BOARD # 364: Empowering Adolescents from Migratory Backgrounds with Gamification and Culturally-Responsive Engineering Design Instruction: A summary of 2-years of effort (EHR:BCSER)

Dr. Dina Verdin, Arizona State University, Polytechnic Campus

Dina Verdín, PhD is an Assistant Professor of Engineering at the Ira A. Fulton Schools of Engineering at Arizona State University. She graduated from San José State University with a BS in Industrial Systems Engineering and from Purdue University with an MS in Industrial Engineering and PhD in Engineering Education. Her research program promotes equity and inclusion in engineering by confronting the pervasive barriers facing minoritized students. Her work addresses the challenges Latinx, first-generation college students, and women in engineering face by focusing on two research strands: access and persistence. Dr. Verdín seeks to create culturally responsive opportunities that broaden engineering access while simultaneously dismantling the systemic obstacles that hinder minoritized students' identity development and persistence. With this work, Dr. Verdín is committed to transforming engineering education and ensuring that all minoritized students can thrive. She currently has three active grants with the National Science Foundation aimed at supporting the mission of her research program. She has won several awards, including the 2022-2023 Outstanding Research Publication Award by the American Educational Research Association (AERA) Division I, the 2022 ASEE ERM Apprentice Faculty Grant, and the 2018 ASEE/IEEE Frontiers in Education Best Diversity Paper Award.

Tim Wells, Arizona State University, Polytechnic Campus

Timothy C. Wells (PhD, Arizona State University) is a Postdoctoral Research Scholar in the Polytechnic School at Arizona State University. He has expertise in embodied learning, restorative practices, and cultural and education. His research draws upon social theory, historical context, and experimental methodologies to bring insight and innovation to the challenges of contemporary schooling. He has published in Teachers College Press, Qualitative Inquiry, and Discourse: A Journal of Culture and Education.

Ulises Juan Trujillo Garcia, Arizona State University

Ulises Trujillo Garcia (he/him/él) holds a bachelor's degree in civil engineering and a master's in engineering education. He is currently pursuing a PhD in engineering education at Arizona State University, where his research centers on the experiences of individuals from migratory/seasonal farmworker backgrounds in engineering. Ulises explores the unique funds of knowledge these individuals acquire while growing up and how they leverage these skills to navigate engineering spaces. He was named a fellow of the National Science Foundation Graduate Research Fellowship Program 2022; he is also a former fellow for the Station1 Frontiers Fellowship, the Micron Academy for Inclusive Leadership, and HACU ¡Adelante! Leadership Institute. In the summer of 2021, he initiated a scholarship for migrant students in Eastern Oregon to support their pursuit of higher education. As a first-generation, low-income Latino from a farm-working family, Ulises is deeply committed to his community, dedicating his time to advancing educational and leadership causes.

Andrea Lidia Castillo, Arizona State University

A.Lili Castillo is a second-year graduate student in the Engineering Education Systems and Design PhD program at Arizona State University. Lili is a recipient of the 2022 National Science Foundation's Graduate research fellowship. Her research interests include engineering identity formation, high-impact learning experiences, and Latino/a/x & first-generation college student pathways in engineering. Through her research, Lili hopes to amplify the voices of historically underrepresented populations in engineering to foster an inclusive space in engineering education for diverse students through asset-based and culturally relevant approaches.

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Introduction

Access to enriching engineering experiences remains a challenge, particularly for Latinx high school students with one or more parents who are migratory seasonal farmworkers, herein referred to as migratory students. A migratory student is a child/ whose parent(s) is a migratory agricultural worker. There are approximately half a million migratory children navigating the American education system, and they face unique challenges—including frequent relocations, English language learners, and disrupted schooling—that significantly impact their academic outcomes and career aspirations [1], [2]. Migratory students have limited access to engineering learning experiences and also encounter curricula that often fail to connect meaningfully with their lived experiences and cultural contexts. Yet, these challenges are not indicative of a lack of potential or interest in engineering but rather of systemic inequities in educational access and engagement. Addressing these dual challenges is critical for expanding pathways into engineering for migratory students. To help address these inequities, we developed and implemented a culturally responsive, gamified activity aimed at teaching the engineering design process to high school students from migratory families. Using the culturally responsive pedagogical character profiles [4] and principles of gamification [3], we designed an activity that combined culturally validating practices with gamified challenges to create a relevant and engaging learning experience, see Figure 1.

