"But There's a Lot of People It Would Help": An Initial Investigation of Youth Approaching and Engaging in Engineering Problem Definition

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Abstract: Although included in the Next Generation Science Standards, surprisingly little is known about youth engineering practice. This beginning analysis used sociocultural perspectives to investigate the approaches youth take to the foundational engineering practice of problem definition. Data were collected with seven youth at an engineering summer program implemented, in part, by the author. Data were coded and analyzed to produce themes related the ways in which these youth engaged in the problem definition work. Presented analysis discusses how youth leveraged personal and community knowledge within problem definitional work. This study suggests youth bring their everyday knowledges to bear in problem definition, while simultaneously developing technical orientations to the work. Overall, this study aimed to further complicate the ways youth engineering practice is conceptualized.

Introduction

The recent 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 (NGSS: Lead States, 2013; Pruitt, 2014). The idea of educators working with children as early as kindergarten on an engineering design cycle could be considered both exciting and daunting, especially given the lack of apprenticeship for teachers teaching or students doing engineering design. What's more, unlike other science content or practices such as argumentation or modeling (e.g., Osborne, Erduran, & Simon, 2004), little is understood about how youth approach or engage in engineering practices. How, then, should the field of education respond to the newness of engineering in K-12 spaces? We seek to expand work in this area by exploring how youth approach defining and delimiting problems. Problem definition is an important disciplinary practice in engineering design work and is called out as an engineering practice in the NGSS. We looked at this practice through a sociocultural lens, exploring what practices and knowledges youth applied to defining engineering problems. Although an initial analysis, the findings offer an in-depth perspective about youth engineering work as situated in young people's actual lives and experiences.

Conceptual frame

This work is motivated by trying to better understand how youth engage in problem definition and delimitation. Often, youth engineering is reduced to deficit narratives, where youth bring little to engineering because it is "too technical" (e.g., Bethke Wendell & Rogers, 2013; Brophy, Klein, Portsmore, & Rogers, 2008). In other instances, authors investigate how to increase young peoples' interest in engineering, but may not attend to the technical engineering processes (Purzer et al., 2014). To merge these literatures, we explored the ways youth defined engineering problems from both an engineering studies and sociocultural perspective. We drew on Crismond & Adams's (2012) Informed Design Teaching and Learning Matrix to better define problem definition and delimitation (Crismond & Adams, 2012). Two of its patterns, *Problem Solving vs. Problem Framing* and *Skipping vs. Doing Research* relate to what we call the "designerly behavior" of problem definition, providing us with a field specific frame for youth work. We also drew upon sociocultural literatures that emphasize learning as inherently situated in culture and, "challenge conventional ideas about classroom (academic) practices as being culture-free" (Nasir & Hand, 2006, p. 466). We consider how and in what ways youth draw upon everyday knowledges and commitments to do the work of problem definition and draw heavily on funds of knowledge literature, and funds as capital literature to inform this work (Moll, Amanti, Neff, & Gonzalez, 1992; Rios-Aguilar, Kiyama, Gravitt, & Moll, 2011). This perspective allows us not only to explore where youth knowledge came from (the fund) but also how it was leveraged (the capital) in defining engineering problems.

Study design

The research questions that guided the study are:

- In what ways did youth engage in a community engineering program approach and with defining and delimiting engineering problems?
    - What knowledges or practices do they articulate in initially defining problems?

- In what ways does their work look similar or different to canonical engineering work?

Context and participants

This study is part of a larger project focusing on community engineering program design. The project is a partnership at a large Midwestern university between the school of education and the college of engineering. The programming was designed to create data-driven participatory engineering experiences for youth and the research team using sensing and social science research methods, with a goal toward community action (Vakil et al., 2016). From this participatory model, we hope to engage *with* youth in research and subsequent engineering design that connects to their community, while also addressing the ways the NGSS conceptualizes science and engineering work. This analysis focused on programming that ran for 4 weeks between July and August of 2017 in a large Midwestern city. We worked with a youth summer camp program of a well-known community organization. This analysis focuses on 7 youth working with us in the program.

Data collection and analysis

As part of the larger project, we collected data that would help examine how youth approach and engage in the practice of problem definition. The analysis is bounded to the sessions focusing on problem definition, which occurred primarily in the first week of programming, though we collected data throughout the programming. We collected 8 hours of video data, youth-produced documents, and 6 reflections completed by all youth. We also collected pre-survey and focus group data as part of the larger project, which we used as secondary sources for triangulation. In the data analysis, we drew upon previous work in the science education literature describing youth knowledge and cultural practices towards disciplinary knowledge and cultural practices (Atman et al., 2007; Osborne et al., 2004). Looking at the youth-produced artifacts, surveys and video, we first used *invivo* and process coding (e.g., Saldaña, 2014) to examine what youth were saying and doing during problem definition. We compared this to descriptions of problem definition work in the design thinking literature. Finally, we developed codes related to Funds of Knowledge literature, noting where students referred to or used particular knowledge, practice or commitment in the problem definition process (Moje et al., 2004). We considered if and/or how a particular knowledge or practice was leveraged toward an end goal (Rios-Aguilar et al., 2011). In this analysis, we looked at defining a community engineering problem as the end aim. After the final coding cycle, we generated patterns and assertions most supported by the primary data and triangulated using other data sources.

Findings

In the following section, we begin to explicate findings that reflect ways in which youth approached the work of defining engineering problems. To do so within the space limitations, we chose two exemplar interactions transcribed from video that were representative of what we saw across sources. We argue the youth brought their everyday knowledges and practices to defining problems and began to engage work of designing while doing so. While more work is needed, these patterns speak to the need for greater nuance and complexity in researching, discussing and supporting youth engineering learning and work.

