Understanding Youth Collaboration: How learners experience the design process in a collaborative context (fundamental)

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Michelle Jordan earned her PhD in Educational Psychology at the University of Texas at Austin, focusing her studies on learning, cognition, and motivation with an emphasis on classroom discourse. She joined the Mary Lou Fulton Teachers College at Arizona State University in 2010. Her interdisciplinary research draws on traditions in qualitative inquiry, sociolinguistics, complexity theories, and the learning sciences. Partnering with teachers and researchers across multiple contexts, Michelle's research agenda explores the relationships among small-group interactions, the experiences they facilitate, and their potential to extend human learning in diverse contexts including K-12 engineering design teams.

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Born in Mexico City, Tonatiuh Munguía Villanueva was raised in Tabasco, México. He is currently pursuing a bachelors degree in Biology at the "Universidad Juárez Autónoma de Tabasco" (final thesis pending). On 2012 he co-founded a science communication club called "Jóvenes por la Ciencia" (Youth for science), which allowed him to take part in local, national and international events ranging from conducting demonstrations of scientific phenomena for K-12 students to participating on the XIII International Symposium of the "Instituto Politécnico Nacional". On 2014 he was honored to participate on the "Latin American Summer Research Program" at the University of Arizona under the mentoring of Michelle E. Jordan, PhD, exploring the experiences of learners engaged in collaborative engineering design projects.

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Providing young learners a foundation in engineering design practices helps them aspire to address major challenges of the society and environment that they will face in the decades ahead, and to interest them in pursuing higher education in STEM fields. Such a foundation should include collaborative experiences because engineering practices are highly social and communication plays critical roles in design processes.[1-5] In particular, communication among team members is a fundamental aspect of engineering design.[6, 7] Yet, even undergraduate students often fail to recognize the inherently collaborative nature of engineering.[8]

Preparing the next generation of engineers to meet the challenges and opportunities of the future requires that they learn to engage in analytical thinking, argumentation, and collaborative teamwork and that they see such practices as central to design processes. Engaging middle school learners in collaborative engineering design projects can provide them with opportunities to develop communicative competencies related to speaking like an engineer by participating in talk about designed products, design processes, and metacommunicative talk about design communication itself.[9-11]

The K-12 engineering education community also recognizes collaborative interaction as a key engineering practice. The National Research Council identified communication as a vital engineering "habit of mind."[12] Additionally, the Next Generation Science Standards (NGSS) foregrounds the importance of collaboration in science and engineering practices by integrating communication as a fundamental criterion at all levels of K-12 education: "Engineers need to be able to express their ideas, orally and in writing, with the use of tables, graphs, drawings, or models and by engaging in extended discussions with peers."[13] Such communication practices are necessary for generating design solutions and for planning and carrying out collaborative investigations.

Previous studies indicate that young learners encounter communication challenges related to task, relational, and identity issues when collaborating on engineering design projects.[14, 15] Other research has identified effective scaffolding to support middle school leaners' communication during collaborative design activities[16, 17] as well as between-group influences on design activity.[18, 19] However, systematic studies of young adolescents' peer interaction among team members during collaborative design activity are rare, and little is yet understood about how learners' perceive of their collaborative interactions.

The purpose of this qualitative study was to improve understanding of how middle school learners experience the design process as they engage in collaborative engineering challenges. To achieve this aim, we investigated how participants in afterschool engineering clubs

experienced collaborative aspects of design challenges. Initial research questions that guided analysis include:

- What do learners report about how they experience collaborative aspects of engineering design challenges?
- Which aspects of collaborative design processes are most salient to these learners?
- Which aspects do they experience more negatively or positively?

Method

Study participants were voluntary members of middle-school afterschool engineering clubs in eight Southwestern U.S. schools in one urban district. The long-standing university-facilitated program sought to provide opportunities for ethnic minority, female, low-income, and first generation college-bound students to experience hands-on exploration of STEM fields and peer-group experiences to support college aspirations. Club meetings generally took place once a week over five months, with club members working in collaborative teams to complete one of eight engineering design challenges (e.g., a prosthetic arm, a windmill, a water transportation system). A regional competition occurred in January and a state competition was held in April.

