Work in Progress: Citizen Scientists' Description of an Engineer

Dr. Kenneth Stewart, Angelo State University

Dr. Kenneth L. Stewart is retired professor of sociology at Angelo State University where he served on the faculty from 1975 through 2018. He was also among the founding faculty members of the Master of Public Health Degree at Texas Tech University Health Sciences Center. Dr. Stewart's scholarly work has a distinctively interdisciplinary flavor overlapping the fields of sociology, history, political science, public health, and engineering. He is author or co-author of three scholarly books and two edited volumes. Sixteen of his scholarly articles have been published in refereed journals or as book chapters. He has delivered professional presentations in venues including the Cancer Prevention Research Institute of Texas, the Crossroads Conference on Rural Health, Texas State Historical Association, American Sociological Association, and the Oxford Round Table at England's Oxford University. As director of Community Development Initiatives at ASU, Dr. Stewart implemented numerous community research, program evaluation, and community organizing projects. He continues to be an advocate for the vulnerable members of communities in West Texas.

Dr. Daniel Ivan Castaneda, James Madison University

Daniel I. Castaneda is an Assistant Professor at the Department of Engineering at James Madison University.

Daniel earned his PhD in 2016 and his Master's in 2010, both in civil engineering from the University of Illinois at Urbana-Champaign. He previously earned his Bachelor's in 2008 from the University of California, Berkeley. After graduating from Berkeley, Daniel worked as a Systems Analyst at ATAC Corporation – a Federal Aviation Administration subcontractor specializing in analytical software solutions – before enrolling at Illinois.

Dr. Daniel Castaneda has research interests in alternative cements and concrete, fast-setting repair materials, freeze-thaw durability of concrete, instrumentation of infrastructure, residual stress modeling, rheology, and quantitative image analysis. He has taught a variety of courses including civil engineering materials, dynamics, engineering design, engineering economics, matrix analysis, mechanics, probability and risk in engineering, statics, and structural analysis.

Dr. Azadeh Bolhari P.E., Angelo State University

Dr. Bolhari is currently an Assistant Professor of Environmental Engineering at Angelo State University. She has previously served as a lecturer at University of Colorado-Denver. Dr. Bolhari hold her PhD from Colorado State in Environmental Engineering. Her research interests include: fate and transport of contaminants, resilient communities, citizen science, engineering identity, and retention of minorities in engineering.

Work in Progress:
Citizen Scientist Descriptions of Engineers and Engineering

Abstract

Observations from a citizen science engineering research project revealed implications for the formation of engineering students. Citizen scientist participants engaged in a months-long project to design, build, and use rainwater harvesting tanks. Their perceptions toward engineers and engineering were gathered from interviews and focus groups conducted at the start, interim, and conclusion of the project. Through a domain analysis of the transcripts, the authors found that the citizen scientists' perceptions toward engineering as a process were greatly influenced by their participation in the project. However, their perceptions of engineers as persons did not change. Interestingly, the citizen scientists volunteered their own "funds of knowledge" about engineering skillsets and "habits of mind" but did not connect their personal traits and skills to engineering or engineers. Since the rainwater harvesting project of the citizen scientists was similar to the open-ended, project-based learning experiences of many engineering students, we posit that student perceptions of the engineering process are strongly influenced by project-based learning, but the impact on their engineering identity is limited. We explore the theoretical possibility of using asset-based community development (ABCD) mapping techniques to connect personal student strengths to communities in the context of open-ended, project-based engineering design.

Introduction

Engineers design solutions to make things work in a context. Accordingly, engineering students must develop this thinking capacity in their undergraduate programs of study.

As part of this practice, engineers solicit input from community members who are not wholly trained in the design principles of the field. Most often, community stakeholders provide input through a variety of human-centered design techniques [1-2]. Another approach is Polak's (2008) design revolution that demands input from the most vulnerable, marginalized and under-informed community members [3].

Engineers translate the needs of a community into actionable designs in both approaches. However, regardless of the approach, the practice of engineering establishes hierarchical relationships posturing the engineer as someone who knows more of a community's needs than its citizens do. If these relationships produce acceptable results for engineers and communities, then the relationship reinforces the development of a hierarchal power mindset in engineering students.

This hierarchical mindset holding that 'engineers know more' can be difficult to dispel in the development of engineering students. To counteract the attitude, educators present shocking case studies and anecdotal stories of engineers swooping into developing neighborhoods, countries, and global regions only to leave behind destructive and unsustainable results. Service-learning projects now call for developing a new generation of professionals to work through organizations

like Engineers without Borders to be change-makers, peacemakers, social entrepreneurs, and facilitators of sustainable human development [4-5].

Our work in progress focuses on how citizen science-based engineering projects might help dispel the hierarchical power mindset and foster more equitable relationships between communities, engineers, and engineering students. We focus on a citizen science engineering research study (supported by NSF Award # 1744006) and extrapolate implications to engineering formation in students.

Methodology

We approach the broad issues raised by the hierarchical mindset formed in engineering students from the vantage point of a research project exploring the development of drought-resilient communities by rainwater harvesting in a semi-arid region in the southwest United States [6]. The project recruited low-income Latinx families because they represent a vulnerable population who often do not participate in citizen science projects or other civic developments. Members of the Latinx community are also under-represented in engineering disciplines.

Five low-income households, including adult householders and four children, participated in the project (Table 1). Four of the five are Latinx households and one is black or African-American. Three households speak Spanish as the primary language at home. Four adult heads of households are female, and one is male. One earned a master's degree at the local university, but the other four have limited educational attainment. The household heads range in age from 25 to 72 years. The children are 8-16 years old.

A research team repeatedly interviewed all 5 households' participants – dubbed citizen scientists – to gather attitudes and perceptions toward engineers and the citizen science engineering project as it progressed. Only two households completed the project to its end, which required a commitment lasting approximately six months to construct a rainwater harvesting tank and to collect rainwater samples for water quality testing. The other families initiated the project and exited at various points before reaching the end of the project, yet they still participated in various interviews.

A civil engineer, an environmental engineer, and a sociologist analyzed interview transcripts to identify citizen scientist attributions describing engineers and engineering. The analysts used a domain analysis approach [7] to classify attributions according to a taxonomy based the framework developed by Grubbs *et al*. (2018) for engineering education [8]. The framework incorporates three dimensions of literacy: knowledge of engineering; engineering skills; and engineering habits of mind. A Delphi method required the three analysts to reach consensus on classification of each attribute through repeated review and discussion of the interview transcripts [9]. Appendix A includes taxonomy used by the analysts to classify attributes generated by the citizen scientists who participated in the rainwater harvesting project.

Table 1 Demographic Traits of Participating Households					
Household Number	1	2	3	4	5
Age of Householder	35	72	27	42	25
Gender of householder	F	M	F	F	F
Race/ethnicity	Black	Latinx	Latinx	Latinx	Latinx
Education of householder	High School	Primary	High School	High School	Master's Degree
Primary language at home	English	Spanish	Spanish	Spanish	English
Child participants	1	2	0	1	0
Age of children	11	10, 8	n/a	16	n/a
Project completion	N	Y	N	Y	N

We now compare the attributes of the citizen scientists participating in the rainwater harvesting project to the results of contemporary studies describing engineers and engineering.

Contemporary Studies

Studies about student descriptions of engineers and engineering comprise one thread of current research. Originating from Mead and Metraux's 1957 study of high school student images of scientists [10], more recent research has focused on comparing K-12 student drawings of scientists and engineers [11-14].

The Fralick *et al*.'s 2009 [13] study is of interest to our work in progress because it developed a robust taxonomy for comparing drawings of scientists (DAS) and engineers (DAE) by middle school level students (see Appendix A). They developed three general categories: species; objects; and inferred actions. We employ the Fralick *et al*. taxonomy to identify intersections between the descriptions of engineers and engineering we collected from our citizen science participants and images produce by K-12 students.

Similarly, we employed another contemporary taxonomy developed by Lucas and Hanson [15]. Their classification system is focused on how engineers think and act, namely their habits of mind. Lucas and Hanson derived the taxonomy from a mixed-methods analysis using qualitative interviews, an online survey, and expert panel discussions conducted with members of the Royal Academy of Engineering in the United Kingdom. The results feature seven general learning habits of mind (L-HoMs) which inform six specialized engineering habits of mind (E-HoMs) (see Appendix A). Again, we use the framework to identify intersections between the descriptions of our citizen science participants and the foundations of engineering thought and action as represented by British engineers.

