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Developing Engineering for Social Impact Beliefs among Migratory High School Students Through a Culturally Responsive Engineering Design Activity (RTP, Diversity)

Dr. Timothy 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.

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.

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Abstract

Broadening participation in engineering needs to be different from filling the pipeline or national competitiveness. We should seek to empower students to use engineering knowledge and skills to create social change, address injustices, or develop problem-solving skills that can help transform lives. This study examined how migratory high school students developed beliefs about engineering's capacity for social impact through participation in an activity where they learned how the engineering design process could be used to solve a need impacting agricultural workers. Specifically, we investigated how students' interest in engineering, their self-efficacy in applying engineering concepts, and the development of an identity as a future engineer influence the formation of their beliefs about their capacity to act purposefully and effectively using engineering practices.

Migratory high school students represent an overlooked and underserved segment of students in U.S. schools. These students, often from Latinx backgrounds, remain underrepresented in engineering fields. To investigate the development of "engineering for social impact" among migratory high school students, we designed and implemented a culturally responsive and gamified engineering design activity. The activity aimed to connect engineering concepts to students' cultural backgrounds and experiences while leveraging game-based learning elements to increase engagement. We administered pre- and post-surveys to measure changes in students' engineering impact, interest, self-efficacy, and identity ($n = 235$). We used a multiple linear regression model to examine the relationships.

Our results show that migratory students' engineering interest and self-efficacy significantly supported the development of their belief that engineering could be a tool for social impact. Specifically, as students' engineering interest increased, their perception that engineering could be used as a practice to address injustices significantly increased by 0.335 points. Similarly, as students' engineering self-efficacy beliefs increased, that led to a significant increase of 0.346 points in their social impact beliefs. However, being recognized as someone who can do engineering (i.e., recognition beliefs) did not have a significant effect. The model explains approximately 46.7% of the variance in students' beliefs about engineering as a tool for social impact. Our findings suggest that students' engineering for social impact beliefs develop through experiences that enable them to see themselves as engineers and use engineering knowledge in meaningful ways. Our culturally responsive and gamified approach positively influenced students' beliefs by fostering both interest and self-efficacy in engineering contexts. The results underscore the importance of creating learning environments and activities that not only spark interest in engineering but also build students' confidence in their abilities to engage in engineering practices. For migratory Latinx high school students who face unique challenges in their educational journeys, cultivating engineering for social impact may be particularly crucial in garnering interest in the field.

This study contributes to the growing body of research on the importance of connecting engineering to social and cultural context and provides insights into effective strategies for supporting underrepresented students in engineering. Future work should explore the longitudinal effects of such interventions and investigate additional factors that may influence the development of students' social impact beliefs among migratory students.

Introduction

Many students graduate from high school without taking a single engineering course or gaining formal engineering experience [1]. Lack of engineering access is a problem that is especially pronounced in under-resourced schools, where a majority of students qualify for free or reduced-price lunches [2]. Systemic inequities further exacerbate the problem, as these schools predominantly serve low-income and minoritized communities, creating disproportionate barriers to engineering education for these students. Adolescents who are children of migratory and seasonal farmworkers represent one such community that faces systemic marginalization and remains invisible in the conversation of access to engineering-enriching activities. Still, access is only part of the problem. STEM educators struggle to create meaningfully engaged classrooms, as students often perceive their science courses as irrelevant [3], and report declining interest in STEM fields over time [4]. For racially and ethnically diverse students, the problem is compounded by STEM classrooms that lack culturally relevant content and instructional practices [5], [6]. Issues of access and relevance present significant obstacles to engage and support diverse student populations in engineering education.

Moreover, engineering as a field tends to neglect important social, community, and humanistic considerations. Calls to increase participation typically invoke national competitiveness and the need to fill employment pipelines [7] rather than notions of empowerment and justice. Similarly, the teaching of engineering tends to favor technical over socio-cultural aspects. This is what Leydens and Lucena [8] describe as the prioritization of problem-solving over problem definition: the former relies on engineering skills, whereas the latter relies on societal understanding. When engineering education leaves out problem definition, students are left unprepared to address the complex challenges and ethical dilemmas that inevitably arise in engineering work. Another way of saying this is that engineering education needs to do more to cultivate students' ability to make socially informed and intentional decisions.