This qualitative descriptive study relied on semi-structured interviews[20] consisting of open-ended questions about collaboration in engineering design challenges. Forty-eight students were randomly recruited from across the eight clubs to participate in the one-on-one interviews (based on availability and willingness to participate); selected from a pool of the 108 club members who participated in a previous survey study. Eight interviewees were eighth-graders, 25 were seventh-graders, and 15 were sixth-graders; 48% were female; 64% were Hispanic, 13% White, 7% African American, 7% Asian, and 2% Native American. Of these students, 73% were eligible for free or reduced lunch.

Interviews were conducted with individual club members by the first author immediately before or after club meetings, usually in a nearby empty classroom. They ranged in length from 10 to 20 minutes. Interviews were recorded and later transcribed and checked for accuracy. For purposes of the current study, analysis was constrained to three open-ended questions and follow up prompts related to team collaboration: (1) What is it like to work in a team to complete an engineering design challenge? (2) What's the best thing about working with a team? (3) What's the most challenging thing about working with a team?

Analysis utilized constant comparative methods[21] to inductively interpret interview responses. Iterating through several cycles, both researchers independently read interview transcripts, wrote extensive memos, and identified tentative themes before meeting to share and negotiating understandings. During team meetings, we compared our interpretations in order to enrich our

joint construction of meaning, frequently sketching hypothesized relationships to inform the emerging model.

Results

Three interrelated themes emerged through analysis. The first two themes both address RQ1 and RQ2; the third theme addresses RQ3.

Theme 1. The first theme generated through analysis was that a prominent aspect of how learners experienced engineering in a collaborative context was the salience of how they managed ideas. Specifically, when students were asked, "What is it like to work in a team to complete an engineering design challenge?" their responses commonly focused on how ideas were created, evaluated, developed, and implemented in their collaborative design team. Examples of students' perceptions of each of these processes are illustrated in Table 1.

Table 1. Examples of Students' Perceptions of How Their Teams Managed Ideas

Creation	*"It's easier, and you have different ideas. If you work alone it's harder because you don't have different ideas. And when you work with different people you get what they think, and then you try all the different things out".*
Evaluation	*"Like it's different because you have to – there's a lot of ideas, so you have to – if two of them are really good, you have to really in a team effort really just decide which one is the best."*
Development	"*Well, I think it's kind of exciting because you might have one idea, then your other teammate might have another one, and maybe another teammate will have another one, and then from that you create another challenge trying to combine all of those three to make one idea."*
Implementation	*"It's like fun because you get everybody's ideas on it and when you get it all together, it looks perfect and it works out."*

Students might have noted many aspects of collaboration associated with working on engineering design challenges in response to this open-ended question. That their responses focused on managing ideas seems to reflect many of these students' sense that engineering design is largely a process of generating and bringing ideas to fruition and that this process is inherently collaborative.

Theme 2. Additional examination of students' perceptions of how they managed ideas led to further insight about how they perceived their team. Specifically, the second theme identified through analysis was that some participants perceived of their teams as *Collaboratives* and others perceived of their teams as *Collections of Individuals*. Furthermore, those perceptions related to their construction of identities and roles within the team. Participants who viewed their teams as a Collaborative perceived themselves as having a team centric ownership of ideas; i.e., the evaluation, development and implementation of ideas were carried out by the team as a whole, for example, when ask about the best thing of designing with a team, one student replied:

> *One of the best things is that you can all put your ideas together and it kind of works out. You can keep on working together and making it better, using everyone's ideas…We try to think of ways that they could all work together, like if somebody says we can do this thing and somebody else says we can do that, we try to think of ways where they can just work together then put them both on the project to make it work.*

When asked why that was important to her, she replied:

> *Student:* *It's important to me because it makes everybody feel like they're wanted, and plus, it helps make the project better because it's helping the project.*
> *Interviewer:* *What's the most challenging thing about working with a team to design?*
> *Student:* *I like working with the team. I don't really think that there's a lot hard with it because it really helps you design and make it better. So I can't really think of anything that's really hard for it.*

Obvious in these responses is that the integration of everyone's ideas was important to this student and that her perception was largely positive.