Intersections

Table 2 counts the qualitative artifacts produced by the citizen scientists in the rainwater harvesting project and coded by the authors as expressions of various attributes about engineers and engineering.

Table 2
Intersections of Qualitative Artifacts Produced by Citizen Scientists, Middle School Students, and British Engineers

Households	Artifacts	%	Engineer Artifacts	%	Engineering Artifacts	%	Intersections with Current Studies*	%
Household 1	8	11.9%	4	20.0%	4	8.5%	9	7.4%
Household 2	16	23.9%	5	25.0%	11	23.4%	27	22.3%
Household 3	2	3.0%	1	5.0%	1	2.1%	4	3.3%
Household 4	38	56.7%	9	45.0%	29	61.7%	75	62.0%
Household 5	3	4.5%	1	5.0%	2	4.3%	6	5.0%
Project Completed Households	54	80.6%	14	70.0%	40	85.1%	102	84.3%
Total	67	100.0%	20	100.0%	47	100.0%	121	100.0%

*Instances of artifacts coded by the authors intersecting with the Fralick *et al*. [13] and Lucas and Hanson [15] taxonomies.

Overall, the citizen scientists produced 67 artifacts (see Table 2). The majority (47 or 70%) expressed attributes about engineering activities, while the remainder were attributes about engineers as people. Significantly, the participants from the two households that completed the project produced 85.1% of the engineering attributes, 70% of the expressions about engineers, and 80.6% of all the artifacts.

To understand how attributes changed with experience, we focused our analysis on artifacts produced by the citizen science participants from the households that completed the rainwater harvesting project (see Appendix B). The research team completed nine total interviews and focus groups with households two and four. Each household had an entry and exit interview. Five interim focus group discussions or interviews occurred between the entry and exit discussions. Table 3 identifies engineer attributes classified by the authors. Some attributes may have been expressed more than once in an interview or focus group. For our purpose, however, Table 3 identifies "unique" attributes that were produced at least once in a session by participants. The table also reports intersections with the Fralick *et al*. [13] and Lucas and Hanson [15] taxonomies.

The rows in the table do not indicate matching attributes and intersections. Instead, the columns show aggregates of unique attributes that intersected with collections of categories from the Fralick *et al*. [13] and Lucas and Hanson [15] taxonomies. Green shaded items originate from the entry interviews, while those with red shading are from exit interviews. Items originating from the interim sessions appear with yellow shading.

Table 3
Intersections Based on the Authors' Classification of Attributes about Engineers Produced by Citizen Scientists from Households that Completed the Rainwater Harvesting Project

Attributes Collected from Two Entry Interviews		
Authors' Classification	Fralick *et al*. [13] Intersections	Lucas & Hanson [15] Intersections
Gender: Male	Gender: Male	L-HoM: Curiosity
Planner/Designer of Construction Projects	Other attributes: Glasses/goggles	L-HoM: Ethnical consideration
Curiosity	Objects: Blueprints	E-HoM: Improving
Tech-savvy	Objects: Measuring Tools	E-HoM: Creative problem solving
Design: Improve	Objects: Math symbols	E-HoM: Systems thinking
Skills: Using Tools and Materials	Objects: Other people	E-HoM: CEM- Making things
Skills: Mathematical reasoning	Inferred actions: Designing	
HoM: Executive Functioning	Inferred actions: Explaining	
HoM: Systems Thinking		
HoM: Sustainability thinking: Environmental impact		
Attributes Collected from Five Interim Interviews or Focus Groups		
Authors' Classification	Fralick *et al*. [13] Intersections	Lucas & Hanson [15] Intersections
Gender: Male	Gender: Male	
Intelligence	Objects: Signs of thinking	
Attributes Collected from Two Exit Interviews		
Authors' Classification	Fralick *et al*. [13] Intersections	Lucas & Hanson [15] Intersections
Design: Improve	Inferred actions: Designing	E-HoM: Improving
HoM: Systems Thinking		E-HoM: Systems thinking

Citizen scientists were most prolific at generating ideas about what engineers are like during the entry interview stage of the rainwater harvesting project. Participants from the two households that completed the mission produced 10 unique thoughts about engineers in the entry phase. Some thoughts reckoned with popular stereotypes like the implicit assumption that engineers are male. When asked whether they know anyone who might become an engineer, for instance, one adult female project participant explained:

> "I have a kid at school, … she is learning English …, and I'm always pushing her like don't let that stop you, you raise your hand, you participate! Sometimes she tells me, 'but I'm a girl' and I'm like, 'more power to you girl,' so she is one of those kids I think."

Other ideas from the entry interviews ranged from viewing engineers as curious or tech-savvy people to individuals who possess various skills like mathematical reasoning. However, the most sophisticated ideas defined engineers in terms of certain habits of mind. For instance, and adult citizen scientist though:

> "For me, an engineer is someone that probably can look at something and, figure out why it's moving a certain way or, how it could be made better."

One of the children participating in the project saw an engineer as, "A person that helps the environment by creating things that will help the environment."

Overall, the authors identified 15 unduplicated intersections between the concepts used by citizen scientists to describe engineers and the taxonomies revealed in the Fralick *et al*. [13] and Lucas and Hanson [15] studies. Interestingly, only one additional unique trait was attributed to engineers during the interim and exit sessions with rainwater harvesting participants. One of the children reflected on her father as being like an engineer during one of the interim focus groups. "He is intelligent", she claimed, "I have learned from him." All other attributes and intersections during interim and exit meetings mirrored items originally articulated during the entry interviews.

Attributions describing engineering process and activities showed a different pattern. Like the previous list, Table 4 shows aggregates of unique attributes that intersected with elements from the Fralick *et al*. [13] and Lucas and Hanson [15] studies. Again, green shaded items are from entry interviews, while red shading indicates exit interview artifacts and yellow depicts those from interim sessions.

Table 4
Intersections Based on the Authors' Classification of Attributes about Engineering Produced by Citizen Scientists from Households that Completed the Rainwater Harvesting Project

Attributes Collected from Two Entry Interviews		
Authors' Classification	Fralick *et al*. [13] Intersections	Lucas & Hanson [15] Intersections
Engineering Skills - Using Tools and Materials	Objects: Other people	L-HoM: Reflection
Knowledge - Engineering Disciplines	Inferred actions: Making	L-HoM: Ethical considerations
Knowledge - Engineering Standards and Codes	Inferred actions: Designing	L-HoM: Collaboration
HoM - Sustainability thinking		E-HoM: CEM-Making Things
HoM: Executive functioning		E-HoM: Systems thinking
HoM: Collaboration		E-HoM: Improving
Attributes Collected from Five Interim Interviews or Focus Groups		
Authors' Classification	Fralick *et al*. [13] Intersections	Lucas & Hanson [15] Intersections
Communication: Defining roles & expectations	Objects: Other people	L-HoM: Creativity
Knowledge - STEAM connections	Objects: Building tools	L-HoM: Reflection
Design: Ask - Identify needs and constraints	Inferred actions: Making	L-HoM: Collaboration
Design: Create - Build a prototype	Inferred actions: Designing	L-HoM: Curiosity
Design: Imagine - Develop possible solutions	Inferred actions: Experimenting	L-HoM: Resourcefulness
Design: Improve - Redesign as needed	Inferred actions: Operating	L-HoM: Resilience

Table 4 continued

Skills: Technical communication & documentation - communication with constituents	Inferred actions: Explaining	E-HoM: CEM-Making Things
Skills: Developing physical models - Prototypes		E-HoM: Adapting
Skills - Using Tools and Materials		E-HoM: Creative Problem Solving
Skills: Designing under constraint		E-HoM: Improving
Skills - Project Management		E-HoM: Problem finding
HoM - Creativity		E-HoM: Visualizing
HoM - Efficacy		E-HoM: Systems thinking
HoM: Executive Functioning		
HoM: Collaboration		
HoM: Sustainability thinking - Resiliency		
HoM: Optimization		
HoM: Systems Thinking		
Attributes Collected from Two Exit Interviews		
Authors' Classification	Fralick *et al*. [13] Intersections	Lucas & Hanson [15] Intersections
Design: Improve - Redesign as needed	Objects: Danger	L-HoM: Resourcefulness
Skills: Using tools and materials	Objects: Books	L-HoM: Curiosity;
Skills: Research and Investigation	Objects: Studied plants	L-HoM: Resilience
HoM: Sustainability: Environmental impacts	Inferred actions: Making	L-HoM: Ethical considerations
HoM: Ethical considerations	Inferred actions: Designing	E-HoM: Adapting
	Inferred actions: Experimenting	E-HoM: Visualizing
	Inferred actions: Explaining	E-HoM: Creative problem solving

During the entry interviews, citizen scientists generated only six unique artifacts about engineering as a process (Table 4) compared to 10 (Table 3) about engineers as persons. However, participants added 18 unduplicated features about engineering processes and activities after the entry phase. These included 15 unique artifacts during interim sessions and 3 in exit interviews. Post-entry attributes about engineers, on the other hand, included only one unduplicated artifact.

