get enough points to be one of the top teams. But when two people are fighting, there’s always two different sides of the story. So, you can’t really just go with what one person said…” – Adina (Interview 1, emphasis added)

In this, we begin to see a role of context and purpose [41], two concepts that were important in the design of the afterschool engineering program, emerging in how Adina viewed problem solving in this environment. In the robotics example, the problem seemed more straightforward than when her cousins were fighting. Adina’s acknowledgement that there are “always two sides of the stories” brings to mind the different stakeholders in engineering design problems [4], [23]. Connecting to the work that we were doing in the community engineering program, Adina was then asked about how she would describe the data-driven community engineering program:

“Cooperative…instead of us just saying, ‘one person choose where they want to work at or work with,’ we all came together and was like, ‘you know what, instead of doing… instead of working here, we should work here because this spot, or this place seems like it has more promise, or more of a future than this place…” – Adina (Interview 1).

In this answer, Adina acknowledged the cooperation she felt working on the engineering team. She also described how this collaboration with her peers served the purpose to, “[e]nhance background knowledge, and build understandings” of the community issue that the group was working on [32]. In this context, the group discussions about where in their community to research and redesign slowed the decision making and led to further exploration of the problem. For Adina, researching and understanding the problem extended beyond the group discussions and stakeholder conversations in the program. On her own time, she interviewed people in her neighborhood about elements they might like to see in a redesign of prominent park (Figure 1, Briana list document). Bringing her findings to the afterschool group, she noted that she had been excited about the problem and wanted her neighbor’s thoughts on it (Handley Field Notes). In line with her notion that, “there are two sides to every story,” we see that Adina felt a need to seek out more opinions, opinions of potential users, when defining the community problem in the program. This practice mirrors her example she described with her cousins. Thinking again about purpose and context, we see how Adina described her experience across different everyday settings and how these spaces elicited different problem definition practices, ranging from beginner-like to more
informed. As stated previously, this study was not meant to be generalizable. This nuance between the different ways Adina responds leads us to question how we can more thoughtfully consider context in discussions of youth engineering practice, and how certain types of problems might elicit more or less informed problem definition behaviors. These questions will be guiding future work.

Conclusions

In this preliminary analysis, we studied the ways in which two Latina youth, Adina and Marie, discussed and engaged with problem definition in a variety of contexts. Using the Informed Design Teaching and Learning Matrix, we saw images of both beginner and informed problem definition practices in how Adina and Marie discussed problem solving in their everyday lives. Further, we saw how context mattered for both Adina and Marie, eliciting differing practices in response to different problems. Though this analysis is not generalizable to all young people, Marie’s and Adina’s discussions of everyday practices illustrate that they are engaging in informed design thinking. Their abilities to do this work is, however, shaped in important ways by what they know about a situation. In Adina’s case, she knows her siblings’ wants and desires, she knows her parents’ expectations for child care, and she knows the parameters of her problem-solving situation (i.e., she can’t simply provide the children a second phone). In Marie’s case, her understanding of problem-solving as something a designer does not do alone seems critical to her ability to consider larger-scale problems that affect more than just her family or herself. Marie’s recognition that problem-solving and design must include multiple points of view demonstrates her awareness that complex problems could have multiple solutions, solutions that may not please all people or meet all needs. Similar to the findings of other scholars [29], [42], the young women’s awareness and skill in solving problems in everyday life can be leveraged to help them develop skill in more formal definitions of problem definition that they might encounter in engineering tools or other devices intended to address larger social problems.

From these youths’ experiences, we hope to contribute to the understanding of teaching engineering at the K-12 level, and how one might do that inclusively. Often times, youth experience a mismatch between what is expected of them in home environments and school environments [43], [44]. This can be particularly detrimental for youth from backgrounds traditionally marginalized in engineering [26]. From Adina and Marie’s stories, we see that problem definition can be a space where there is connection between the everyday and the formal. While more work is needed to understand this area, Adina and Marie’s experiences contributed to understanding how we might think to make the teaching of engineering, and specifically problem definition, in K-12 settings more inclusive. Overall, these findings add to the growing conversation inclusive classroom environments, that make more explicit connection between youths’ out of school knowledge and practices in school settings.
Works Cited