In contrast with this collaborative visualization of a team, students who viewed their team as a *Collection of Individuals*, each with ownership of their individual ideas, saw the plurality of ideas as a conflict between individuals in terms of social-relational power and decision-making efficiency. For example: one student commented that he preferred working on teams with only one other person. When ask why, he replied:

> *Because I don't have to worry about having all these different ideas and having to say, "Alright, well, you like this, you like that, you like this. Alright, so how is this all come together so we all agree on it and how does it come together just right so it flies properly?"...And so, well, if it's just me and him, then I'm like, "Alright, you like this, I like this. Let's combine that."*

In this case, the student perceived that a large diversity in sources of ideas presented a risk. It is important to note that even students who presented this perception still largely voiced a positive reception to having at least one other teammate in order serve as a different source of ideas. However, these benefits might not outweigh the social stress and tensions of negotiating individual ownership of ideas. As another student said, *"It's really complicated because you have to get all of your ideas in and all of what you guys want to do and what they want to do."*

Theme three. Finally, a third theme identified through analysis was that there were both negative and positive aspects of negotiating decision making around diverse ideas. Negotiating decisions among group members with differing views of how the project should progress was a common topic across responses to the three interview questions. Many students shared that there is a tension between the benefit of diversity of ideas and conflict among ideas, and they reported resolving that tension in multiple ways. Students commonly identified the ability to contrast and compare ideas as a positive aspect of teaming that afforded opportunities to improve one's own ideas and one's thinking about the project and to improve a group product by combining ideas to make the project "easier" and "better." As one student shared,

> *Like, the more thoughts, the more creativity that there is in the group the better it would be for the project because if we were to just have it with one person then the project, it wouldn't be as awesome because there wouldn't be much critiquing doing to it.*

Students also reported that there is social-relational efficacy in sharing diverse ideas in that it helps all group members feel valued. Social-relational harmony and protection of group members' feelings and self-respect was reportedly an important issue of concern to many students. These benefits, however, had to be weighed against challenges associated with negotiating decision-making around diverse ideas. Conflicts associated with diversity of ideas included dealing with stubborn" team mates (e.g., *"probably that some people are stubborn and they don't wanna change their ideas."*), disagreements about how to move forward, not understanding other's ideas, and the group "breaking apart."

The inherent tension between benefits and challenges of diverse ideas was perceived both by learners who saw their teams as a *Collective* and by those who saw their teams as a *Collection of Individuals*, but it was perceived differently by each of these groups. One of the ways this tension was expressed was in the different methods teams use to resolve this tension. Experimenting was commonly reported as a strategy not only for improving a design, but also for resolving social tension:

> *When we were putting the windmill together we were making it – we were trying to see how the fan was going to work with the windmill. And we were trying to see how tall the fan had to be. And some people were like, "oh no, it's fine where it is." And then other people were like, "no, it needs to go lower." And then*

> [inaudible] *was like, "no it's too low." And then we finally figured out that we should just measure it. We used the fan and we put the fan up and down to work with the windmill and see how fast it would go…We measured the distance that the fan was from the table so we can cut off that much from that windmill.*

In this case, the team decided to conduct an experiment as a tool to help make a decision. However, other ways of resolving tension were also noted, such as asking or giving help or advice (e.g., *"It helps me by like when people need help with their thing and all that, I help them."*), compromising (e.g., *"Okay, it's like he has a design that which used 12 propellers and my design was only had nine propellers in it, and it's like, how much do we use? You have 12 and I have only nine? So we think that we just use ten then."*), and researching (e.g., *"He went on the laptop, and he went on Google images and searched for windmills."*).