The emphasis on socially informed and intentional decision-making aligns with what researchers have termed critical disciplinary agency, which is understood as students' capacity to leverage subject matter content toward social justice and empowerment [9], [10], [11]. While different disciplinary-based iterations of the term have been conceptualized, i.e., critical math agency, critical physics agency, critical engineering agency, the underlying goal is to connect student learning with real-world context and action for social change. The framework provides an avenue to address shortcomings in engineering education, such as cultural relevance, socio-cultural connections, and access, by repositioning engineering as a tool for meaningful community engagement and positive change. Yet much remains to be understood regarding the instructional and motivational factors that would support students in seeing engineering as a platform for social change and impact.

In this paper, we investigated migratory students' beliefs about socially impactful engineering as an avenue to address long-standing disparities and integrate social justice into engineering with the goal of empowering them to pursue this field. Migratory students are children whose parent(s) are migratory agricultural workers [12]. For these students, the challenges of learning engineering are further exacerbated by frequent school disruptions, relocations, and learning English as a second language [13]. Our study examines how a culturally relevant engineering design activity influenced migratory students' beliefs about the social impact of engineering, and explores the relationship between students' engineering interest, self-efficacy, and recognition. Specifically, we examine two research questions:

(1) What is the difference in engineering for social impact scores among migratory high school students before and after participating in a culturally responsive engineering design activity?
(2) How do engineering interest, recognition, and self-efficacy predict migratory high school students' beliefs about the social impact of engineering?

Conceptual Framework: Critical Engineering Agency

By reframing engineering as a tool for social impact, the concept of critical engineering agency underscores the necessity of moving beyond technical problem-solving to empower communities through socially impactful engineering practices. The concept of critical engineering agency builds upon research literature on critical math [14] and critical science agency [11]. Drawing on critical and sociocultural theories and qualitative methodologies, researchers in this field understand critical disciplinary agency as a student's capacity to employ disciplinary knowledge for social change and justice. In practice, this involves developing a deep understanding alongside the capacity to use that understanding to enact change. Turner [15] demonstrates this in a study of high school students who used knowledge of mathematical concepts to prove their under-resourced school was unjustly overcrowded. Similarly, Calabrese Barton and Tan [9] demonstrated how students applied knowledge of energy use and urban health to critique city designs that disproportionately impacted low-income communities and people of color. In these cases, the learning outcomes transcended the academic content and classroom boundaries to address social injustices and change in students' communities.

This framework has been extended into engineering education with the conceptualization of critical engineering agency [16] [17]. Following the formulation of a critical math/science agency, a critical engineering agency can be understood as the application of engineering knowledge for social justice and change. This conceptualization serves two functions: it encourages educators and researchers to make the content of engineering practical to students' lived experiences, and it encourages engineers and students to adopt mindsets and actions oriented toward making the world a better and more socially just place.

Research focused on critical engineering agency has predominantly used survey methods and quantitative analysis over qualitative and observational approaches, and has focused on students' agency beliefs rather than their specific actions and behavior. For example, Godwin et al. [17] found that students' engineering identity and agency independently predicted students' engineering career choices. Verdín's [16] study found that first-generation college students who saw themselves as engineers also held greater engineering agency beliefs. The focus on students' beliefs provides an alternative to the challenge of interpreting student mindsets from their behaviors and actions [18], while the use of quantitative methods provides a chance to detect directional relationships in the development of students' critical engineering agency.

In this paper, we focus specifically on students' beliefs about the role of engineering in creating social change, a subset of the critical engineering agency framework. We specifically study how students develop the belief that they can use engineering to positively impact and change their own environments and communities. We employ quantitative methods, such as paired samples t-tests and multiple regression analyses, to examine instructional strategies and dispositional factors that might promote this belief. We focus on three factors: students' interest, self-efficacy, and recognition in engineering. We use the concept of self-efficacy to capture students' perception of their confidence to academically excel in engineering; this construct has substantial operational overlap with performance/competence beliefs. Prior work suggests engineering for social impact supports students' interest, performance/competence, and recognition, which are constructs that collectively inform identity development [16]. However, it might be that the relationship goes both ways: the three constructs may also support the development of student beliefs about engineering as a tool for social impact. Godwin et al.'s [16] and Verdín's [17] research on critical engineering agency focuses on undergraduate engineering students. These are students who have chosen to pursue engineering and likely have already developed an engineering identity to some extent. Our study focuses on migratory high school students, many of whom have no prior formal engineering experience and have likely not developed an engineering identity. For these students, the development of interest, self-efficacy, and recognition in engineering might be a necessary first step before they can develop beliefs about engineering as a tool for social impact. Understanding these pathways could provide educators with strategies for supporting students in engineering fields.