The authors also identified 24 unduplicated intersections between the citizen scientists' thoughts about engineering and categories in the Fralick *et al*. [13] and Lucas and Hanson [15] taxonomies. Nine of these were originally identified in the entry interviews and 15 were associated with the interim and exit focus groups and interviews. Overall, the rainwater harvesting citizen scientists were much more prolific in generating thoughts reflecting what engineers do as opposed to ideas about what engineers are like. This was especially true of the interim and exit stages of the project.

Two more qualitative features distinguish the artifacts about engineers from those about engineering. First, the descriptions of engineers were distinctly objective from the viewpoint of the citizen scientists. One child participant, for example, responded to a question of how he defines an engineer, saying, “I usually think of somebody who's like real tech-savvy and it's like it's a terrible stereotype, but usually somebody who's like, pretty tall and lanky and wears glasses.” Another child answered, “A person that helps the environment by creating things that will help the environment.” One adult, responding to a query about knowing someone who is an engineer, responded:

> “So, there are no engineers in our family. We have a couple of friends, but they live in the Austin area. One of them works at NASA in Houston, and then the lady works at, I don't know, something with buildings, but they're the only ones that I know.”

These statements are about “others” imagined or known to an engineer. In this sense, the engineer is an object that falls outside of the life experience of the citizen scientist.

In contrast, the descriptions participants offered about engineering most often expressed something similar to what the UN Environmental Programme defines as indigenous knowledge, “… broadly defined as the knowledge that an indigenous (local) community accumulates over generations of living in a particular environment” [16]. Reflecting on previous experience before getting involved with the rainwater harvesting project, one adult citizen scientist reported:

> “I have built houses … of brick, and here I made my house with wood. It came out poorly built, but it was built. I made a labyrinth, but everything turned out well. I made a room 3 feet by 6 feet. Look at that grand room. It can’t even fit you or anything else.”

One of the children responded to a question of what needs to be done to ensure a project goes well:

> “I think finding people that you can trust especially when you're like a perfectionist, because you see people do things and you know they're not doing it right. So, you don't really trust anyone with the things that you want done ... so I think, definitely, trusting other people.”

Expressions like these dominate the citizen scientists’ descriptions of engineering processes and activities. Such descriptions are embedded in their own lived experience.

Discussion

Observations from the citizen science project have implications for engineering education. The rain harvesting intervention strongly influenced citizen scientist perceptions of engineering as a process, but there was less influence on their preconceived notions of engineers as persons. The intervention was essentially an open-ended, project-based challenge where citizen scientists used

their own knowledge to design and construct a cylindrical or rectangular tank capable of retaining rainwater.

Since engineering students undertake similar projects in their collegiate experiences, drawing a parallel may be in order. Open-ended, project-based interventions may strongly influence student perceptions of engineering process, while not affecting preconceived notions of engineers as persons. If observations from citizens scientists apply, the implications for formation of student engineering identity call for more curricular experiences guiding students to view themselves, and others like themselves, as engineers or future engineers. This is of paramount importance for persistence within the major by underrepresented groups in engineering such as women and minorities.

Another helpful observation from the rainwater harvesting project focuses on the funds of knowledge [17] that citizen scientists brought with them into the engineering experience. While participants did not see their own skills as qualities that engineers have, each household did articulate and utilize traits and habits of mind that are highly valuable in engineering practice. This 'indigenous knowledge' [16] held by the participants aided the households in surmounting engineering-like challenges in the rainwater harvesting project, as well as past projects implemented by household members. Open-ended, project-based efforts to affirm students' lived experiences in engineering education are akin to drawing out their indigenous knowledge.

A lack of development in engineering identity strongly influences students leaving engineering curriculum and engineering practice. Critical identity dimensions such as gender, socioeconomic status, or language heritage, are sometimes viewed as deficiencies by students in thinking about engineering identity [18]. In our study, for example, a participant shared the story of a young Latina with strong math skills who could not envision herself as an engineer because of her challenges in learning English as a second language. Engineering identity [19], in part, is a process of envisioning the present self as a future engineer self.

A potential means for an engineering instructor to actively affirm a student's lived experiences is to develop open-ended projects that will encourage the student to articulate personal strengths in the context of engineering design. Individual asset strength mapping (IASM) [20] used in "teaming" can be blended with asset-based community development (ABCD) [21]. ABCD mapping entails identifying the strengths held by members of a target community. Thus, blending IASM with ABCD mapping in engineering education can empower both the student and the community.

Recognizing the difference between asset mapping and needs assessment [22] is key to developing effective blended IASM and ABCD mapping projects for engineering education. A needs assessment conducted for engineering is normally limited to providing a technical solution rooted in community needs as grasped by engineers. As such, needs assessments usually establish the hierarchical mindset and encourage delivery of engineering solutions irrespective of a community's ability to sustain it after the intervention is completed. ABCD solutions, on the other hand, focus on incorporating the community's context-specific strengths into the

engineering plan. The resulting plan itself provides a roadmap for the community to sustain the intervention long after completion.

Our work in progress has drawn from a wealth of knowledge offered by a small sample of families who participated in a citizen science engineering project. To further develop the findings, a major curricular intervention must be sought so that student perceptions and attitudes toward engineers and engineering can be captured and assessed before and after two engineering design projects. One engineering design ought to be typical open-ended intervention aimed at fostering development of engineering skills. The other design should seek to blend IASM and ABCD mapping into an open-ended intervention aimed at developing engineering skills and engendering community sustainability. Both designs ought to foster a student-generated narration that connects their own assets as individuals to the target community assets, engineering skill sets, and engineering habits of mind.

In such a study, appropriate quantitative measurements should be combined with sample sizes sufficient to yield the statistical power necessary to test our propositions that (1) typical open-ended, project-based educational interventions strongly influence student perceptions of engineering process, while not affecting preconceived student notions of engineers as persons; and (2) blending IASM with ABCD mapping in open-ended engineering education interventions can empower both the student and the community. Student-generated narration from the study should be analyzed to drill down into the dynamics of change in student attitudes, perceptions, and self-identity in the context of the two engineering designs.

Conclusion

At present, pedagogical efforts that involve the community in open-ended, project-learning challenges might only influence a students' perception of engineering as a process, but not necessarily influence a students' perceptions of engineers as persons, or themselves as future engineers. We posit this based on the outcomes of an open-ended, project-based citizen science engineering project involving families from a vulnerable population who were queried through entry, interim, and exit focus groups to elicit their perceptions of engineering and engineers. We propose that an exercise connecting individual assets and strengths to engineering problems in the context of community assets and strengths might be a viable option to foster an increase in student engineering identity.

Acknowledgments

This study was funded by the National Science Foundation Award # 1744006. The authors are grateful to the help provided by the following research students at Angelo State University: Jesse Lee, Maria Ochoa, Austin Poole, Nicholas Manrique and Timmons (TJ) Spies.

References

[1] M. Cooley (1989). "Human-centered Systems." *Designing Human-centred Technology*, 133–143. Springer.

[2] M. Garbuio, & M. Dressel (2019). *6 Building Blocks of Successful Innovation: How Entrepreneurial Leaders Design Innovative Futures*. Routledge.