Discussion

The middle school afterschool club members who participated in this study expressed various perceptions about their collaborative experiences related to engineering design challenges. An aspect that were most salient to many of these learners was their perceptions of collaboration that middle school participants expressed in interviews often involved the creation, evaluation, development and implementation of design ideas. Students' descriptions of how their teams negotiated the management of ideas and other processes associated with collaborative design activity tended to cluster the participants into two categories: those whose perceived that their teams had a collective ownership of ideas (i.e., Collaboratives), and those who perceived that ideas were generated and defended individually (i.e., Collections of Individuals). In either case, the diversity of ideas from different team members presented opportunities for positive and negative experiences. The tension between the benefits and challenges of diversity was resolved in multiple ways, depending in part on learners' perceptions of the nature of their team. These relationships are illustrated in Figure 1.

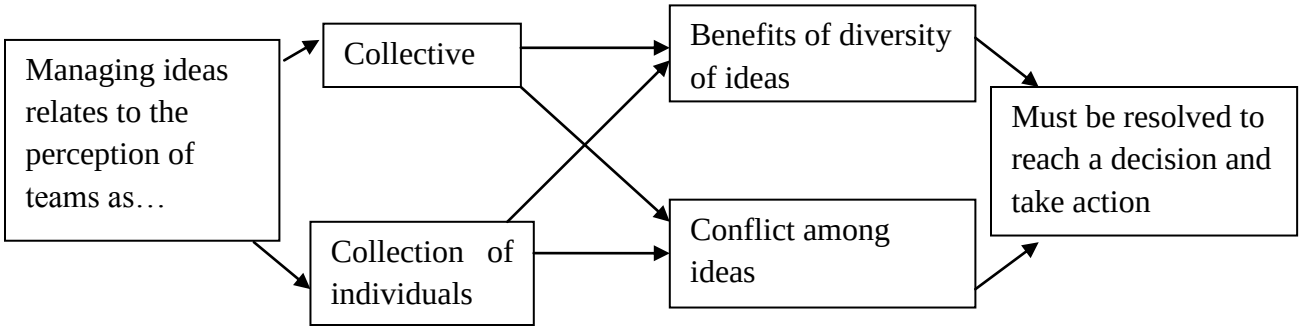

Fig 1. The relationship between the perceptions of the team in a collaborative engineering context and the role of ideas in the team

Ultimately, our hope is that this study will inform practice related to effective collaborative skills needed in engineering design contexts. One initial implication of the findings from this study is that facilitators need to recognize that learners may have varying perceptions of the extent to which design ideas belong to the design team versus individual team members, a perception that influences how teams manage and use conflict among diverse ideas in order to make decisions and take productive action. Facilitators who understand these dynamics may be able to develop strategies for helping students navigate collaborative tensions in ways that enhance design products and facilitate positive collaborative experiences. Supporting such experiences may be especially important for attracting females and members of other underrepresented groups into STEM fields, for supporting their identities as scientists and engineers,[22, 23] and for helping them seek points of contiguity between their collaborative experiences and the discursive values of the larger engineering community.[24]

The findings of this study are particularly important because learners from groups traditionally under-represented in engineering were intentionally recruited into the afterschool clubs that were the context of this study. The cultural capital these students brought to the engineering design context may have influenced their interpretation of these experiences in ways that are potentially different than those of learners from other backgrounds. For instance, students from other cultural contexts may have developed dispositions less accepting of collaboration than the students in this study and therefore may need different levels of support for navigating collaborative design tensions.

Further study is needed to understand the relationship between middle school learners' reported experience of the design process in a collaborative context and the team processes and products associated with such experiences. For example, it may be necessary to identify what factors influence whether participants experience design as a Collective or a Collection of Individuals. Furthermore, what influence does that perception have on design processes and/or products? How effective are various strategies for resolving tensions related to diversity of ideas? It is also important to understand how participants' perceptions of their collaborative experiences in the engineering club compare to their perceptions of other collaborative experiences in their schools, families and communities. Such study is needed to inform the development of instructional practices and tools to support effective collaboration.

