Integrating Asset-based Practices, Engineering, and NGSS: Lessons from Working with Teachers through a Community-focused Approach

Dr. Joel Alejandro Mejia, University of San Diego

Dr. Joel Alejandro (Alex) Mejia is an assistant professor in the Department of Integrated Engineering at the University of San Diego. His research has contributed to the integration of critical theoretical frameworks and Chicano Cultural Studies to investigate and analyze existing deficit models in engineering education. Dr. Mejia's work also examines how asset-based models impact the validation and recognition of students and communities of color as holders and creators of knowledge. His current work seeks to analyze and describe the tensions, contradictions, and cultural collisions many Latinx students experience in engineering through testimonios. He is particularly interested in approaches that contribute to a more expansive understanding of engineering in sociocultural contexts, the impact of critical consciousness in engineering practice, and development and implementation of culturally responsive pedagogies in engineering education.

Dr. Alberto Esquinca, San Diego State University

Alberto Esquinca is an Associate Professor in the Department of Dual Language and English Learner Education at San Diego State University.

Dr. Vitaliy Popov, University of San Diego

Dr. Vitaliy Popov is the Associate Director of Research at the Jacobs Institute for Innovation in Education (JI) at the University of San Diego (USD), a research center named after Dr. Irwin and Joan Jacobs of Qualcomm that has a history in investigating best practices for technology in education. He has both a BA and MS in Education and Learning Sciences with a focus on engineering education, as well as a PhD in Educational Technology. For his dissertation, he looked at how technologies can foster cross-cultural collaboration for students from over 55 countries. Over the last eight years, he has presented and published papers on education and technology at AERA and in journals such as Computers in Human Behavior. Currently, he is serving as a co-principal investigator on two projects funded by the National Science Foundation (Awards #1826354 (RFE) and #1713547 (AISL)); one of these projects is developing a STEM summer camp that supports career pathways for Latinx students.

Melissa M. Arana
Mireya Becker Roberto, University of San Diego
Miss Nicole G. Reyes

Integrating Asset-based Practices, Engineering, and NGSS: Lessons from Working with Teachers through a community-focused approach

Abstract

The goal of this NSF-funded, three-year exploratory study is to provide opportunities for middle school teachers to develop an understanding of and appreciation for funds of knowledge in relation to engineering design learning. This research project supports teachers in integrating asset-based practices (particularly funds of knowledge) into their teaching of engineering, and aims to examine how such integration of can impact Latinx students' and English Learners/Emergent Bilinguals' interest in, and knowledge of engineering. The project offers an opportunity to have an early impact on students' engineering interest while also providing teachers with a broader perspective of how to develop students' engineering habits of mind and dispositions using asset-based practices in ways that are aligned with Next Generation Science Standards (NGSS). This paper focuses primarily on the initial workshop offered to teachers as an opportunity to introduce them to engineering content and asset-based approaches to teaching Science and Engineering Practices.

Introduction

This project centers around middle school students and teachers in the U.S.-Mexico border, particularly a predominantly Latinx area in the Southwest, where more than 36% of the residents are English Learners/Emergent Bilinguals. The number of English Learners/Emergent Bilinguals continues to increase but they continue to have limited access to appropriate STEM content that addresses their linguistic practices [1]. As indicated by the National Academies of Science, Engineering and Medicine in their report *English learners in STEM subjects: Transforming classrooms, schools, and lives* [1], "…children are not typically assessed for their content knowledge when entering U.S. schools…their identification and course placement, at least at the secondary level, is typically determined by their level of English proficiency" (p. 27). There is a perception that students must be proficient in English in order to be successful in STEM-related specific content [2].