[3] P. Polak (2008). *Out of Poverty: What Works When Traditional Methods Fail.* Berrett-Koehler Publishers, Inc.

[4] B. Amadei (2014). *Engineering in Sustainable Human Development*. ASCE Press.

[5] B. Amadei (2015). *A Systems Approach to Modeling Community Development Projects*. Momentum Press.

[6] NSF-EAGER - Early-Concept Grants for Exploratory Research. (2017). Developing Drought-Resilient Communities by Utilizing Acrylic Concrete Structures for Rainwater Harvesting. (NSF Award Number 1744006)

[7] J. P. Spradley (1979). *The ethnographic interview*. Fort Worth, TX: Holt, Rinehart and Winston.

[8] M. Grubbs, G. Strimel, & T. Huffman (2018). Engineering Education: A Clear Content Base for Standards. Technology and Engineering Teacher, 77(7), 32-38.

[9] H. A. Linstone, & M. Turoff (1975). *The Delphi method: techniques and applications*. Addison-Wesley Publishing Company.

[10] M. Mead, & R. Metraux (1957). Image of the scientist among high school students: a pilot study. Science 26: 384-390.

[11] M. Knight, & C. Cunningham (2004). Draw an engineer test (DAET): Development of a tool to investigate students' ideas about engineers and engineering. ASEE Annual Conference Proceedings, 4079-4089.

[12] S. Thomson, & J. Lyons (2006). Investigating the long-term impact of an engineering-based K-12 program on students' perceptions of engineering. ASEE Annual Conference Proceedings, 1-15.

[13] B. Fralick, J. Kearn, S. Thompson, & J. Lyons (2009). How middle schoolers draw engineers and scientists. Journal of Science Education and Technology, 18, 60-73.

[14] F. O. Karatas, A. Micklos, & G. M. Bodner (2010). Sixth-grade students' views of the nature of engineering and images of engineers. Journal of Science Education and Technology, 20(2), 123-135.

[15] B. Lucas, & J. Hanson (2016). Thinking Like an Engineer: Using Engineering Habits of Mind and Signature Pedagogies to Redesign Engineering Education. International Journal of Engineering Pedagogy, 6(2), 4-13.

[16] UN Environment Programme. (2007). About IK. Archived Web page: https://web.archive.org/web/20070815022844/http:/www.unep.org/ik/Pages.asp?id=About%20IK.

[17] N. González, L. C. Moll, & C. Amanti (Eds.). (2006). *Funds of knowledge: Theorizing practices in households, communities, and classrooms*. Routledge.

[18] S. L. Rodriguez, E. E. Doran, M. Sissel, & N. Estes (2019). Becoming La Ingeniera: Examining the Engineering Identity Development of Undergraduate Latina Students. *Journal of Latinos and Education*, 1-20.

[19] D. T. Rover (2008). Engineering identity. *Journal of Engineering Education*, *97*(3), 389.

[20] J. Wolfe (2010). Team writing. *Boston: Bedford/St. Martin's*.

[21] J. McKnight, & J. Kretzmann (1993). Building communities from the inside out. *A path toward finding and mobilizing a community's assets*.

[22] B. R. Witkin, & J. W. Altschuld (1995). *Planning and conducting needs assessments: A practical guide*. Sage.

Appendix A
Relevant Qualitative Data Taxonomies

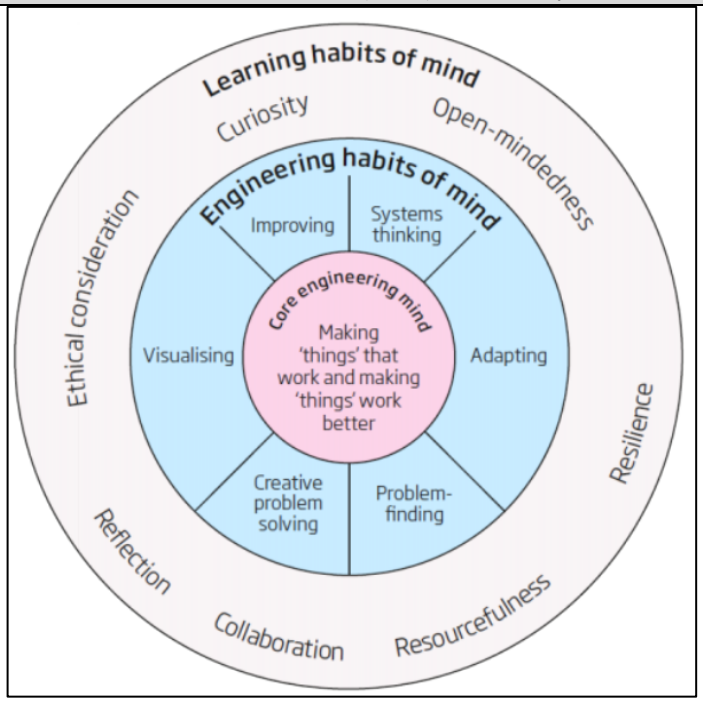
NSF-Eager Qualitative Data Taxonomy
Engineering Literacy Subcodes:
Knowledge of Engineering:
Design as an approach to solving problems or achieving goals.
Technology as a fundamental attribute of human culture.
Engineering disciplines.
STEM (STEAM) connections and applications.
Engineering standards and codes.
Engineering and society.
Engineering Skills:
Designing under constraint.
Using tools and materials.
Developing and testing physical models and/or prototypes.
Research and investigation.
Technical communication and documentation:
Written documents.
Engineering graphics.
Oral communication.
Other media.
Communication with constituent audiences.
Mathematical reasoning and computation methods.
Project management.
Executive Functioning.
Engineering Habits of Mind:
Systems thinking.
Creativity.
Efficacy.
Optimization.
Iteration.
Collaboration.
Sustainability thinking:
Financial feasibility.
Social impacts.
Environmental impacts.
Resiliency.
Empathy.
Inclusion and diversity.
Other ethical considerations.

NSF-Eager Qualitative Data Taxonomy (continued)
Engineering Design Subcodes:
Ask: Identify needs and constraints.
Research or investigate the problem.
Imagine or develop possible solutions.
Plan or select a promising solution.
Create or build a prototype.
Test or evaluate the prototype.
Improve or redesign as needed.
Engineering outcomes:
Rewarding accomplishments.
Contributions to communities or society.
Other Attributes of Engineers.

Fralick, et. al. (2009) Taxonomy	
Species	**Inferred actions**
Human	Making
Non-human	Operating
No person	Explaining
Gender	Designing
Male	Experimenting
Female	Observing
Unknown	No action
Skin color	**Location**
Brown	Indoors
Peach	Outdoors
Yellow	Space
Green	Underground
None	Underwater
Other	Can't Tell
Other attributes	
Crazy hair	
Glasses/goggles	
Lab coat	
Laborer's clothing	

Fralick, et. al. (2009) Taxonomy (continued)	
Objects	
Other people	Fictional machines
Non-humans	Other machines
Body parts	Books
Robots	Furniture
Computers	Math symbols
Building tools	Chemical symbols
Measuring tools	Blueprints
Writing objects	Diplomas
Studied animals	Weapons
Other animals	Keep out signs
Studied plants	Civil structures
Other plants	Danger
Rocks	Chemistry
Pass vehicles	Technology
Const. vehicles	Medicine
Flying vehicles	Meteorology
Rockets	Sports
Trains/tracks	Signs of thinking

