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What Difference Does Difference Make? A Case Study of Racial and Ethnic Diversity in a Summer Intensive Research Institute

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What Difference Does Difference Make? A Case Study of Racial, Ethnic, and Gender Diversity in a Summer Intensive Research Institute

Abstract:
In this paper, we draw on the tenets of culturally responsive pedagogy and the communities of practice framework to explore how differences, specifically race, ethnicity, and gender, functioned in a Summer Intensive Research Institute (SIRI). Part of a larger NSF research project, SIRI was designed to increase persistence and diversity in engineering and cyber-physical systems (CPS) education and in the workforce. For eight weeks, two cohorts of students from mostly historically underrepresented and minoritized backgrounds participated in the SIRI program. Data included transcripts of interviews with SIRI participants. Analyses of students' narratives show that race, ethnicity, and gender supported the students' identity formation as engineering and CPS learners. Their experience in the program centered on the quality of the relationships they formed with peers, mentors, and faculty supervisors; high expectations for performance in the program; the alignment of content with their research and career interests; and the varied resources to which students had access and took up as part of their learning. Implications for STEM learning in higher education institutions are also discussed.

Keywords: STEM, Diversity, Higher Education, and Culturally Responsive Teaching

Introduction

Blacks, Latinx, Native Americans, and women remain underrepresented in science, technology, engineering, and mathematics (STEM) degree programs in postsecondary educational systems [1] and STEM-related job areas [2]. Although the number of bachelor's degrees awarded in STEM has increased by 62% since 2010, gender, racial, and ethnic representation in related job areas has not [3]-[4, p.14].

Across the United States, universities, corporations, non-profits, and other organizations have implemented countless programs and initiatives to broaden the participation of underrepresented groups in all aspects of the STEM fields and across all education levels [5]-[8]. To this end, SIRI aimed to introduce undergraduate students to the interdisciplinary field of Cyber-Physical Systems (CPS) and to inspire them to pursue graduate studies and work in the field. As defined by the National Science Foundation, CPS fields comprise

> engineered systems that are built from, and depend upon, the seamless integration of computation and physical components…CPS technologies are transforming the way people interact with engineered systems, just as the Internet has transformed the way people interact with information…smart CPS drive innovation…in a range of application domains, including agriculture, aeronautics, building design, civil infrastructure, energy, environmental quality, healthcare, personalized medicine, manufacturing, and transportation [9].

This broad range of application domains requires the engagement of diverse members of society who can bring unique insights and perspectives to solution strategies. Several studies argue the importance of developing CPS engineers at all post-secondary levels [10]-[11]. The underrepresentation of learners from historically minoritized groups in STEM education

programs is integral to serving a diverse society. Therefore, it is necessary to examine why students from these populations tend to shy away from engineering fields.

By underrepresented minoritized populations, we are referring mainly to Black, Latinx, and Indigenous groups [3]. We locate the current study within the landscape of culturally responsive teaching and pedagogy [12]-[15]. As used here, culturally responsive teaching (CRT) refers to the learning environment and the ways it connects curriculum to learners' backgrounds, promotes educational equity and excellence, creates community, develops agency, efficacy, and empowerment, and cultivates cooperation, collaboration, reciprocity, and mutual responsibility [16].

Several studies have explored culturally responsive teaching in varied contexts, including STEM technician education [17], science and math education combined with engineering design [18], pre-calculus instruction at a historically Black college/university [19], faculty development at a Hispanic Serving Institution [20], and engaging Native American girls in science, technology, engineering, arts, and mathematics (STEAM) activities [21]. While little research exists examining culturally responsive teaching and learning in CPS, scholars agree that science learning teams with diverse perspectives yield more successful outcomes [22].

In this analysis, we explore (1) the nature of the projects students elected to design in the SIRI program; (2) how they discursively framed the impact of racial and ethnic diversity in the program; (3) how students described relationships with each other, their mentors, and faculty supervisors; and (4) the difference these interactions made in how students experienced the program.

Relevant Literature

We made sense of identity formation in SIRI and the ways difference mattered by bringing together two frameworks of understanding: Wenger's [23] notion of *Communities of Practice* (CoP) and Gay's [16] notion of *Culturally Responsive Teaching* (CRT) [16]. Wenger defines communities of practice as "collective learning" through a shared domain of interest [23, p. 45]. In this case, the CoP included students participating in SIRI, learning to work in cyber-physical systems (CPS) and developing identities as STEM learners and CPS-focused engineers. As used here, identity refers to the complex relations of mutual constitution between individuals and groups [23, p.13]. In other words, identity formation was situated in the students' interactions with SIRI - the bonds they established with each other, their instructors, and mentors, and how they ultimately engaged with the intentional design of the program or imposed SIRI community.