The project aims to explore a situated view of engineering design that accounts for the wealth of knowledge, skills, and practices (i.e., students' embodied knowledge) that students bring into the classroom, including language practices [3]. The larger study follows an asset-based approach to learn more about the engineering practices of Latinx adolescents [3]. The overarching goal of this mixed methods study is to generate knowledge on how and to what extent the integration of funds of knowledge, language, and engineering design can serve as a pathway to and through engineering for Latinx students while helping teachers and students recognize funds of knowledge as assets in solving engineering problems. Specifically, the study is designed to (1) provide middle school teachers with opportunities to recognize, value, and activate Latinx students' funds of knowledge through the emphasis and enactment of engineering design

practices; (2) support middle school teachers in integrating funds of knowledge with engineering design in a manner that meets students' and teachers' individual needs and classroom contexts (co-design of activities); and (3) to create a structure and culture that helps Latinx students cultivate awareness of their own funds of knowledge, and foster their interest in and knowledge of engineering.

During the first year of the project, the research team focused on six major activities: (1) recruit nine teachers from middle schools in the U.S.–Mexico border; (2) conduct initial baseline individual interviews as well as classroom observations with all eight teacher participants; (3) introduce teachers to the principles of the engineering design process; (4) introduce teachers to the principles of funds of knowledge; (5) provide opportunities for teachers to engage in active learning; and (6) identify and co-construct with the teachers learning activities that integrate aspects of funds of knowledge and engineering design while addressing NGSS Science and Engineering Practices [4]. This paper reports primarily on these aspects of the study and discusses the components of the workshop that teachers found more helpful.

Context and Components of the Workshop

For the first major activity, we were able to recruit seven teachers from a STEM-oriented middle school near the U.S.-Mexico border. Due to the different issues related to public school funding, several teachers were hesitant to participate in the project, and some schools could not commit to collaborating with the research team for the project. Thus, the original goal of recruiting 9 teachers had to be reduced to only 7 teachers. The teachers were recruited from Border Middle School (pseudonym), a school wide Title I site where 88% of the students qualify for free and/or reduced lunch. In addition, 98% of the students come from underrepresented groups, primarily Latinx (92%), and 45% of the student population are English Learners/Emergent Bilinguals. The teachers recruited for the project included one computer science/science 8th grade teacher (female), one 8th grade bilingual science teacher (male), one 7th grade bilingual science teacher (female), one 7th grade bilingual mathematics teacher (female), one 8th grade bilingual social science teacher (male), one 7th grade Spanish teacher (female), and one 7th grade English teacher (female).

The second major activity, to collect baseline individual interviews and classroom observations, was met once teachers had been recruited. Each teacher was interviewed using an interview protocol developed for that purpose. During the interviews, teachers were asked about their understanding of the concept of funds of knowledge as well as strategies they thought would be important to use to elicit them. They also shared their understanding of the engineering design process.

For the third and fourth major activities, the research team provided 25 hours of professional development to the teachers over the summer. This professional development opportunity, which we referred to as "the workshop," was divided into a three-day experience (5 hours each day) where teachers learned about the engineering design process, funds of knowledge, and NGSS science and engineering practices. The workshop was facilitated by the PI, co-PIs, and three

assisting undergraduate researchers hired for this project. It was important for the research team to provide an overview of these topics given that not all teachers were familiar with the science and engineering practices. The overarching purpose of this workshop was to provide opportunities for multiple subjects teachers to develop an understanding of and appreciation for funds of knowledge, and support them in integrating funds of knowledge into their classes while emphasizing engineering design.

Workshop Results and Lessons Learned

For the engineering design process, the teachers were asked to work in teams and build a tower that would be used to monitor weather changes. Teachers learned about the importance of defining and framing problems in engineering, asking questions, searching for information, considering constraints, ideating, evaluating potential solutions, building and testing prototypes, and communicating solutions [5-7]. The engineering design process utilized in the engineering activity was a seven-step process [4]. The steps included: identify the problem, research, brainstorm ideas, draw your design, build a prototype, test the prototype, and then evaluate and re-design [4].

For the funds of knowledge component of the workshop, the teachers learned about funds of knowledge [8-10], explored and discussed their own funds of knowledge through a reflective activity [8], described the ways in which they could elicit the funds of knowledge of their students, and analyzed representative examples of culturally responsive STEM activities that draw from funds of knowledge [11-14].