Lucas and Hanson (2016) Taxonomy



Appendix B

Artifacts from Households that Completed the Rainwater Harvesting Project

Date	Household	Transcript	Context	Artifact
1/31/2018	2	Entry Interview	Subject asked to describe an engineer	Yes, I know more or less. Yes, I know it. Do you mean construction engineers or what kinds of engineers?
			Authors' Coding based on Grubbs, et. al. (2018)	Knowledge of Engineering Disciplines
			Fralick, et. al. (2009) Intersection	Inferred actions: Making
			Lucas & Hanson (2016) Intersection	E-HoM: CEM-Making Things
1/31/2018	2	Entry Interview	Subject asked to describe an engineer	They bring the plans to read, and they know the measurement, and they have the knowledge of the project. So that is the work of an engineer.
			Authors' Coding based on Grubbs, et. al. (2018)	Planner/Designer of Construction Projects
			Fralick, et. al. (2009) Intersection	Inferred actions: Designing | Objects: Blueprints
			Lucas & Hanson (2016) Intersection	E-HoM: CEM-Making things
1/31/2018	2	Entry Interview	Subject asked to describe an engineer	Well yes, I understand that an engineer is the one who brings projects, that everyone else will work on. That is what I understand.
			Authors' Coding based on Grubbs, et. al. (2018)	HoM: Executive functioning
			Fralick, et. al. (2009) Intersection	Inferred actions: Designing
			Lucas & Hanson (2016) Intersection	E-HoM: CEM-Making things
1/31/2018	2	Entry Interview	Subject asked about things an engineer should have	Well, an escruado, a tool especially made for measuring.
			Authors' Coding based on Grubbs, et. al. (2018)	Skills - Using tools & materials
			Fralick, et. al. (2009) Intersection	Objects: Measuring tools
1/31/2018	2	Entry Interview	Subjects reflect on previous projects	I have built houses. Yeah, of brick, and here I made my house with wood. And it came out poorly built, but it was built. I made a labyrinth, but everything turned out well. I made the living room 3 feet by 6 feet. Look at that grand living room. It can't even fit you or anything else.
			Authors' Coding based on Grubbs, et. al. (2018)	Skills - Using tools & materials
			Fralick, et. al. (2009) Intersection	Inferred actions: Making | Inferred actions: Designing
			Lucas & Hanson (2016) Intersection	L-HoM: Reflection

Date	Household	Transcript	Context	Artifact
1/31/2018	2	Entry Interview	Subjects reflect on previous projects	A porch. The city came and tore down what was mine… I've never made a porch before. I've built a house before but never a porch... No one will live there, just the car. And the city came, and they saw it and told me, "it must come down." Well they told me that I should knock it down, if not they would. I knocked it down.
			Authors' Coding based on Grubbs, et. al. (2018)	Knowledge - Engineering standards & codes
			Fralick, et. al. (2009) Intersection	Inferred actions: Making
			Lucas & Hanson (2016) Intersection	L-HoM: Reflection
1/31/2018	2	Entry Interview	Subjects reflect on previous projects	Uh, well I, for example, with paint look for the type that is more durable... An example is that if there's a paint rated for 5 years and 10, I buy the 10... The floors should be sure so that the kids don't slip, that they don't fall, that they remain well cared for.
			Authors' Coding based on Grubbs, et. al. (2018)	HoM - Sustainability thinking
			Lucas & Hanson (2016) Intersection	L-HoM: Ethical considerations
2/2/2018	4	Entry Interview	Subject asked some who could be an engineer	I have a kid at school, and she is learning English, but I have been telling how amazing she is in science and math. And I'm always pushing her like don't let that stop you, you raise your hand, you participate! And sometimes she holds it back because of the language, and I tell her, no no no, you go ahead, you answer, because she's just amazing. And sometimes she tells me, "but I'm a girl" and I'm like, "More power to you girl!", so she is one of those kids, I think.
			Authors' Coding based on Grubbs, et. al. (2018)	Gender: Male | Skills: Mathematical reasoning
			Fralick, et. al. (2009) Intersection	Gender: Male | Objects: Math symbols
2/2/2018	4	Entry Interview	Subject asked some who could be an engineer	I go to school with some sort of pretty, pretty interesting, some pretty amazing minds especially, you know, being on the spot on the academic team that I'm a part of. There's some kids who I know who, I mean, they've taught themselves all sorts of different things. They know how to build computers. They, they understand, you know, astronomical physics like all these different things that a lot of these kids have taken upon themselves to teach themselves. It's just amazing that you have amazing minds.
			Authors' Coding based on Grubbs, et. al. (2018)	Curiosity

			Fralick, et. al. (2009) Intersection	Objects: Other people
			Lucas & Hanson (2016) Intersection	L-HoM: Curiosity
Date	Household	Transcript	Context	Artifact
2/2/2018	4	Entry Interview	Subject asked to describe an engineer	For me it's someone that probably can look at something and, figure out why it's moving a certain way or, how it could be made better maybe?
			Authors' Coding based on Grubbs, et. al. (2018)	HoM: Systems thinking
			Fralick, et. al. (2009) Intersection	Inferred actions: Explaining
			Lucas & Hanson (2016) Intersection	E-HoM: Systems thinking; Improving
2/2/2018	4	Entry Interview	Subject asked to describe an engineer	I would say that it's umm, somebody who's creative who works to make life better and more efficient for all of us.
			Authors' Coding based on Grubbs, et. al. (2018)	Creative
			Lucas & Hanson (2016) Intersection	E-HoM: Creative problem solving
2/2/2018	4	Entry Interview	Subject asked to describe an engineer	Yea like, one of the people who comes to mind is umm, is probably my dad cause he's one of those people who like, understands how things just like, you know get put together. I usually think of somebody who's like real tech-savvy and it's like it's a terrible stereotype but usually somebody who's like, pretty tall and lanky and wears glasses.
			Authors' Coding based on Grubbs, et. al. (2018)	Tech-savvy | HoM: Systems thinking
			Fralick, et. al. (2009) Intersection	Other attributes: Glasses/goggles
			Lucas & Hanson (2016) Intersection	E-HoM: Systems thinking
2/2/2018	4	Entry Interview	Subject asked to describe an engineer	Someone that thinks of what- how something could work better.
			Authors' Coding based on Grubbs, et. al. (2018)	Design: Improve | HoM: Systems thinking
			Lucas & Hanson (2016) Intersection	E-HoM: Systems thinking; Improving
2/2/2018	4	Entry Interview	Subject asked to describe an engineer	A person that helps the environment by creating things that will help the environment.
			Authors' Coding based on Grubbs, et. al. (2018)	Design: Improve | HoM: Creativity; Sustainability thinking: Environmental impact
			Fralick, et. al. (2009) Intersection	Inferred actions: Designing
			Lucas & Hanson (2016) Intersection	L-HoM: Ethnical consideration | E-HoM: Creative problem solving

Date	Household	Transcript	Context	Artifact
2/2/2018	4	Entry Interview	Subjects reflect on previous projects	I think finding people that you can trust especially when you're like a perfectionist, because you see people do things and you know they're not doing it right. So you don't really trust anyone with the things that you want done ... so I think, definitely, trusting other people. Working together, I think that was a big thing ... being patient, that was the other thing, we had to be patient ...
			Authors' Coding based on Grubbs, et. al. (2018)	HoM: Executive functioning; Collaboration
			Fralick, et. al. (2009) Intersection	Objects: Other people | Inferred actions: Making
			Lucas & Hanson (2016) Intersection	L-HoM: Collaboration | E-HoM: Systems thinking; Improving
4/16/2018	4	Focus Group after Construction Workshop	Child asked about learning design	Uhh no I forgot, we learned it in school, but I forgot.
			Authors' Coding based on Grubbs, et. al. (2018)	Knowledge; STEM connections
			Fralick, et. al. (2009) Intersection	Inferred actions: No action
4/16/2018	4	Focus Group after Construction Workshop	Subjects reflect on construction workshops	I think I had uh more like a vision I wanted something compared to what we have at home you know and so he was thinking maybe something … bigger. Bigger, you know but I was thinking about the space that we already have and where its gonna go so I was you know trying to stay that ... I think it's fine like that. It fits very nicely where we're gonna put it because we rearranged the garden so put that certain spot for it to go there in front of the house.
			Authors' Coding based on Grubbs, et. al. (2018)	Design: Improve
			Fralick, et. al. (2009) Intersection	Inferred actions: Designing
			Lucas & Hanson (2016) Intersection	E-HoM: Improving
4/16/2018	4	Focus Group after Construction Workshop	Subjects reflect on construction workshops	Like, for me it was like wow we came, and we had no idea how to do this. And we worked together and at the end we have something you know that was rewarding for me because it was like finally, we have something.
			Authors' Coding based on Grubbs, et. al. (2018)	HoM: Collaboration
			Fralick, et. al. (2009) Intersection	Objects: Other people | Inferred actions: Making
			Lucas & Hanson (2016) Intersection	L-HoM: Collaboration