In this project summary (NSF EHR:BCSER #2225306), we briefly describe the culturally responsive gamified activity and provide an overview of its effectiveness of how the activity supported migratory adolescents' engineering interest, self-efficacy, aspirational engineering identity, and engendered positive perceptions of using engineering as a tool for social justice.

Activity Overview

The activity's effectiveness stemmed from its culturally responsive and gamified approach, which resonated with the unique experiences of migratory high school students. By providing a supportive space for problem scoping, brainstorming, prototyping, and evaluating, we created an environment where students could apply their perspectives to a real-world engineering challenge. The project centered around an activity that introduced high school students to the Engineering Design Process. The activity took about two hours to complete and included two parts. The first part guided students through a computer-based storyline that taught them about the Engineering Design Process. Students met the story characters Sol y Luna, who represented children of migratory agricultural workers; these characters worked with the migratory students to understand and design a solution to an issue affecting their community. In the problem scoping phase, the migratory students identified that exposure to high-levels of pesticide in the crops created health issues for the farmworkers. In the brainstorming phase, they identified a viable solution

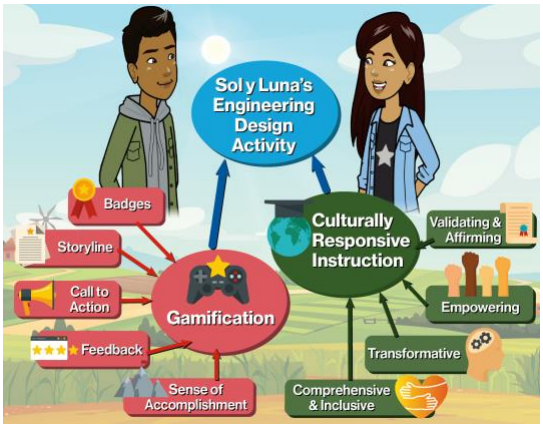

Figure 1
Culturally responsive and gamification elements used in the activity

using strategies such as interviewing farmworkers, observing how they perform their job through a documentary video, and by conducting research on the topic. Following the brainstorming phase and after arriving with a clear design solution, the migratory students shifted to building a physical prototype of their design solution. The second part of the activity guided the migratory students through a hands-on Arduino building activity in which they built a working device to detect pesticides in the soil. Students were not actually exposed to pesticides. The sensor was designed to test for moisture in the soil. In designing the activity, we specifically leveraged principles of gamification (e.g., the use of storylines, goal-oriented tasks, badges, and feedback/rewards structures [3]) and dimensions of culturally relevant instruction (e.g., cultural affirmation, empowerment, and inclusivity [4]) to maximize engagement and relevance in the instruction.

Participants and Data Collection

The migratory high school students (n = 206) were all from Latinx backgrounds and were associated with the Migrant Education Program in the Southwest and Pacific Northwest. The cohort included 118 (57%) girls and 85 (41%) boys. Two percent of the students did not complete the demographic part of the survey. The migratory students who participated ranged from 9th through 12th graders. Pre-and-post-survey data were collected by asking students about their level of engineering interest, engineering self-efficacy beliefs, recognition as engineers, and engineering agency beliefs. These measures were collected using a 0-4 rating scale, asking students to rate their level of agreement with the survey statements. All survey data were collected during the 1.5-hour session.

A mixed ANOVA was conducted to assess changes in students' responses to the survey measures before and after the activity and to determine whether they differed by gender. Data were examined for multivariate outliers using Mahalanobis distance; the one case that violated the assumption was removed. Univariate normality assumptions were assessed through skewness and kurtosis z-scores; all values were within an acceptable range. The assumption of homogeneity of covariances was assessed using Box's test; no violations were detected. All constructs had Cronbach alpha values that exceeded the recommended cutoff value of 0.70.

