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Pilot Study Using a Culturally Relevant Approach to Expose Migratory High School Students to the Engineering Design Process (Work in Progress, Diversity)

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Dr. Szkupinski Quiroga is a child of immigrants, born and raised in the Los Angeles area. She is an anthropologist with 25 years of applied research experience with immigrant, refugee, farmworker and other marginalized communities, and 15 years experience in advising and mentoring students, particularly those who are first-generation, Latino, and working-class. She is the co-PI and Director of the College Assistance Migrant Program (CAMP) and the Migratory Student Summer Academy (MSSA) at Arizona State University. Both of these successful programs provide holistic support to migrant and seasonal farmworker students with a focus on STEM.

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Introduction

Early experiences, provided through an individual's environment, are critical for the development of STEM interest, from a child's early years [1]–[3], to their secondary education [4]–[9]. Engagement with informal learning environments supports students' interest to pursue a STEM degree [10], [11] and can also enrich learning in formal environments [12]. Students in grades K-12 spent only 18.5% of their time in formal learning environments (i.e., classrooms), while the majority of their time is spend in informal learning environments [13]. Thus, out-of-school experiences offer students' an opportunity to foster interest in STEM-related activities and sustain their interest over time [14]–[16]. Prior work has found that interest and engaging in out-of-school activities in middle school has a significant long-term effect on students' choice of pursuing a STEM career (Chan et al., 2020; Kong et al., 2014; Maltese & Tai, 2010); however, our study found that Latinx students were not engaged in out-of-school activities during middle school. In-and-out of class learning experiences during middle school and high school have also been found to impact students' decision to pursue a STEM major [17]–[24].

Yet, studies have found that Latinx students are less likely than other groups to participate in out-of-school activities or school-based extracurricular activities [25]–[29]. Chan et al.'s [28] study, which used the High School Longitudinal Study: 2009 dataset, reported that Latinx students from high and low socioeconomic status were less likely than their White peers to participate in science and mathematics out-of-school programs during middle school. Verdín et al.'s [30] examination of three thousand undergraduate Latinx students' found experiences that fostered interest in engineering occurred during 10th through 12th grade for both women and men [30]. In a separate study examining a general undergraduate engineering student sample, Cass et al. 2011 reported that the majority of students 81% became interested at the end of high school, thus necessitating the importance of providing experiences during students' high school years. While interest in STEM can be triggered at different points in time (i.e., elementary, middle school, and high school; [14], studies have confirmed that out-of-school learning experiences in high school have benefited students' intensions to pursue an engineering major in college [6], [10], [11], [19]–[22]. Collectively, we have ample evidence documenting the effect out-of-school learning experiences have on students interest, beliefs about their abilities to do STEM, and decision to pursue STEM career (e.g., [8], [10], [14], [17], [20], [31]–[33]). However, missing from our current conversation about providing access to STEM learning opportunities, both in-and-out of the classroom, is an examination on how to support a vulnerable and invisible student population (i.e., migratory students).

A large proportion of students identified as migratory students come from Latinx backgrounds yet have vastly different lived experiences compared to most Latinx students discussed in the literature. Migratory students are children of migratory and seasonal farmworkers who live below poverty level and attend under-resourced schools (i.e., Title 1 schools). There is currently no body of work understanding the pathways for migratory high school students to become interested in engineering, and broadly STEM, careers. Much of the literature currently available on high school migratory students emphasize their educational disadvantages, needs, and report dismal high school completion rates (e.g., [34]–[38]). Yet, migratory students who do enroll in college and are provided with support tailored to their lived experiences, through support efforts such as a College Assistance Migrant Program (CAMP) or other support efforts targeting migratory students, do succeed in college [39]–[42]. Underscoring the notion that when migratory students enroll in college, despite the educational barriers and challenges they face, they, nevertheless, succeed.

This preliminary work seeks to further expand our understanding of support efforts for migratory students to include access to engineering-related activities grounded in a culturally relevant approach. This work-in-progress reports on data collected in a pilot study aimed at exposing migratory students to the engineering design process.

Children of migratory or seasonal farmworkers

Migratory or seasonal farmworker families experience difficulty in receiving continuous, high-quality educational services for their children due to their high rate of mobility, cultural and language barriers, social isolation, disruption of their children's education, and the lack of resources in the areas in which they live and work. Maricopa, Pinal and Yuma Counties are home to 93% of Arizona's migratory students. Overall, the size of Arizona's MSFW student population, concentrated in 24 school districts, is ranked 8^{th} in the nation. During the year, Arizona migratory families migrate through Oregon, Idaho, Washington, California, Nevada, Utah, Colorado, New Mexico and Texas and back again, while others follow migrant streams within the state. It is estimated that there are half a million children eligible for the Migrant Education Program (MEP), a federally funded program created under a Title I landmark act [43]. However, the exact number of migratory or seasonal farmworkers' children is only an estimate as there is no centralized database of migrant children and at any given year a child can reside in two, three or more states making it difficult to aggregate state data [43].