Date	Household	Transcript	Context	Artifact
4/16/2018	4	Focus Group after Construction Workshop	Engineer/Subject exchange	Engineer: We're going to get these special bottles in as soon as possible. Subject: What are the bottles for? Because its contaminated by the umm..the concrete right? Engineer: Hmm-hmm...it can be contaminated by the concrete and we're interested to see how bad. Subject: How much? Engineer: We are going to show how you can use the water, but never never never drink it. Subject: Ok.
			Authors' Coding based on Grubbs, et. al. (2018)	Design: Ask - Identify needs & constraints
			Fralick, et. al. (2009) Intersection	Inferred actions: Designing
			Lucas & Hanson (2016) Intersection	L-HoM: Curiosity | E-HoM: Improving
4/16/2018	4	Focus Group after Construction Workshop	Subjects reflect on previous projects	There was already a pipe there …, but there were rocks, big rocks, and we had to use that machine to break them. The house is on the side of the hill. .. So there's lots of lime, like limestone, and so we have to break everything... and then put all the piping, but you know, you have to measure everything and then you have to cut... We ended cutting spare pieces of PVC to even do the fittings. Of course, because it's going down a hill. You know it's not like something straight.
			Authors' Coding based on Grubbs, et. al. (2018)	Skills: Developing physical models & prototypes
			Fralick, et. al. (2009) Intersection	Inferred actions: Designing
			Lucas & Hanson (2016) Intersection	L-HoM: Resourcefulness | E-HoM: Adapting
4/16/2018	4	Focus Group after Construction Workshop	Subjects reflect on previous projects	We ended cutting spare pieces of PVC to even do the fittings. Of course, because it's going down a hill. You know it's not like something straight. No, we had to do bunch of coupling and fitters and ... we did a bunch of 45 degree. Because it was going down.
			Authors' Coding based on Grubbs, et. al. (2018)	HoM: Creativity
			Fralick, et. al. (2009) Intersection	Inferred actions: Making
			Lucas & Hanson (2016) Intersection	L-HoM: Resourcefulness | E-HoM: Adapting

Date	Household	Transcript	Context	Artifact
4/16/2018	4	Focus Group after Construction Workshop	Engineer/Subject exchange	Engineer: Could you build this tank with different materials that are not the ones that we had? Subject: Yes – with the um shorter…the chicken wire…smaller holes – it's easier to maneuver. Engineer: Ok…Do you have that material at home already? Subject: Yeah…in Mexico….. We usually use it to make the sand really fine.
			Authors' Coding based on Grubbs, et. al. (2018)	Design: Imagine – Develop possible solutions
			Fralick, et. al. (2009) Intersection	Inferred actions: Designing
			Lucas & Hanson (2016) Intersection	L-HoM: Reflection | E-HoM: Adapting
4/16/2018	4	Focus Group after Construction Workshop	Subjects reflect on construction workshops	So, we put screen and then we were thinking oh we're gonna paint it and it wasn't as easy to paint on the inside. We thought we would be like without little rocks and sediment inside of it. We thought we were gonna go like a house and you know, make it flat but never mind. We used the spatula because whenever you grabbed it in the sand would like carry the other paint off …. whenever you'd spread it at the same place it would take the paint off and we would have to re-do it, a couple times to really make it stick on there. I think that's the reason why you had to do another coat and another coat because the sand kept tearing away the paint.
			Authors'' Coding based on Grubbs, et. al. (2018)	Skills – Using tools & materials
			Fralick, et. al. (2009) Intersection	Objects: Building tools | Inferred actions: Experimenting
			Lucas & Hanson (2016) Intersection	L-HoM: Curiosity | E-HoM: Problem finding; Adapting
4/16/2018	4	Focus Group after Construction Workshop	Subjects reflect on construction workshops	I think we had enough [guidance and instruction]… we didn't really need that much. We just kinda figured it out. And also um I mean we asked questions like why did you use this and you guys answered you know whatever questions we had so. That was good because then there was a reason for that, not just random …. it was a good experience overall.
			Authors'' Coding based on Grubbs, et. al. (2018)	Skills – Using tools & materials
			Fralick, et. al. (2009) Intersection	Inferred actions: Making
			Lucas & Hanson (2016) Intersection	L-HoM: Collaboration | E-HoM: Adapting

Date	Household	Transcript	Context	Artifact
4/16/2018	4	Focus Group after Construction Workshop	Subjects reflect on construction workshops	Uh, I think having choices like for example ... the bag ties didn't work. So then there was something else available. If you would have said this is it, you know, the only thing we can use, then that would have been a little harder or we would have had to think of something different. And like even the tools around, you know like you had extra pliers or extra things, choices. You know, you supplied us with things and you'd give us advice whenever we had a problem. Like you could use this or you could use this method to do this...you could change it out.
			Authors" Coding based on Grubbs, et. al. (2018)	Skills: Designing under constraint
			Fralick, et. al. (2009) Intersection	Objects: Building tools | Inferred actions: Making
			Lucas & Hanson (2016) Intersection	L-HoM: Collaboration | E-HoM: Adapting
4/16/2018	4	Focus Group after Construction Workshop	Subjects reflect on construction workshops	We didn't expect anything really, we just, we just kinda went with whatever was gonna come at us. Probably the same thing like we didn't know what to expect you know because like you told us you know this is the material we're gonna use and then you decide how big you want it and so it was up to us you know. Which is cool because then you know it's your project and you decide how big or how tall or whatever you know.
			Authors' Coding based on Grubbs, et. al. (2018)	Communication: Defining roles & expectations | HoM: Optimization
			Fralick, et. al. (2009) Intersection	Objects: Other people | Inferred actions: Making
			Lucas & Hanson (2016) Intersection	E-HoM: Adapting
5/22/2018	4	After Water Workshop Focus Group	Subjects reflect on the rainwater harvesting project	I know we, uhm, we couldn't come to an agreement over to do it round or square. But we kind of knew what size we wanted it, because of the container we already had at home right. So we thought, you know, we need it this big, or this tall. We should have measured before we came.
			Authors' Coding based on Grubbs, et. al. (2018)	Skills - Designing under constraint
			Fralick, et. al. (2009) Intersection	Inferred actions: Designing
			Lucas & Hanson (2016) Intersection	E-HoM: Adapting

Date	Household	Transcript	Context	Artifact
6/21/2018	4	Next Steps Workshop	Subjects reflect on sharing the rainwater harvesting project with other people	They don't understand what it's going to do, risk. And it's the whole problem with the thing, they don't want to take risk anymore. It'll benefit you; how do you know. Doesn't work? Cause they had money. I'm going to look up the most ridiculous town hall presentations. Right? The whole town just listening to one song?
			Authors' Coding based on Grubbs, et. al. (2018)	Skills: Technical communication & documentation - Communication with constituents
			Fralick, et. al. (2009) Intersection	Inferred actions: Explaining
			Lucas & Hanson (2016) Intersection	L-HoM: Reflection | L-HoM: Collaboration
6/21/2018	4	Next Steps Workshop	Subjects reflect on the rainwater harvesting project	The other day we went to a lady who was having trouble with her car and she didn't have any money to fix it, so I tell my husband if he could go and check it out for her and he said yea, and he said to her, well it costs this much for the part, and she said, well I just don't have the money, and he said, well if you want me to help you the only thing I can do is I can rewire this, and she said how come it's like this, he says because an engineer decided it was that way. But he said I can make it work for you until you have the means to fix it. He got the wire, and he called it a bridge, a bypass and he goes, here you go. It's not going to heat up, you know it's going to work and stuff, but she was just like, wow. You just have to think about how it's working or how it's wired. You know, then you can look into it and be like, woah. You know there's a bypass here that could cut out all this.
			Authors' Coding based on Grubbs, et. al. (2018)	Design: Imagine - Develop possible solutions
			Fralick, et. al. (2009) Intersection	Inferred actions: Designing
			Lucas & Hanson (2016) Intersection	E-HoM: Adapting; Visualizing; Creative problem solving
6/21/2018	4	Next Steps Workshop	Subjects reflect on the rainwater harvesting project	You know what I was thinking as I was watering the other day? ... What I was thinking was, we probably should have put like a little faucet you know? On the bottom and put it [the tank] higher… if it was higher and a had a little faucet, then it would be easier to take out.
			Authors' Coding based on Grubbs, et. al. (2018)	Design: Improve - Redesign as needed
			Fralick, et. al. (2009) Intersection	Inferred actions: Designing
			Lucas & Hanson (2016) Intersection	E-HoM: Adapting; Visualizing; Creative problem solving