Finally, for the science and engineering practices the teachers were divided into groups and each group was in charge of describing two of the eight science and engineering practices assigned to them for the activity. They identified the practices that were primarily described as science or engineering and the ways in which these practices overlapped. The eight science and engineering practices included: (1) asking questions and defining problems; (2) developing and using models; (3) planning and carrying out investigations; (4) analyzing and interpreting data; (5) constructing explanations and designing solutions; (6) using mathematics and computational thinking; (7) engaging in argument from evidence; and (8) obtaining, evaluating, and communicating information [4]. Through these activities, the teachers had an opportunity to not only see the differences and similarities about these practices but also develop a greater understanding of a holistic overview of how engineering and science can be approached from an interdisciplinary perspective. This workshop also served as a vehicle to build *confianza* (trust) with the teachers and allow for a better collaboration.

As a result of this summer workshop, the teachers came up with two thematic units: (1) the sociotechnical implications of creating of new settlements in a different planet, and (2) the redesign of the school cafeteria. As indicated before, one of the specific objectives was to provide teachers with an opportunity to learn more about funds of knowledge and engineering design. Many teachers, however, were not able to connect their subject contents to engineering design because they may have had little to no explicit exposure to engineering design before the

workshop. The workshop, although it provided teachers with an opportunity to foster deeper learning of engineering design and funds of knowledge, was not sufficient for teachers to effectively implement these practices in effective ways. There were many instances in which teachers felt "stuck" because it was harder for them to see the connections between engineering and their subject matters (e.g., language arts, social sciences).

In addition, the workshop incorporated different features that aim to enhance teachers' understanding of funds of knowledge and engineering: (1) a focus on the subject matter content; (2) participation in active learning; (3) support from experts in engineering, bilingual education, and learning sciences; and (4) collective participation. Teachers learned that knowing about and eliciting their students' funds of knowledge can help students connect to the learning processes at school while challenging deficit models. Nonetheless, it was difficult for some teachers to differentiate between funds of knowledge and "prior knowledge." As a result, future work emerging from this research will
try to focus more on helping teachers develop a better understanding of the origins of funds of knowledge, its purpose, and the importance of theorizing practices of the household to eliminate perceptions of "scarcity" of resources in students' homes and communities. It is also important to note that the initial goal of funds of knowledge was not to equate the wealth of knowledge emerging from households and communities to culture. In fact, funds of knowledge sought to reject the idea that culture is homogeneous, bounded, and static by challenging the oversimplistic analysis of the students' homes. Funds of knowledge sought to provide "mutual transformation" by allowing teachers to explore the ways in which household and community knowledge informs academic knowledge in the classroom [9]. Thus, future work will highlight the importance of learning to theorize and explore the complexities of communities, households, knowledges and contexts [9].

During the interviews with the teachers on the final day of the institute, they shared recommendations for future iterations of institutes and for improvements going forward in the project. Although the workshop included 25 hours of presentations, activities, and curriculum co-construction between PIs and teachers in thematic units, the teachers wanted more time to work together and complete their planning. They wanted to leave the workshop with a completed product because they agreed that finding time during the school year was challenging. Several suggested a release day or a paid Saturday workday prior to implementation of their activities to complete their planning. All of the teachers concurred that regular meeting times going forward would be helpful to maintain momentum throughout the project. Suggested times varied, but all expressed a desire for consistency. Many of the teachers have personal obligations that affect their availability outside the school day, and like to know their schedules in advance so they can plan ahead for childcare conflicts. Some of the teachers indicated that future workshops should include (1) templates for activities, (2) representation of more subject areas and engagement of more teachers, (3) having engineers and engineering students provide more support, and (4) provide literature and other resources to learn more about funds of knowledge.