[Redacted institution] created a summer academy, in a virtual format due to COVID-19, that spanned four weeks in Summer 2021 for high school aged migratory students residing in Arizona. The summer academy targeted migratory students, specifically those who were identified as "priority for services," and who need the motivation to succeed in school and beyond. "Priority for services" is an action plan under the Every Student Succeeds Act (ESSA) to support migratory students who are most at risk of failing to meet state standards and whose parents' agricultural occupational work require they move on a yearly basis [44]. The [redacted] program was inaugurated in Summer 2021 and consists of four sessions, each session lasted one-week and took place one after the other. Rising seniors and juniors attended session one and two, respectively. While freshmen and sophomore students were divided into third and fourth sessions. The summer academy had programmatic efforts centered on developing college-knowledge, helping migratory students develop confidence and critical thinking skills, and centered on encouraging migratory students to be excited about continuing their education and beyond through exposure of various STEM and non-STEM career options.

Connecting an Engineering Design Activity with Culturally Relevant Approaches

The aim of the engineering activity was to connect the design process with a need that is intimately connected to the migratory and seasonal farmworker community. To develop the activity the first author focused on the following culturally relevant approaches, documented in Ladson-Billings book *The Dreamkeepers,* 1) engage students through a critical perspective, 2) "utilize students' culture as a vehicle for learning" [45, p. 161], 3) foster a community of learners, 4) "meet students where they are intellectually and functionally" [46, p. 104], and 5) "helps students to accept and affirm their cultural identity" [47, p. 469]. The first tenant, engage students through a critical perspective, was address by framing the overall storyline so as to critically examine the current work practices of migratory/seasonal farmworkers. The characters Sol y Luna reference harsh working conditions and the effect these conditions have on their parents' body and, most importantly, how these working conditions need to be improved to keep their families healthy. The second tenant was addressed by situating the entire storyline through the lived experiences of migratory/seasonal farmworkers. The third tenant, foster a community of learners was addressed by creating a virtual atmosphere that invited the participating migratory students to providing input and make decisions that helped the characters moved forward. There were interactive features embedded throughout the activity, these features were designed such that the participating students would feel as though they were contributing to Sol y Luna's understanding of the engineering design process. The fourth tenant, meeting students where they are intellectually was considered by creating an activity that did not presume prior knowledge of engineering or the design process. Most students in the summer academy were being exposed to engineering for the first time through this activity. The last tenant, affirming students' cultural identities was realized by creating fictional characters that were depicted as high school aged students whose families were also farmworkers, who also spoke Spanish, and framing their home and cultural knowledge through the activity as assets that would be leveraged to solve their design challenge.

Since there was no expectation that these characters or the students would know about the engineering design process, they enlisted the support of their science teacher to help explain steps of 1) problem scoping, 2) brainstorming, 3) prototyping, building, testing, and 4) evaluating design solution. However, Sol y Luna independently applied the steps to their problem. The aim of the activity was to create an environment where the participating migratory students could see themselves as students who could apply the engineering design process to solve a community need. The community need was intimately connected to the daily struggles migratory and seasonal agricultural workers endure while working in the fields thus, bridging the gap between engineering ways of knowing, doing, and thinking to migratory students' lives and prompting a critical examination of farmworkers' conditions in the field. The activity was presented through a web-based platform, it offered interactive prompts, and read similar to a comic book. The participating students were first given an introduction to the lives of Sol y Luna through a conversation amongst the characters over a book Luna was reading about engineering. Luna briefly starts to describe engineering to her classmate Sol. Sol becomes particularly intrigued on *how* engineering is used to make 'peoples' lives simpler, safe, or efficient' as he reflects on the intense hard work his parents have to endure while working as agricultural workers. This dialogue, briefly