Date	Household	Transcript	Context	Artifact
6/21/2018	4	Next Steps Workshop	Subjects reflect on the rainwater harvesting project	I think I would leave it [the tank] long... because of the spacing of where it was going. That's why we made it that size, you know how it goes exactly in the garden. Yea but.. there's no plants on this [the other] side... We could have made it bigger, yea like a square. Ah, instead of round. And then raised it and put the faucet. We could even put it at an angle, tilt it just a little bit, and put the faucet like a little PVC pipe and just plug it... we just take out the little plug, put the water, and then put back the plug.
			Authors' Coding based on Grubbs, et. al. (2018)	Design: Improve - Redesign as needed
			Fralick, et. al. (2009) Intersection	Inferred actions: Designing
			Lucas & Hanson (2016) Intersection	E-HoM: Adapting; Visualizing; Creative problem solving
6/21/2018	4	Next Steps Workshop	Subjects reflect on the rainwater harvesting project	It's what I do every day, like I'll find copper wire, and then use it for my speakers... We have old tv, this little piece of equipment, but I guess since he saw it, he knew what it was for. And so he got it, and he connected the whole thing, and now we have a surround system from old speakers. Well no, they're good speakers because they sound really good, even when they're full blast... I like playing with extensions and modification cables, things like that.
			Authors' Coding based on Grubbs, et. al. (2018)	Skills: Developing physical models & prototypes
			Fralick, et. al. (2009) Intersection	Inferred actions: Designing
			Lucas & Hanson (2016) Intersection	L-HoM: Resourcefulness | E-HoM: Adapting; Improving
6/21/2018	4	Next Steps Workshop	Subjects reflect on the rainwater harvesting project	It's really good, and you know what we're doing? We found a container, maybe like a five gallon container ..., and it's short, and we put it where the water from the A/C is coming out, and the other day we left it out for two days...., we left it alone, and it was all the way to the top. It was just little drops. And it was just a little drops all day long. And it was like five gallons I would say, so we have water for the garden. Water for the dog. So, we spend less water on the water bill with not using it.
			Authors' Coding based on Grubbs, et. al. (2018)	HoM: Systems thinking; Sustainability thinking - Resiliency
			Fralick, et. al. (2009) Intersection	Inferred actions: Operating
			Lucas & Hanson (2016) Intersection	L-HoM: Resourcefulness | E-HoM: Systems thinking; Improving

Date	Household	Transcript	Context	Artifact
6/21/2018	4	Next Steps Workshop	Subjects reflect on the rainwater harvesting project	I think, I don't know if this is something that could be brought to school, you know to the idea of something like this to a school, because you know how they have the STEM classes now at the middle school level. I see this with my kids, the city doesn't have enough programs to expand that. Even making them aware, having someone speak during team leadership programs. It's a class, one of the students come and talk to them about the importance of recycling and water. I think the kids would love to see that, but there's nothing out there. I joined STEM, and they told me this and this, you're not really going to be doing projects in 6th grade, 8th grade is most of it. Even in team leadership they're always looking for ways to make the kids aware of things to better the community and stuff and I think this is something great that could be included. Just through talks. And the teachers would love it. The city is in a drought.
			Authors' Coding based on Grubbs, et. al. (2018)	Knowledge: STEM connections & applications
			Fralick, et. al. (2009) Intersection	Objects: Other people
			Lucas & Hanson (2016) Intersection	L-HoM: Resourcefulness | E-HoM: Systems thinking; Improving
7/10/2018	2	Focus Group after Construction Workshop	Child reflects on father being like an engineer	He's intelligent. I have learned from him.
			Authors' Coding based on Grubbs, et. al. (2018)	Intelligence
			Fralick, et. al. (2009) Intersection	Objects: Signs of thinking
7/10/2018	2	Focus Group after Construction Workshop	Child reflections on being like an engineer	I am. She's not.
			Authors' Coding based on Grubbs, et. al. (2018)	Gender: Male
			Fralick, et. al. (2009) Intersection	Gender: Male
7/10/2018	2	Focus Group after Construction Workshop	Subjects reflect on construction workshops	Well that's still being done… we were making the concrete mix, and putting it on… I liked everything...
			Authors' Coding based on Grubbs, et. al. (2018)	Skills - Using tools & materials
			Fralick, et. al. (2009) Intersection	Inferred actions: Making

			Lucas & Hanson (2016) Intersection	E-HoM: CEM-Making things
Date	Household	Transcript	Context	Artifact
7/10/2018	2	Focus Group after Construction Workshop	Children reflect on working with father	Um, like be with him, sharing with him, how to work... [He doesn't] help me. Rather [he] shows me sometimes when the car leaks, well I watch how [he] does it… I like to invent, things. He made a bicycle. I liked making the seat.
			Authors' Coding based on Grubbs, et. al. (2018)	HoM - Creativity
			Fralick, et. al. (2009) Intersection	Inferred actions: Making
			Lucas & Hanson (2016) Intersection	L-HoM: Creativity
7/10/2018	2	Focus Group after Construction Workshop	Father/Children reflect on construction workshops	Father: And what about the project? What did you use? Child: Paint! Sand! Father: No, at the start, what did you use? Child: Mesh. Father: What kind of mesh? Mesh made of wires? First the wire, and then the mesh. .. what did we use? Child: The wire. And then the mesh, and then we put it together. Well we tied it. First, we chose the mesh and material Then we cut it. How do you say, we tied the wire to the mesh, and then we tied it. And then when we left, we started putting on the mix. You changed it so that it was stronger, less bumpy.
			Authors' Coding based on Grubbs, et. al. (2018)	Skills - Using tools & materials
			Fralick, et. al. (2009) Intersection	Inferred actions: Making
			Lucas & Hanson (2016) Intersection	L-HoM: Reflection
7/10/2018	2	Focus Group after Construction Workshop	Children reflect on construction workshops	I loved it. My daddy... that means like... because I worked with my dad. Isn't that true, that my mom wasn't here when we'd screw things up? That's really good!
			Authors' Coding based on Grubbs, et. al. (2018)	HoM - Efficacy
			Fralick, et. al. (2009) Intersection	Inferred actions: Making
7/10/2018	2	Focus Group after Construction Workshop	Subjects reflect on construction workshops	With gloves, I felt fine with the gloves. I did not feel great with the gloves. Every once in a while, when I had them on, they would just nearly fall off. I felt fine with the glasses.
			Authors' Coding based on Grubbs, et. al. (2018)	Skills - Using tools & materials
			Fralick, et. al. (2009) Intersection	Inferred actions: Making
			Lucas & Hanson (2016) Intersection	L-HoM: Reflection

Date	Household	Transcript	Context	Artifact
7/10/2018	2	Focus Group after Construction Workshop	Engineer/Subject exchange	Engineer: Could you build this tank? Father: If she works the concrete mix, I cannot make it in two days. Maybe we can make it in 3 or 4. Child: Oh well, well you would need to buy all the mesh, tie it, sometimes the mesh in two days. Engineer: Do you think that you can finish it in two days? Child: 4 or 5. Father: I tell you that if we put ourselves to this all day, and working here, we could finish it in 2 days. But what we want to tell the teacher here the engineer, that we can get a little bit of mesh of wire. It's fine. And we'll invite you when we finish it, and all of us will pour water...
			Authors' Coding based on Grubbs, et. al. (2018)	Skills - Project management | HoM: Executive functioning
			Fralick, et. al. (2009) Intersection	Inferred actions: Making
			Lucas & Hanson (2016) Intersection	E-HoM: Adapting
7/10/2018	2	Focus Group after Construction Workshop	Engineer/Subject exchange	Subject: Hm, [it was] hard work. It was easy and it was hard. It was easy because we used the lab. And it was hard because we had to figure out how the walls go together, and if we didn't do it right, we'd have to start anew. Here, there are good tools, there is good material, there's plenty of space, and we can make any tank that we'd like squared, round… Engineer: Since you're going to continue with this tank at home without us, are you going to keep everything the same? Subject: Yes. .. it's the same tools that you use, ... the same things that you showed us, and we'll make it the same exact way that we made it here...
			Authors' Coding based on Grubbs, et. al. (2018)	HoM - Efficacy
			Fralick, et. al. (2009) Intersection	Inferred actions: Designing
			Lucas & Hanson (2016) Intersection	E-HoM: Creative problem solving
Date	Household	Transcript	Context	Artifact
8/9/2018	4	Exit Interview	Subject asked to describe an engineer	I think it's someone with like, lots of ideas. Innovative. Someone that looks from a structure to a system. They see how it works, and they see how they can change it. Someone for me that would like to make a system better, make a brand-new system that would help someone else, in their life.
			Authors' Coding based on Grubbs, et. al. (2018)	Design: Improve | HoM: Systems thinking
			Fralick, et. al. (2009) Intersection	Inferred actions: Designing