Overview of Key Findings

The results showed substantial growth across all core survey measures: engineering self-efficacy, interest, recognition, and agency beliefs. Engineering agency beliefs refer to students' ability to use engineering knowledge and skills to enact meaningful change in their community. This belief reflects the idea that engineering can be used in powerful ways to address societal challenges, improve one's quality of life, and make a tangible impact on people's lives. The activity intended to provide an example of how migratory adolescents can create social change in their community, i.e., by developing a device to help detect levels of pesticide and, in turn, mitigate health issues related to this exposure. The intervention helped reinforce migratory students' engineering agency beliefs by increasing participants' perceptions of how engineering can be a tool for positive social change and narrowing the gender gap. As Figure 2a shows, the increase in girls' engineering agency beliefs was over two times that of boys, demonstrating the intervention's unique impact on migratory high school girls.

Prior work has confirmed that engineering self-efficacy, recognition, and interest support the development of an engineering identity [5]-[9], and we found that both boys and girls scored significantly higher on these measures after engaging in the culturally responsive gamified activity (Figure 2b-d). Across all measures, girls demonstrated greater gains than boys, in some cases

closing pre-existing gender gaps. Specifically, when evaluating changes in migratory students' interest in engineering, we can see there was a 0.48-point gap between boys and girls. At the onset, migratory boys showed significantly greater interest in engineering compared to girls; however, after the activity, this interest narrowed to a non-significant gap (Figure 2b).

Learning how to apply engineering practices alongside Sol y Luna and observing how they engaged with engineering professionals and community members allowed the migratory student participants to feel recognized as engineers and bolstered their confidence, Figure 2c and Figure 2d. Migratory boys did show significant gains in these two affective measures. However, the activity was particularly impactful for migratory girls, leading to a 0.55-point increase in their sense of recognition as engineers and a 0.73-point rise in their confidence levels. In the activity, the female avatar, Luna, took on leadership roles and made critical decisions about how to proceed through the engineering design process. We believe that seeing Luna as a proactive, knowledgeable go-getter helped the migratory girls envision themselves in similar roles. How Luna was represented in the activity challenged traditional gender stereotypes and provided a relatable role model; this, in turn, could explain why girls' engineering self-efficacy and sense of recognition as engineers increased after the activity. By challenging traditional gender stereotypes and providing a culturally and contextually relevant role model, the activity helped migratory girls see themselves as individuals who can do engineering, supporting their self-efficacy and recognition.

Implications

Seeing oneself as an engineer, i.e., developing an engineering identity, has been found to support students' choice to enroll in an engineering program and persist toward degree completion [6]-[9]. The factors that help promote the development of an engineering identity include having confidence in their abilities to do well in engineering, akin to self-efficacy beliefs, being interested in the subject area, and receiving recognition from influential others [5]-[9]. These findings demonstrate how culturally responsive, gamified activities can effectively support the critical factors that help develop migratory students' perceptions of identifying as future engineers. The significant increase in engineering self-efficacy, recognition, and interest among the participants also suggests that when educational content authentically connects to students' lived experiences and cultural context, it can impact their abilities to see themselves as engineers in the future. The increase in engineering interest observed among girls is particularly noteworthy, as interest has been shown to be a powerful influence on program persistence among minoritized female students [7]. The substantial narrowing of the gender gap across multiple measures indicates that culturally responsive approaches, combined with relatable role models like Luna, can help address persistent gender disparities in engineering education.

The findings underscore a broader implication for engineering education: the critical importance of leveraging students' sociocultural realities and lived experiences in designing instruction. This study demonstrated that when engineering content is made relevant and accessible through cultural responsiveness and gamification, it can significantly impact how students, particularly those from underserved populations, perceive and engage with engineering. The virtual format's success in fostering engineering agency beliefs suggests that well-designed online experiences can create meaningful learning environments that affirm students' identities while building engineering competencies.

These results have important implications for broadening participation efforts in engineering. Traditional approaches often focus primarily on academic preparation while

potentially overlooking the powerful role that cultural validation and identity development play in students' educational trajectories. The present study suggests that integrating culturally responsive practices with engaging instructional strategies like gamification can create learning experiences that simultaneously build technical understandings while fostering the affective and motivational foundations for long-term engineering participation. As educators and policymakers work to address persistent inequities in engineering education, these findings point to the value of designing interventions that intentionally connect students' lived experiences while providing interactive, culturally affirming learning environments.