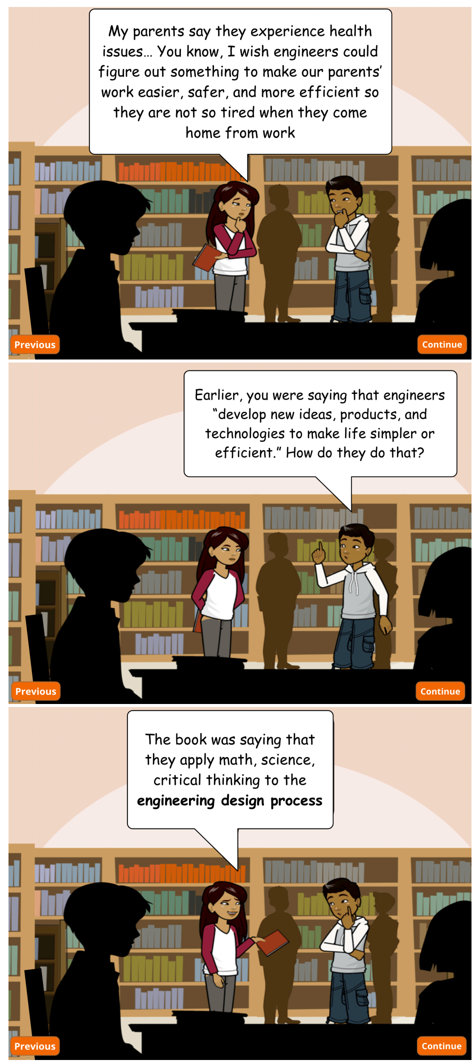

Figure 1. Excerpt of Sol y Luna's conversation

presented in Figure 1, was meant to situate the characters' journey towards learning how to apply the engineering design process to solve a community need and align the fictional characters' lives with the lives of the participating migratory students. In addition to the storyline, that was design with a culturally relevant approach, students also had the opportunity to learn how to design a component from Sol y Luna's engineering design solution using TinkerCAD online software. Students were instructed to watch a 'How-To' Video while they simultaneously created a component of Sol y Luna's design solution. The 'How-To' Video served to exposed students to the TinkerCAD software and walked them through the process of generating a 3D model of the component.

The aim of the pilot study was to understand how migratory high school students' perceptions of themselves relative to engineering may have shifted after being exposed to Sol y Luna's storyline. Therefore, pre- and post-surveys were collected to test the following hypotheses:

- H1. The activity would increase students understanding of engineering.
- H2. After participating in the activity, students' perceptions of how engineering could create social change (i.e., engineering agency beliefs) would increase.
- H3. Students' perceptions of their engineering tinkering capabilities would increase after participating in the engineering design activity (i.e., tinkering self-efficacy).
- H4. Students would feel recognized as individuals that can do engineering after participating in the engineering design activity.

Method

Sixty-three migratory high school students participated in the summer academy predominately of Mexican heritage, however only n = 18 students completed both the pre- and post-survey 12 girls and 6 boys. There was an equal number of 10th, 11th, and 12th graders (i.e., 5 per grade band) and 3 students were 9th graders. More than half of the students reported never participating in an engineering or STEM-like program prior to this summer, see Table 1. To understand if the engineering design activity shifted students' perceptions of engineering and of their capabilities to engage in engineering, a test examining changes between paired observations (i.e., pre- and post-survey) was conducted. A paired-samples t-test was used to determine if there were significant changes in students' mean scores at two different time points. To ensure if there was enough statistical power to detect changes given the small sample size, a post-hoc power analyses was performed using the G*Power 3.1 software [48]. A sample size of 18, using a power level of 0.80, was found to have enough reliability to detect a medium-small effect size (i.e., d = 0.61) for a paired t-test [49]. Three survey measures were used to test the hypothesis were tinkering self-efficacy (three items, Cronbach alpha value 0.89), engineering recognition (3 items, Cronbach alpha value 0.85), and engineering agency beliefs (seven items, Cronbach alpha value 0.87; [50]–[53] and one item to examine understanding, i.e., *I know what engineering is*. All survey questions were measured using a Likert scale of 0- "strongly disagree" to 4- "strongly agree." Engineering agency beliefs is a less familiar concept, it refers to "students' perceptions of their ability to change their

Table 1 Out-of-school STEM exposure

Categories listed on Survey	Yes	No
Science fair	6	12
Robotics competition	1	17
Engineering competition	1	17
After school STEM program/club	4	14
After school non-STEM program/club	10	8
Visited college(s)/universities	9	9

world through everyday action [and] involves how students see and think about STEM as a way to better themselves and the world" [54, p. 251].

Results

First, normality assumptions were evaluated using a QQ plot with 95% confidence intervals, all values were within acceptable ranges. Similarly, values of skewness and kurtosis were within acceptable ranges. A summary of the hypotheses can be found in Table 2.

We hypothesized that the activity would increase migratory students' understanding of engineering (H1), it was determined that participants did report higher means after the activity ($M = 3.00$, $SD = 0.97$) compared to before ($M = 2.33$, $SD = 1.03$), and this change was significant $t(17) = 3.68$, $p < .001$, $d = 0.87$. After experiencing how engineering could be used to solve a design problem closely aligned to their community, a narrative embedded in the larger storyline, migratory students' perceptions of engineering as a tool to create change in their community positively increased (H2; $M\Delta = 0.40$, $t(17) = 3.64$, $p < .001$, $d = 0.88$). Migratory students' confidence in their abilities to use tools, manipulate devices, and apply technical concepts in engineering increased after the activity ($M = 3.00$, $SD = 0.76$) compared to before the activity ($M = 2.52$, $SD = 0.97$), this change was significant $t(17) = 3.01$, $p < .01$, $d = 0.71$. The significant positive shift in migratory students tinkering self-efficacy (H3) may be a result of the TinkerCAD component of the activity, underscoring the benefit of virtual hands-on approaches to learning engineering. Most interestingly, students' perceptions of being *recognized* as an engineer by peers, teachers, and through a hands-on experience (i.e., engineering recognition) increased after participating in the design activity, $t(17) = 2.43$, $p < .01$, $d = 0.57$. The increase in mean score before and after the activity ($M = 3.16$, $SD = 0.57$ and $M = 3.55$, $SD = 0.44$, respectively) supported our fourth hypothesis and underscored how vicarious experiences can also support recognition beliefs.