References

1. Brereton, M. F., Cannon, D. M., Mabogunje, A., & Leifer, L. J. (1996). Collaboration in design teams: How social interaction shapes the product. In N. G. Cross, H. H. C. M. Christiaans & K. Dorst (Eds.), *Analysing Design Activity* (pp. 319-341). Chichester: Wiley.
2. Cross, N., & Cross, A. C. (1998). Expertise in engineering design. *Research in Engineering Design, 10*(3), 141-149.

3. Dannels, D. P., Anson, C. M., Bullard, L., & Peretti, S. (2003). Challenges in learning communication skills in chemical engineering. *Communication Education, 52*(1), 50-56.
4. Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education, 94*(1), 103-120.
5. Otto, K. N. & Wood, K. L. (2000). *Product design techniques in reverse engineering and new product development.* Upper Saddle River, NJ: Prentice Hall.
6. Darling, A. L., & Dannels, D. P. (2003). A report on the role of oral communication in the workplace. *Communication Education, 52*, 1-16.
7. Kittleson, J. M., & Southerland, S. A. (2004). The role of discourse in group knowledge construction: A case study of engineering students. *Journal of Research in Science Teaching, 41*(3), 267-293. doi: 10.1002/tea.20003
8. Dunsmore, K., Turns, J, & Yellin, J. M. (2011). Looking toward the real world: Student conceptions of engineering. *JEE, 100*(2), 329-348.
9. Dannels, D., Gaffney, A. H., & Martin, K. N. (2008). Beyond content, deeper than delivery: What critique feedback reveals about communication expectations in design education, *International Journal for the Scholarship of Teaching and Learning*, 2(2), 1-16.
10. Logan, C. (2008). Metaphor and pedagogy in the design practicum. *International Journal of Technology and Design Education, 18*(1), 1–17. doi: 10.1007/s10798-006-9009-x.
11. Morton, J. & O'Brien, D. (2006). Selling your design: Oral communication pedagogy in design education. *Communication Education, 54*(1), 6–19. doi:10.1080/03634520500076885.
12. National Research Council. (2009). *Engineering in K-12 education: Understanding the status and improving the prospects*. Washington, DC: The National Academies Press.
13. National Research Council. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press, p. 51.
14. Jordan, M. E. & Babrow, A. S. (2013). Communication in creative collaborations: The challenges of uncertainty and desire related to task, identity, and relational goals. *Communication Education, 62*(2), 105-126. doi: 10.1080/03634523.2013.769612
15. Jordan, M. E., & McDaniel, R. R. (2014). Managing uncertainty during collaborative problem solving in elementary school teams: The role of peer influence in robotics engineering activity. *Journal of the Learning Sciences, 23*(4), 490-536. doi:10.1080/10508406.2014.896254
16. Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., & Ryan, M. (2004). Promoting deep science learning through case-based reasoning: Rituals and practices in learning by design classrooms. In N.M. Seel, & S. Dykstra (Eds.), *Curriculum, plans and processes of instructional design: International perspectives.* Lawrence Erlbaum Associates: Mahwah, NJ.
17. Kolodner, J. K., Zahm, B., & Demery, R. (2015). Project-based inquiry science. In C. I. Sneider (Ed.), *The go-to guide for engineering curricula, grades 6-8: Choosing and using the best instructional materials for your students.* Thousand Oaks, CA: Corwin.
18. Roth, W.-M. (1995). Inventors, copycats, and everyone else: The emergence of shared resources and practices as defining aspects of classroom communities. *Science Education, 79*, 475-502.
19. Roth, W.-M. (2004). Art and artifact of children's designing: A situated cognition perspective. *Journal of the Learning Sciences, 5*(2), 129-166.
20. Spradley, J. P. (1979). *The ethnographic interview*. New York, NY: Holt Reinhart.
21. Lincoln, Y .S. & Guba, E. G. (1985). *Naturalistic inquiry*. Newbury Park, CA: Sage.
22. Aschbacher, P. R., Li, E, & Roth, E. J. (2010). Is science me? High school students' identities, participation, and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching, 47*, 564-582
23. Laursen, S., Liston, C., Thiry, H., & Graf, J. (2007). What good is a scientist in the classroom? *CBE-Life Sciences Education, 6*(1), 49-64.