Engineering Design Process Activity

We developed a two-part activity (two modules) for migratory high school students using the engineering design process, a fundamental concept in K-12 engineering education [19]. The first module engaged students through an online narrative following the characters Sol and Luna, who were portrayed as teenage children of agricultural workers, as they confronted pesticide exposure issues in the fields. The second module transitioned to hands-on learning, where students built and tested Arduino-based soil sensors. Throughout both modules, students practiced the key engineering design process steps: problem scoping, brainstorming, prototyping/building/testing, and evaluating. The engineering design activity integrated authentic problem-solving with culturally relevant contexts and elements of gamification. By following the engineering design process, students gained practical engineering experience while addressing real social justice issues affecting agricultural workers. The activity we presented to students provided a systematic framework for them to understand how engineering concepts could address challenges within their communities.

We designed the activity to leverage cultural responsiveness by connecting engineering to students' lived experiences through the Sol y Luna storyline, whose family situations and cultural backgrounds reflect those of our participants. This narrative framework, combined with documentary footage of real migrant workers, helped students recognize engineering's potential for social impact. The characters and cultural representation throughout the modules affirmed students' identities while demonstrating how engineering skills could address community challenges. The hands-on Arduino component strengthened students' skill sets by transitioning from abstract understanding to practical application. Through guided construction and testing of the soil sensors, students developed technical skills while experiencing engineering's real-world utility centered on an issue of social justice. Though the sensors detected moisture rather than pesticides, the activity successfully connected engineering principles with tangible experience in engineering design and implementation.

The activity leveraged elements of gamification by integrating a storyline with challenges and reward structures within a supportive and simulated environment. The Sol y Luna storyline challenged migratory students to create a device that agricultural workers could use to identify harmful pesticides in the soil. Students were rewarded with completion badges as they progressed through each step of the design process. When a student got stuck on a step, they received feedback and opportunities to try again. The entire first part of the activity is simulated in an online environment using the Canvas learning management system. The simulated environment allows students to experience the entirety of the engineering design process in a manageable time, something that would normally take weeks or months. The gamified elements created a supportive and engaging structure that allowed students to develop interest and confidence in their engineering capabilities.

Methodology

This study analyzed pre- and post-survey data collected during a culturally responsive, gamified engineering activity to examine its impact on students' beliefs and interest in engineering. Data were collected during two summer programs (2022–2023) at a Southwestern university and a Pacific Northwest community college, where high school students completed an online survey in a classroom setting immediately before and after the activity. Institutional Review Board approval was obtained from both universities prior to data collection. Given that participants were minors, parental consent and student assent were obtained for all participating students. To protect students' privacy, all responses were anonymized. A total of 235 high school students from migratory backgrounds participated in the study, all of whom were enrolled in a summer program designed for migratory students. All participants were of Latinx heritage. Of these, 132 students (55%) were girls, 97 (41%) were boys, and 5 (2%) did not report their gender or complete the demographic section of the survey. More than half of the students indicated no prior experience in an engineering or STEM-related program.

Survey Instrument

We used the following four survey scales to answer our research questions. Information about the specific survey items used for each scale can be found in Table 1.

Engineering for Social Impact Scale. Engineering for social impact reflect students' beliefs about using engineering to make the world a better place. Previously validated as a measure of engineering agency beliefs [16], the scale has been renamed here to reflect a focus on engineering for social impact. We calculated a composite score across five Likert scale items, ranging from 0 ("strongly disagree") to 4 ("strongly agree") (Cronbach's alpha = 0.92).

Engineering Recognition Scale. Engineering recognition captures students' beliefs about how others perceive them in the engineering field [20]. We created a composite score of these items to measure engineering recognition. All questions used a 5-point Likert scale ranging from 0 ("strongly disagree") to 4 ("strongly agree") (Cronbach's alpha = 0.77).

Engineering Interest Scale. Engineering interest reflects students' disposition toward engineering activities, education, and career paths [17]. We created a composite score from these items to measure engineering interest (Table 1). All questions used a 5-point Likert scale ranging from 0 ("strongly disagree") to 4 ("strongly agree") (Cronbach's alpha = 0.89).

General Engineering Self-Efficacy Scale. The self-efficacy scale measured students' confidence in their ability to excel academically in engineering using domain-general items with demonstrated validity in assessing engineering self-efficacy [21]. We created a composite score from four items to measure general engineering self-efficacy. All questions used a 5-point Likert scale ranging from 0 ("not at all confident") to 4 ("very confident") (Cronbach's alpha = 0.89).