We draw on the theoretical framework of culturally responsive teaching [16] to explore the potential of SIRI as a context for science identity formation and learning for historically underrepresented and minoritized groups pursuing STEM degrees in higher education settings. If we conceive of CRT as a series of the connections that students build with all aspects of the learning environment – including curricula, people, and ways of thinking about CPS-related matters (cf. [24]) – then it is through such ties that students form and reform their learner identities.

Methodological Framework

The data we present here stem from a larger study of Human CPS. The larger project has two main goals: (1) to broaden the participation of historically underrepresented groups in computing and (2) to exploit opportunities for mentoring and visible representation of minority scientists and engineers in CPS fields of study. In this case, SIRI was designed to provide a coordinated program of research and professional development for students, supporting their successful transition from *novice* to *expert* in CPS content; and bridging students' cultural backgrounds to their CPS learning experiences.

This analysis focuses on two sessions of the Summer Intensive Research Institute (SIRI) – year one, online in 2021, and year two, in person, in 2022. Over the course of eight weeks, students participated in a range of activities at a historically Hispanic-serving research-intensive university (HSRU) located in the American Southwest and a predominantly white institution (PWI) in the Midwest. Eighteen students participated in the program between the summers of 2021 and 2022, engaging in activities aiming to introduce students to the logistics of applying to graduate school and getting them excited about pursuing graduate studies in engineering and persisting in related workforce fields. Of these 18, a small subset of six agreed to participate in the study. In addition to activities and workshops, students worked on a CPS-focused research project or experiment with scaffolded support from higher education practitioners and workforce professionals. Table 1 summarizes the demographic information of the participants from years 2021 and 2022.

Table 1: Demographic Overview of SIRI Participants in Years 2021 and 2022

Year	Gender	Ethnicity/Race
2021 (online)	1 Female 9 Males	4 Black/African descent 2 Latinx 3 South East Asian 1 White/European descent
2022 (in-person)	1 Female 7 Males	2 Black/African descent 1 Latinx 3 South East Asian 1 Middle Eastern descent 1 White/European descent

Data were gathered using ethnographic research methods [25]-[26]. The students and their experiences are the focus of this analysis. As such, we draw on transcripts of interviews with them as primary data sources. The excerpts we cite are representative of the participants' reflections. Our analysis for this article centers on the ways race, ethnicity, and gender intersected with the norms, rules, and expectations governing the students' participation in SIRI, the meanings participants attach to these norms, how this knowledge showed up in the students' language and social interaction, and how these understandings folded into a community of

practice [23]. We are African American women scholars, Peele-Eady working in education and the social sciences, and Reid, an engineer. Peele-Eady gathered the data, and Reid was an instructor and faculty mentor in the program. Data generation and analysis are ongoing.

Findings

Relationships. Findings from years one and two of the program show that students' learner identity formation centered heavily on the relationships they formed with peers, mentors, and faculty supervisors, the curricula, and the varied resources to which students had access and took up as part of their learning [24]. For several students, initial rapport formed along the lines of the similarities students shared with their peers and mentors, often based on race and ethnic background. Students found comfort in the shared understandings there formed along these lines. The following excerpt illustrates this point.

> I feel like being [Black, Indigenous, and people of color] in America- you just walk through this world differently. You have different rules, you have different consequences than others, and having someone that understands that, that lives that, but also prevailed in spite of that, really, really, helps me….I need someone that understands me that doesn't see me expressing concerns as complaining or giving me advice that necessarily wouldn't work for me and things of that nature.

It follows then that students relied on these shared understandings to facilitate their learning and overall experience in the SIRI program. As illustrated in the excerpt above, students found refuge in working with peers and instructors who understood what it took to persist in this kind of science learning, "someone that understands" and prevails despite challenging realities. Consider the following:

> [My instructors and peers were] the main resource that I [used] because sometimes reading documents from websites, or a lot of text, is very difficult for me to understand, but if there's someone [to] explain it for me, then it will be much easier.

Similar to this alignment is having the opportunity and space to engage in self-learning, even in the context of a support network. The following illustrates this point:

> Even though I had the support of like, from the Ph.D. student and the professor, and my fellow researcher, I think like there was a lot of independent research on my end; and that was really good and really helpful because it allowed me to grow. Because I didn't just depend on other people for them to explain it to me. I had to go and understand it on my own. That was the most valuable experience for me.

Another student commented:

> I definitely do it by myself. I think going to [a predominately white institution (PWI)], I don't think my professors are really culturally aware to give me the information I need to connect it, for me or for my demographic. So I definitely have to do that work myself, which is perfectly fine because it usually introduces me to different opportunities and pathways that I would have never known otherwise.