Table 2. Summary of Pre-and Post-Survey Response Mean Values

	Mean (M), Std. Dev. (SD)	Change (MΔ)	Paired t-test	Cohen D
H1: "I know what engineering is."	**Post: $M = 3.00$, $SD = 0.97$**	0.67 ↑	$t(17) = 3.68$, $p < .001$	0.87
	Pre: $M = 2.33$, $SD = 1.03$			
H2: Engineering Agency Beliefs	**Post: $M = 3.55$, $SD = 0.44$**	0.40 ↑	$t(17) = 3.64$, $p < .001$	0.88
	Pre: $M = 3.16$, $SD = 0.57$			
H3: Engineering Tinkering Self-Efficacy	**Post: $M = 3.00$, $SD = 0.76$**	0.48 ↑	$t(17) = 3.01$, $p < .01$	0.71
	Pre: $M = 2.52$, $SD = 0.97$			
H4: Engineering Recognition	**Post: $M = 3.55$, $SD = 0.44$**	0.39 ↑	$t(17) = 2.43$, $p < .01$	0.57
	Pre: $M = 3.16$, $SD = 0.57$			

Discussion

COVID-19 created a major disruption to students learning experiences, most after-school or summer programs in 2021 were cancelled or abruptly moved to an online format. The aim of this pilot study was to deliver migratory students a meaningful virtual learning experience that was culturally relevant and position engineering as a tool that can be used for social good. This aim was achieved by creating congruence among the fictional character's background, experiences, and culture with the participating migratory students' backgrounds, experiences, and culture. Thus, migratory students' culture and lived experiences were the vehicle for which to learn about the engineering design process. Applying this culturally relevant technique in a virtual environment created a space were students felt the motivation to learn and provided an opportunity to shift their perspectives about themselves in relation to engineering.

In the activity, Sol y Luna conversated about their labor intensive work their parents had to endure while working in the fields and the health problems that resulted from such work. Yet, they were positioned as individuals who can make a difference in their parents and community members lives through their design of an exoskeleton system that could relieve the physical demand on one's body. From this design solution the participating migratory students used TinkerCAD software to bring to life a component of the broader exoskeleton system. After this experience migratory students' perceptions of using engineering as a tool to create change in their community (i.e., engineering agency beliefs) significantly and positively increased. Developing an engineering agentic perspective positions students as individuals who can apply engineering knowledge to change their lives or the world around them [55], [56]. The concept of agency comes from the work of Holland et al. [57] who defines agency as "the realized capacity of people to act upon their world ... purposively and reflectively, to reiterate and remake the world in which they live..." [p. 42]. The capacity students hold to make changes in their lives and the world around them by using engineering as the vehicle to make a change can subsequently supports students' views of themselves as an engineering type of person [52], [56], [58]. There was no expectation that these students would have already started developing a critical engineering agentic perspective, as most students were beginning to learn about engineering through the virtual summer academy. The aim was that the culturally relevant engineering design activity would begin to shape students' position in society as active contributors to their community through engineering.

Additionally, migratory students' confidence in their abilities to tinker (i.e., applying technical concepts in engineering and assembling, disassembling things) and their perceptions of being *recognized* as an engineer both increased after participating in the activity. Migratory students' vicariously and directly experienced engineering through two approaches 1) walking alongside Sol y Luna as they applied the engineering design process and 2) helping in Sol y Luna's decision making, using interactive features embedded in the activity, and creating a 3D model of a component of Sol y Luna's design solution. We postulate that learning how to do engineering, alongside Sol y Luna, prompted migratory students to adopt the meanings or beliefs of seeing themselves as engineers. Being recognized as someone that can do engineering is a precursor to identity development and recognition in a domain (i.e., engineering) supports students' choice to pursue STEM degrees [53], [56]. This project is a pilot to a more expansive project that aims to support migratory students' access and pathway into engineering, the preliminary work presented shows promising signs of impacting how they see themselves in relation to engineering. Most importantly this pilot study, and larger project, brings to the forefront a student population that has been practically invisible in the broadening participation conversation in our field.

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