Table 1. *Construct and corresponding survey items*

Constructs	Indicators
Engineering for Social Impact[1]	"I can make changes in my community with engineering." "Engineering will give me the tools and resources to make an impact in my community." "Engineering can be a resource for my community." "I can make an impact in peoples' lives through engineering." "Engineering can improve the quality of life in my community."
Interest[2]	"I am interested in learning more about engineering." "I enjoy learning engineering." "I find fulfillment in doing engineering."
Recognition[2]	"I believe my parents see me as an ENGINEER." "I believe my teachers see me as an ENGINEER." "I believe my friends see me as an ENGINEER."
Self-efficacy[3]	"I believe I can master the content in even the most challenging engineering classes." "I believe I can do an excellent job on engineering-related problems." "I believe I can learn the content taught in engineering-related classes." "I believe I can earn a good grade in engineering classes." "I am confident that I can understand engineering in class"

[1] Adapted from Verdín [16], [2] Modified from Godwin [20], [3] Adapted from Mamaril et al. [21]

Analysis

To answer the first research question (RQ1), a paired t-test was conducted to assess changes in students' engineering for social impact beliefs. Specifically, we examined whether students' engineering for social impact beliefs significantly increased following participation in the culturally responsive, gamified engineering activity. Prior to conducting the paired t-test, we assessed the data for outliers by inspecting a boxplot of the difference scores (i.e., post-score of engineering for social impact beliefs minus pre-score of engineering for social impact beliefs). Nine outliers were identified; however, none of these values were in the extreme range and were retained in the analysis. We evaluated the assumption of normality by visually inspecting a Normal Q-Q Plot of the difference scores. The data appeared to follow a normal distribution with slight tails on the top and bottom but still satisfying the assumption.

To examine the different factors that supported migratory students' engineering for social impact beliefs after the activity (RQ2), we used a multiple regression analysis. Specifically, we looked at how, if at all, students' recognition as engineers, interest, and self-efficacy beliefs supported their perspectives of engineering for social impact. We evaluated four assumptions of our multiple regression model. We confirmed there was a linear relationship between each independent variable and the dependent variable through an examination of the scatterplots and partial regression plots. We evaluated the assumptions of homoscedasticity by assessing the predicted values and the studentized residuals plot. Since the model appeared to have violated the homoscedasticity assumption, we applied a correction method to the standard errors, i.e., Robust Standard Errors (HC3). We confirmed the data were normally distributed by examining the normal probability plots and confirmed we did not have multicollinearity issues via the variance inflation factors (VIF). All VIF values were less than 10, which indicates multicollinearity was not a concern in our model.

Results

There was no expectation that migratory students would have developed a belief that engineering can be used as a form of empowerment, as many of our participants had minimal exposure. After analyzing the difference scores related to the engineering for social impact construct, we found a significant increase in students' engineering for social impact beliefs after participating in the activity, with a moderate effect size of (d = 0.57; Figure 1). While the activity contributed to changing migratory high school students' beliefs, we believe other factors may have also influenced this shift. To explore this further, we examine whether interest, self-efficacy beliefs, and recognition in engineering also played a role in boosting students' engineering for social impact beliefs using multiple regression. Using the post-activity responses, we found that interest and self-efficacy explained nearly half of the variance in engineering for social impact beliefs, Adjusted $R^2 = 0.47$. Our findings emphasize the potential of culturally responsive interventions to enhance students' beliefs about engineering's social impact, providing valuable implications for designing equitable engineering activities that support diverse student populations.

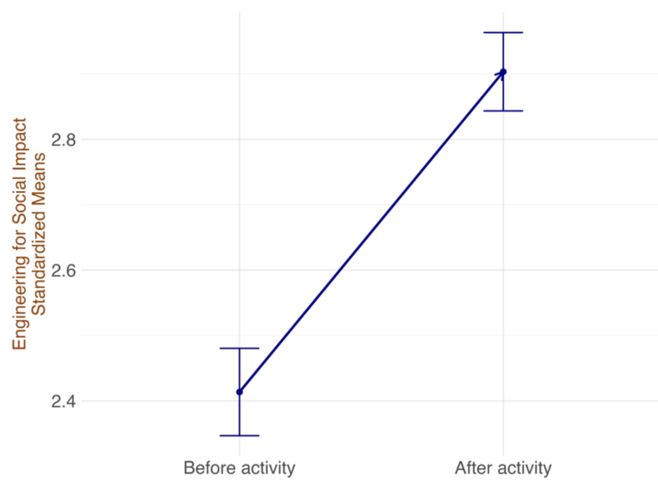

Figure 1.
Mean Score of Engineering for Social Impact beliefs, Before and After Activity