Conclusion

The workshops, as indicated by the teachers, were effective and provided them with an introduction to engineering, asset-based practices, and NGSS science and engineering practices. The time spent on the workshop was limited by several factors, including availability of teachers, lack of childcare resources, and limited background knowledge on the topics presented. Although teachers learned a lot about engineering design and the science and engineering practices, several expressed that they still felt they had a lot to learn and improve upon. Nonetheless, teachers enjoyed the activities and expressed that they learned a lot about how to integrate engineering into their classroom, particularly through cross-curricular integration. Future work will include more collaborations with teachers to ensure successful completion of their thematic unit elements and subsequent classroom implementation of units developed.

It is important to mention that most of the teachers involved in this project are not engineers, or science teachers. We did this purposefully because research has indicated that there is no emphasis on the importance of language in learning STEM content [1]. Language proficiency is traditionally seen as separate from STEM learning. Therefore, this project has given the teachers from different subject content areas (e.g., English, Spanish, Science, Mathematics, Social Studies) an opportunity to learn more about how language is embedded in STEAM learning. Moreover, the project also provided an opportunity for all teachers to explore how engineering can be used as the integrator in STEAM. The project also introduced teachers to a more holistic view of engineering as a sociotechnical endeavor and how different disciplines can work together to create transformative learning experiences for minoritized students.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 1826354. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation

References

[1] National Academies of Sciences Engineering and Medicine, *English learners in STEM subjects: Transforming classrooms, schools, and lives*. Washington, D.C.: National Academies Press, 2018.

[2] P. C. Gandara and M. Hopkins, *Forbidden language : English learners and restrictive language policies*. New York: Teachers College Press, 2010.

[3] J. Mejia, D. Ruiz, V. Popov, A. Esquinca, and D. Gadbois, "Asset-based Practices in Engineering Design (APRENDE): Development of a Funds-of-Knowledge Approach for the Formation of Engineers," presented at the ASEE Annual Conference & Exposition, Tampa, FL, 2019.

[4] NGSS Lead States, *Next generation science standards : for states, by states*. Washington, District of Columbia: National Academies Press, 2013.

[5] J. L. Kolodner, "Facilitating the learning of design practices: Lessons learned from an inquiry into science education," *Journal of Industrial Teacher Education,* vol. 39, 2002.

[6] C. Sias, A. Wilson-Lopez, and J. Mejia, "Connecting students' background experiences to engineering design," Technology and Engineering Teacher, vol. 76, p. 30, 2016.

[7] A. Wilson-Lopez, C. Sias, and J. Mejia, "Fundamental literacies in English learners' engineering design work," 2015.

[8] N. González, L. C. Moll, and C. Amanti, *Funds of knowledge: Theorizing practices in households, communities, and classrooms*. Mahwah, NJ: Lawrence Erlbaum, 2006.

[9] N. González, L. Wyman, and B. H. O'Connor, "The past, present, and future of "funds of knowledge"", in *A Companion to the Anthropology of Education*, G. Levinston and M. Pollock, Eds. Malden, MA: Wiley-Blackwell, pp. 481-494, 2011.

[10] L. C. Moll, C. Amanti, D. Neff, and N. Gonzalez, "Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms," *Theory into practice,* vol. 31, pp. 132-141, 1992.

[11] J. A. Mejia, "A sociocultural analysis of Latino high school students' funds of knowledge and implications for culturally responsive engineering education," PhD, Engineering Education Utah State University, Logan, UT, 2014.

[12] J. A. Mejia, A. A. Wilson, C. E. Hailey, I. M. Hasbun, and D. L. Householder, "Funds of knowledge in Hispanic students' communities and households that enhance engineering design thinking," in *American Society for Engineering Education Annual Conference*, Indianapolis, 2014, pp. 1-20.

[13] J. A. Mejia and A. Wilson-Lopez, "STEM education through funds of knowledge: Creating bridges between formal and informal resources in the classroom," *The Agricultural Education Magazine,* vol. 87, pp. 14-16, 2015.

[14] A. Wilson-Lopez, J. A. Mejia, I. M. Hasbún, and G. S. Kasun, "Latina/o Adolescents' Funds of Knowledge Related to Engineering," *Journal of Engineering Education,* vol. 105, pp. 278-311, 2016.