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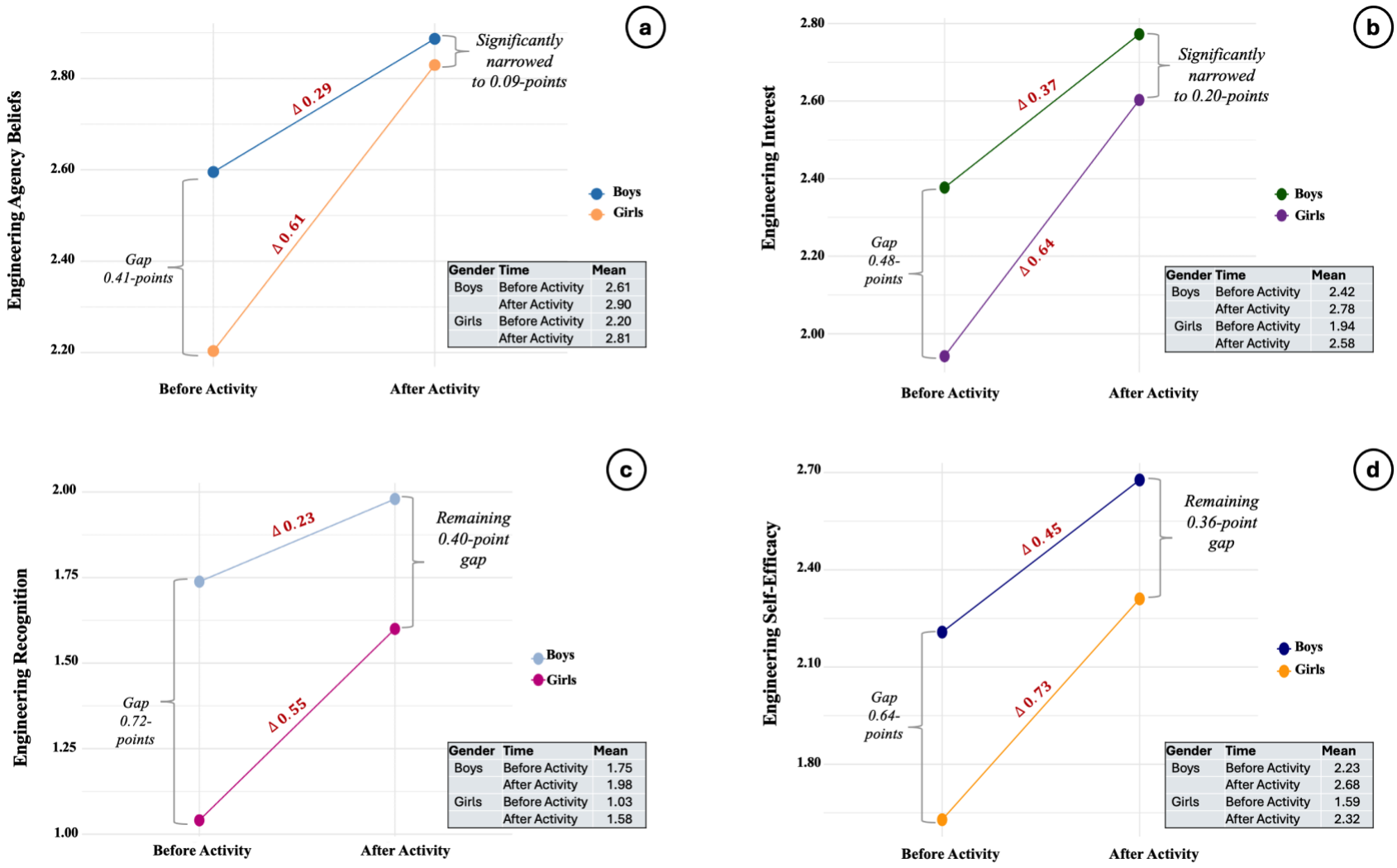

Figure 2

Results of pre-and-post survey responses collected before the activity and immediately after the activity