Changes in migratory high school students' engineering for social impact beliefs
The results of the paired-sample t-test show that students rated themselves higher after participating in the activity (mean score = 2.89 points) than before the activity (mean score = 2.42 points) (Table 2). This suggests the activity elicited an increase of 0.471 (95% CI, 0.36 to 0.58) points in students' rating of their engineering for social impact beliefs (Table 3). Following the activity, students reported a statistically significant increase in scores compared to their pre-activity scores $t(220) = 8.51$, $p < .0001$ (Table 3). The magnitude of change is considered moderate (d = .57).

Table 2. Descriptive Statistics for Engineering for Social Impact Beliefs

	Mean	*N*	*SD*
Pre-Activity – Eng for Soc Impact	2.420	221	0.989
Post-Activity – Eng for Soc Impact	2.891	221	0.877

Note. SD = Standard Deviation

Table 3. Paired Samples Test

	Mean Difference	*SE*	*95% CI of diff*		*t*	*df*	*sig.*
			LL	*UL*			
Pre – Post	0.471	0.055	0.361	0.580	8.506	220	<.001

Note. SE = Standard Error of Mean; CI of diff = Confidence Interval of Mean Difference

Additional factors that support engineering for social impact beliefs

To identify other factors that supported migratory students' engineering for social impact beliefs, we examined the potential influence of engineering recognition, interest, and self-efficacy on their beliefs about engineering's social impact. The overall model was statistically significant, $F(3, 233) = 69.13$, $p < 0.001$, explaining approximately 46.7% of the variance in students' engineering for social impact beliefs, see Table 4. Specifically, migratory students' interest in engineering and their confidence to academically excel in the subject area emerged as significant contributors to the model. Interest was positively associated with social impact beliefs, $\beta = 0.403$, $p < 0.001$, indicating that higher levels of students' interest in engineering were linked to an increase in their belief that engineering could impact society.

Similarly, self-efficacy was positively associated with impact beliefs, $\beta = 0.359$, $p < 0.001$, suggesting that students' self-efficacy in their engineering skills significantly influenced their sense that engineering could positively impact society. In contrast, recognition did not significantly predict impact beliefs. This finding suggests that being recognized by others was not a meaningful contributor to the development of students' engineering for social impact beliefs in this context. Overall, these results highlight the importance of fostering students' interest and self-efficacy in engineering to enhance their impact beliefs, while recognition by others appears less influential.

Table 4

Multiple regression results for Engineering for Social Impact Beliefs

Eng for Soc Impact	*B*	95% CI for *B*		*RSE*	*β*	*R²*	*Adj. R²*
		LL	*UL*				
Model						.474	.467***
Constant	1.144	.84	1.44	.15			
Recognition	-.037	-.128	.054	.044	-.048		
Interest	.335	.193	.477	.072	.403***		
Self-efficacy	.346	.193	.500	.078	.359***		

Note. *B* = unstandardized coefficient; CI = confidence interval; RSE = robust standard error at HC3; *β* = standardized coefficient; R^2 = coefficient of determination; *Adj.* R^2 = adjusted R^2. ***$p < .001$

Discussion

Engineering education has a twofold problem: not enough students experience engineering at the pre-college level, a problem particularly affecting minoritized student populations, and engineering education too often lacks social and cultural relevance, neglecting key issues and practices that hold potential for engaging diverse populations. Our research extended the critical engineering agency framework to understand the effects of a culturally responsive engineering design activity. We specifically examined the difference in engineering for social impact belief scores before and after participating in the activity and how engineering interest, recognition, and self-efficacy supported migratory high school students' beliefs about the social impact of engineering.

We found that after participating in the engineering design activity, students rated their engineering for social impact beliefs significantly higher than before the activity. This finding supports and extends a growing body of literature on the promise of culturally responsive instruction for improving educational outcomes [22], [23], [24]. We also found a positive relationship between students' engineering interest and self-efficacy and their engineering for social impact beliefs. This finding adds to a large body of evidence on the importance of interest and performance beliefs for improving engineering education outcomes [17], [25], demonstrating that students with higher engineering interest and self-efficacy also tend to hold stronger beliefs in their ability to use engineering to create positive change – an insight for developing interventions that integrate technical knowledge with meaningful social applications.