Youth leverage everyday knowledges in problem definition

In this program, problem definition seemed to be particularly well suited for youth to leverage their everyday knowledges and practices. Young peoples' knowledges and experiences continued to arise in the problem definition discussions and reflections that guided their project focus for the program. This occurred through the way they considered people in the design process, how they discussed and considered place, and how they leveraged personal experience in discussion. For example, youth drew upon their everyday knowledges in defining a particular problem focus of interest for their engineering project:

> Angela: We should do the bike thing…
> Jackie: No, but most times **people drive their cars**…
> Rosa: But there's a lot of **people that it would help**…
> Cesar: One day**, me and my cousin** we were riding our bikes and we were in the bike lane but this car… it came and took the bike place and then **we had to go into the street and then the sidewalk**… (Video Transcript, July 18, 2017)

In this short exchange, Angela references a stakeholder's idea of better marking bike lanes from a previous meeting. Leveraging her knowledge of the community, which is heavily structured around motor transport, Jackie responds to Angela with a potential limit to the problem space: Bike lanes may not assist the community in a way that the group would like. Rosa re-opens the problem space by offering a different perspective from her knowledge

of the community, that better marked bike lanes would help both cyclists and drivers stay safe (Author Field Notes, July 19, 2017). Prompted by the discussion of safe biking, Cesar seems to offer his experience with an unsafe biking situation as a support to considering this problem space. He discusses how he and his cousin were affected. Within this exchange, everyday knowledges are leveraged to shape the eventual defined and delimited problem space through argument and discussion. The conversation then appears to take a different direction, as Angela offers another aspect of bike safety for consideration:

> Angela: And they should have…if they had bike rails to put your bikes in…they should have a lock…but they should have a machine to **tell you what the lock numbers are**…
> Matteo: No, because then that might reveal them and if **they do it again then somebody might steal them…**
> Cesar: You should use the **type of locks where you type in your own code** then you close them, then you can use it to open them again… (Video Transcript, July 18, 2017).

In this part of the discussion, Angela proposes a locking solution for biking storage within the space. Matteo responds to suggestion with a concern about someone stealing the bikes. In this, he seems to leverage his understanding of crime within the community, a concern that he continued to raise in the work of defining problems, such as the groups' research plan (Author Field Notes, July 19th, 2017). His understandings of their community seem to prompt a design need, to attend to theft concerns in the area, that Cesar responds to, suggesting locks that would protect the users from theft. Across examples, young people leverage their everyday knowledge in ways that support the definition of a tangible engineering problem.

Young peoples' everyday knowledges support designerly behavior

Some of the ways young people in the program brought their everyday experiences to the work of problem definition aligned with the beginnings of "designerly behavior," as defined by the best practices of *Doing Research* and *Stakeholder Scoping* in the design thinking literature (Cardella et al., 2006; Crismond & Adams, 2012). In this, youth demonstrated the beginnings of these best practices through their approaches, questions and suggestions for more perspectives on the work from outside of our group. For example, in an exemplar discussion after engaging in a stakeholder meeting, youth discussed the role of stakeholders in the process:

> Angela: All the things that they said…when I asked them what they wanted to change about the area…**can't we add it to community problems**?
> Facilitator (author): Yeah! That sounds like a good idea.
> Jackie: But that's not like the **real, real problem**…
> Angela: I think we should be **now asking people** what they should want to change (Video Transcript, July 18, 2017).

During a stakeholder meeting, Angela had asked the panel what they would like to see improved in the community. She requests to add these community suggestions to the problem lists that are being created, seeming to acknowledge the importance of having multiple points of view when thinking about community problems. She goes on to say that the group, "…should now be asking people what they should want to change," suggesting an interest in learning more about the community problem spaces from those in the community. Further, her suggestion emphasizes a need to, "build an understanding of users" before jumping to a solution (Crismond & Adams, 2012). This response again mirrors beginning level technical work and best practices that many researchers define relative to problem definition and engineering design (Buchanan, 1992; Dorst, 2006).

Responding to Angela, Jackie states the areas of improvement suggested by the group are not the "real, real" problem. Checking in with her the next day about this statement, she clarifies:

> They might not be actually what we want to do…we might need to know more – Jackie (Handley Field Notes, July 19, 2018).

Jackie seems to suggest that there may be more to understanding a problem than just what someone suggests. In this, she begins to "…[delay] making design decisions in order to explore, comprehend and frame the problem better," exhibiting more technical design practice in her thinking (Crismond & Adams, 2012, p. 748). In this, youth began to demonstrate an ability and orientation towards doing the designerly work of problem definition through seeking to better understand the problem space.

Closing thoughts

Taking the above findings as a whole, a complex story emerges, one that requires scholars in the field of K-12 engineering education to treat discussions of youth engineering with more nuance. As such, the story becomes not *if* youth can do the work of engineering, but *in what ways* they engage in this work and *how* this work might look compared to traditional notions of engineering practice. As we continue to call for youth engineering design work in K-12 spaces, more exploration of specific engineering practices from multiple perspectives is necessary. Further, continuing to learn about how youth do the work of engineering allows the field to complicate the deficit narratives around youth engineering. From exploring these youths' experiences, we hope to put technical engineering perspectives and sociocultural perspectives into conversation to demonstrate that these can both inform and support each other. Often times, youth experience a mismatch between what is expected of them in home and academic environments (Bang, 2015). This can be particularly detrimental for youth from backgrounds traditionally marginalized in engineering (Calabrese Barton & Tan, 2009). Research using sociocultural frames, such as tracing youths' everyday knowledge in and beyond their engineering work, can begin to illuminate these discrepancies between spaces youth may experience in engineering work. Combining this with technical lenses can help the field better develop engineering opportunities for youth that are both honest to the discipline and connect to youths' everyday experiences and commitments in meaningful ways.

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