These excerpts show that while students recognized the network that SIRI provided – a doctoral student, a faculty supervisor, and their peers – it was also important for them to engage in "independent research," viewing such an opportunity as a meaningful demonstration of "growth" and knowledge production. For SIRI participants, relationships with their SIRI mentors and social networks, racial and ethnic diversity, and shared understandings with peers and mentors of marginalized experiences were important resources that informed learning and participation in the program. Students described SIRI mentors as available and always "there to help." One student observed, "They were very supportive of whatever we needed. They were literally there, I had their phone numbers, and we used Slack [regularly]. They were there, like, at 10:00 at night." Another student said, "My faculty advisor was the only one who could help me. [My graduate student mentor] was helpful when I started to analyze the data, but that's it." Students formed similar reliances on each other, as one student noted, "I would go first to the Ph.D. student; then I would go to the professor. There was only once or twice to the professor. [My partner and I relied] on each other."

Building positive associations in and beyond the boundaries of the learning context is a core principle of culturally relevant and responsive teaching [16],[27]-[28]. Students appreciated when their instructors showed interest and investment in their learning and them as individuals.

Community. By all accounts, SIRI did a good job comprising the program with diverse bodies. Still, it is important to note that participants had varied views about feeling part of a community. Our efforts to encourage community building among the students (e.g., planned social gatherings) worked for some, but not all participants. For instance, when asked if she felt like a member of the learning community, one student commented,

> When you stick out…, it's like, hmmm, why are you here? [My peers] found community, I didn't. My saving grace was the Black grads, having a Black mentor; my PI was a Black woman, thank God, so I had support there…I was able to find a community, I just had to jump through hoops…. which took time away from my learning. You never get used to being the only one…

In this excerpt, the student, a Black woman, describes the challenges she continually faces as typically "the only one," meaning a Black person, in her science learning environments. Even though SIRI was diverse demographically, this student felt like she stuck out as a Black person and found community and a safe space with the other Black graduate students and her Black mentor. Just as the notion of community allows for complexity, it may also perpetuate racialized hierarchies. To reconcile the disconnect between our vision of a community with the ideas that students held, we draw on [29] definition of a *learning community* as "one that resists essentialized harmony and sameness and instead demands, embraces, and exploits (in a good way) difference in the service of generating among learners new understandings of the world, of each other, and of themselves" [29, p. 230]. From this perspective, the importance of community in SIRI showed up as connectedness and feelings of belonging to the program's broader goals and shared understandings of themselves as members of historically underrepresented minoritized communities with shared behaviors, values, histories, and experiences [30]. As such, students found community when they could effectively draw on race, ethnicity, and gender as part of a broad repertoire of understandings with others.

Curricula. Students also appreciated when they found connections between the curricula and their background experiences or supported their desire to engage in work that would benefit their communities and society. Research shows that for underrepresented minority students or URMs, "firing creative juices" occurs "by linking the work done in their STEM fields to personal and culturally valued outcomes" [3, p.4]. In addition, several SIRI participants specified commitment to the community as their primary goal and purpose for pursuing engineering degree fields. Specifically, as one participant noted, "One of my goals as an engineer is to make the day-to-day life of society easier. " This student further elaborated:

> I have to connect what you're teaching me to the real world and how I can apply it to my life or how I can apply it to other people's lives to make their life better….In order for me to fully understand, I have to create something that's going to help my community. …if I can't connect it to my community, if I can't connect it to me or someone that looks like me, I can't really understand it. I think that's probably why I struggle with science, 'cause it's all like, I can't connect a newton to a person.

This student's reflection underscores the importance of creating space for learners to connect course content to real-life experiences. SIRI provided students with the leeway to design projects that interested them. Estrada [3] encourages higher education institutions "to find ways to emphasize how classroom content relates to prosocial communal outcomes" [3, p.4], and we could not agree more.

Discussion and Conclusions

In conclusion, difference was fundamental in shaping the students' experience in SIRI. Students appreciated the racial and ethnic diversity that SIRI provided, which was an intentional aspect of the program's design. This sentiment showed up in comments like, "They did a good job with diversity" and "We even joked that there was only one white American in the group. The majority were the minority." It was clear to us that the racial and ethnic makeup of the group mattered to the students. They paid close attention to it and utilized it to cultivate relationships and facilitate their learning.

The relationships students established in SIRI manifested through what [24] call *identity resources* or resources that support students' learning. *Material* resources refer to the physical artifacts in the learning setting; *relational* resources point to the interpersonal connections that learners make to others in the learning setting; and *ideational* resources refer to the ideas students take up about themselves and the learning setting, as well as ideas about what is valued and what is good in the context. For SIRI participants, these resources included their SIRI mentors and social networks, the racial and ethnic diversity of the program's design, and shared understandings with peers and mentors. In this way, culturally responsive teaching shows promise for engaging, recruiting, and retaining students from historically minoritized populations in STEM fields. CPS engineers will find this SIRI description helpful in designing culturally relevant and responsive programs.

Research programs, such as the Summer Intensive Research Institute, show promise in helping students form identities as future cyber-physical systems researchers by connecting curricula to students' lived experiences, creating space for students to work with mentors and

peers who look like them, who value them as learners, and who understand their unique experiences, and by engaging students in work that connects to their communities and fosters a sense of belonging to the broader STEM culture.

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