The high predictive relationship between interest and self-efficacy in students' engineering for social impact beliefs suggests these constructs may be fundamental components in engineering for social impact development. This extends previous research that demonstrated engineering agency beliefs support the development of interest, recognition, and performance/competence [16]. Our results suggest the reverse direction in this relationship is also possible; that is, interest and self-efficacy support the development of engineering for social impact beliefs. Perhaps what this means is that the development of students' impact beliefs do not exist in isolation and can emerge through multiple factors. Students also need to feel efficacious about their abilities and have a level of engagement (interest) in the field to help foster a critical agentic perspective. The non-significance of engineering recognition suggests differing pathways in the development of engineering for social impact for pre-college students who have not yet formed strong engineering identities. While prior research has emphasized recognition as crucial for engineering identity development [17], our findings suggest its role may be more complex, particularly in contexts where students are still developing their engineering identities.

Previous research has theorized agency primarily through observational and inferential approaches [15], [9], relying on the researcher's interpretation of students' actions and behaviors [18]. Gathering student beliefs directly centers their own perspective, providing an understanding of students' perceived capacity to enact social change that is not subject to researchers' interpretation. In the context of migratory populations, centering students' perspectives challenges traditional power dynamics in educational research and deficit-based narratives about students' capabilities in engineering. Self-reported beliefs also provide a more direct indication of how students are engaging with an academic domain. Insight into student engagement is particularly important in engineering, where racial/ethnic and gender disparities persist. Understanding student beliefs provides insight into the pathways that may lead to sustained participation among diverse populations.

Implications for Engineering Educators

Our findings have specific implications for engineering educators working with minoritized student populations. The increase in students' engineering for social impact beliefs suggests the importance of integrating social justice and cultural relevance in engineering instruction. Prior research has similarly found that incorporating social issues and context in engineering can be beneficial for engaging minoritized populations, specifically female students [26], [27], [28]. With the ongoing need to engage diverse populations of students in engineering [29], educators could deliberately create learning experiences that connect engineering concepts to students' lived experiences and show how engineering can be utilized to create meaningful social change. We demonstrated this connection through the narrative of Sol y Luna and the social injustice of pesticide exposure among migratory farmworkers. The activity also included representative characters and the use of Spanish as well as English. These elements made the learning experience familiar and bridged the divide between students' homes, communities, and their classrooms.

The gains in engineering for social impact beliefs also highlight the importance of combining conceptual understanding with practical applications through hands-on learning. The Arduino soil sensors allowed students to experience engineering as a tangible tool for addressing community challenges rather than as an abstract concept. While developing technical competence remains important in engineering, educators could equally emphasize engineering's potential for social change. Experiencing the full engineering design process can be a meaningful way to do this [19].

Educators could focus on developing students' engineering for social impact perspective, interest, and self-efficacy through authentic problem contexts that frame engineering challenges within real-world scenarios resonating with students' cultural backgrounds and community experiences. Our focus on agricultural worker safety in the engineering design process activity provided a meaningful context that connected to migratory student family backgrounds and lived experiences. Others have similarly shown that leveraging students' ability to connect their lived experiences and funds of knowledge to engineering coursework strengthens both their performance/competence beliefs and interest in engineering [30].

Limitations and Future Research

This study has several limitations that suggest directions for future research. First, while we found significant increases in students' engineering for social impact beliefs following our intervention, the short-term nature of the study limits our ability to understand how these beliefs persist or evolve over time. Longitudinal research tracking students' engineering beliefs throughout high school and into college would provide valuable insights into the stability and development of these beliefs. Second, our focus on measuring engineering for social impact beliefs, while methodologically important, cannot capture how these beliefs translate into actual engineering-related actions and behaviors. Future studies could employ mixed methods approaches to examine both beliefs about social impact and actions, helping to identify potential gaps between what students believe about their engineering and how they exercise it.

Conclusion

This paper demonstrates the potential of culturally responsive engineering education to enhance migratory high school students' beliefs about engineering as a tool for social impact. The findings underscore the importance of creating learning experiences that simultaneously build interest, develop competence, and connect to students' cultural contexts. As engineering education strives to become more inclusive and socially relevant, understanding and fostering engineering for social impact beliefs becomes increasingly important for preparing diverse students to use engineering as a tool for social change and justice.

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