			Lucas & Hanson (2016) Intersection	E-HoM: Systems thinking; Improving
Date	Household	Transcript	Context	Artifact
8/9/2018	4	Exit Interview	Subject asked about engineers they know	Ok well, all my uncles, well not all of them. But most of them were mechanics. They aren't engineers. Every single one of them, except for the women, every one of them is a mechanic. So there's no engineers in our family. We have a couple of friends, but they live in the Austin area. One of them works at NASA in Houston, and then the lady works at, I don't know. Something with buildings but they're the only ones that I know.
			Authors' Coding based on Grubbs, et. al. (2018)	Design: Improve | HoM: Systems thinking
			Fralick, et. al. (2009) Intersection	Inferred actions: Designing
			Lucas & Hanson (2016) Intersection	E-HoM: Systems thinking; Improving
8/9/2018	4	Exit Interview	Subjects reflect on the rainwater harvesting project	I still think I'm going to convince my husband to put a base, and then the faucet. I think that I am going to do that. He'll see me pouring the water, I'm going to say hey can we raise it?
			Authors' Coding based on Grubbs, et. al. (2018)	Design Process: Improve - Redesign as needed
			Fralick, et. al. (2009) Intersection	Inferred actions: Designing
			Lucas & Hanson (2016) Intersection	E-HoM: Adapting; Visualizing; Creative problem solving
8/9/2018	4	Exit Interview	Subjects reflect on the rainwater harvesting project	I was thinking too, I don't even know the material, this is what my husband and I were talking about, even um, denim, and then put it in the paint, and then patch it. Kind of like what you guys did, you did it with the mesh. But denim is another ... way and it's durable and it gets covered. Patching and that.
			Authors' Coding based on Grubbs, et. al. (2018)	Skills - Using tools & materials
			Fralick, et. al. (2009) Intersection	Inferred actions: Experimenting
			Lucas & Hanson (2016) Intersection	L-HoM: Resourcefulness | E-HoM: Adapting
8/9/2018	4	Exit Interview	Subjects reflect on the rainwater harvesting project	It was hard, because you know we had little pieces of sand and stuff, so you would put it on, but it would fall off, how heavy it was, and go back and go, and it'd stick. And then the last time, my husband came with me, and our mistake was that we didn't have enough ventilation. My head was hurting, and I felt like nauseated... You know we were going inside and painting instead of going outside. But other than that, as much as you want to do thick layers, you can't because it's too heavy when it's wet, so you have to do a couple of layers, like a thinner. But you can't see the holes or where it was missing, once it finally dried, then you could see.

			Authors' Coding based on Grubbs, et. al. (2018)	Skills - Using tools & materials
			Fralick, et. al. (2009) Intersection	Objects: Danger | Inferred actions: Making
			Lucas & Hanson (2016) Intersection	L-HoM: Resourcefulness | E-HoM: Adapting
Date	Household	Transcript	Context	Artifact
8/9/2018	4	Exit Interview	Subjects reflect on the rainwater harvesting project	The gutter we had, it was interesting because we didn't even have to buy it, the gutter we had by the doors in the garage, they weren't being used, so my husband said to my oldest son, why don't you move it up? And then you can use it for that. Because there's no use for it in the back. Who cares if the cars get wet or whatever? Then it ended up, and it fits, not perfectly, but it fits.
			Authors' Coding based on Grubbs, et. al. (2018)	Design: Improve - Redesign as needed | HoM: Financial feasibility
			Fralick, et. al. (2009) Intersection	Inferred actions: Making
			Lucas & Hanson (2016) Intersection	L-HoM: Resourcefulness | E-HoM: Adapting; Improving
8/9/2018	4	Exit Interview	Subjects reflect on the rainwater harvesting project	You know, yes we have to keep an eye on how much time we do bathing, when we brush our teeth, things like that. I think we've read the consequences about if we don't take care of this now, the children or their grandchildren may not have what we have now. Generations, yes, and that's the only reason why we recycle you know, we used to, back when the city didn't have that, we used to have this big container of trash, and people would always tell me so many things we could recycle, but it's still going to go to the trash. So now they pass every two weeks and we have a lot of recycle in our trash can, every week is maybe a third. We've been reading, just different books and stuff, and because we are interested in gardening and other things, we've read about if we don't make changes, and if we don't do this or that. It's something that we've done. We started reading about it in Minnesota ... Here, you become more aware of what's going on. People told us ... do not drink the water from the faucet, and never eat fish from the river. We didn't know why, because it looked so beautiful, but once we started walking along we noticed why. There's so much trash and contaminates here, we need to make a change.
			Authors' Coding based on Grubbs, et. al. (2018)	Skills: Research & Investigation | HoM: Sustainability: Environmental impacts; Ethical considerations

			Fralick, et. al. (2009) Intersection	Objects: Books; Studied plants | Inferred actions: Explaining
			Lucas & Hanson (2016) Intersection	L-HoM: Curiosity; Resourcefulness; Resilience; Ethical considerations
Date	Household	Transcript	Context	Artifact
4/19/2018	4	Water Workshop	Subjects reflect on the rainwater harvesting project	What if it doesn't rain? We just keep the water collected?
			Authors' Coding based on Grubbs, et. al. (2018)	Design: Ask - Identify needs & constraints
			Fralick, et. al. (2009) Intersection	Inferred actions: Operating
			Lucas & Hanson (2016) Intersection	E-HoM: Problem finding
4/19/2018	4	Water Workshop	Subjects reflect on the rainwater harvesting project	You know what we could do? Put the cover for it, and then like a hole in the middle. That's what I was thinking I was going to ask you if we could have a piece of the mesh, to cover it with. That's a big improvement…
			Authors' Coding based on Grubbs, et. al. (2018)	Design: Imagine - Develop possible solutions; Improve
			Fralick, et. al. (2009) Intersection	Inferred actions: Designing
			Lucas & Hanson (2016) Intersection	E-HoM: Improving
4/19/2018	4	Water Workshop	Subjects reflect on the rainwater harvesting project	That's what I was talking to my husband about, cause he said well when it rains you don't have to use it, it's like days after, so you let it sit there for the day, and then those days after when the dirt or the soil is dry now that's when we use it.
			Authors' Coding based on Grubbs, et. al. (2018)	HoM: Sustainability thinking - Resiliency
			Fralick, et. al. (2009) Intersection	Inferred actions: Operating
			Lucas & Hanson (2016) Intersection	L-HoM: Resilience
4/19/2018	4	Water Workshop	Engineer/Subject exchange	Subject: Okay so here's a question: let's say that it rains a lot, so like on Saturday for example, repeats, and it fills up, and we think that we should take advantage of this, so how do measure then, that we collected that much, but then we used them so, do we do that more than once a week? ... What if it's raining we can't collect anymore, because it's so what I do in the other container is I get it out on a pale, and then I put it in another container and I save it, so that way I have more space - what do you want me to do in this case? Engineer: Yes, if you're saving it, just keep recording it, because that's really valuable for me to know, that not only you have this one, but also are saving more.

Authors' Coding based on Grubbs, et. al. (2018)	HoM: Sustainability thinking - Resiliency
Fralick, et. al. (2009) Intersection	Inferred actions: Operating
Lucas & Hanson (2016) Intersection	L-HoM: Resilience

Acronyms:
CEM, Core Engineering Mind | HoM, Habits of Mind | L-HoM, Learning Habits of Mind | E-HoM, Engineering Habits of Mind