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Work in Progress: Broadening Participation in Engineering with the STEM Excellence in Engineering Equity (SEEE) Project

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STEM Excellence in Engineering Equity (Work in Progress)

Introduction

Labor market indicators predict continued growth of well-paid employment in science and engineering[1], but evidence suggests lower readiness among rural students for jobs in these fields. Rural students are now graduating at rates comparable to their urban and suburban peers, but continue to fall behind in pursuing postsecondary education, including in engineering[2]. Multiple studies indicate that these differences begin long before individuals enter the workforce and are based in large part on the students' sense of belonging in science, technology, engineering, and mathematics (STEM)[3-4]. Evidence points to the positive role that an equitable learning environment (ELE) can play in secondary classrooms to ensure that all students, particularly those underrepresented in STEM, succeed and persist in STEM coursework and programs[5-8]. An ELE requires administrators, teachers, counselors, community members, and parents to work collaboratively to understand the *foundational practices* required to improve all students' outcomes[9]. Understanding of the importance of diverse and culturally relevant learning environments in engineering education is growing[10]. However, the field lacks effective PD (Professional Development) models and curriculum for developing and sustaining ELEs in rural settings to improve students' pursuit of postsecondary engineering programs. Rural schools often lack access to engineering professionals or rigorous high-quality engineering education[11]. We believe that needs to change.

This paper introduces work in progress on an early-stage Design and Development Study for the National Science Foundation's (NSF's) Broadening Participation in Engineering program. In 2022, a university, a nonprofit, and a research organization launched the STEM Excellence in Engineering Equity (SEEE) project with two goals:

1. Advance understanding of an instructional methodology for developing equitable learning environments (ELEs) in high school STEM classrooms; and
2. Examine the effects of a PD program to enhance and promote this methodology and the emerging practices.

The objectives of the work were set as follows:

1. Integrate four research-based and practitioner-tested educational equity constructs for the classroom into a program combining high-quality engineering design content and a model to for developing equitable learning environments.
2. Pilot the program by identifying teachers (20 STEM teachers) from two similar rural PA high schools to participate in a 3.5-day PD workshop, supported by their administrators, to prepare them for pilot implementation.
3. Identify two to four engineering students from rural PA to provide program support, serve as role models for high school students, and coach teachers delivering the program.
4. Following the workshop, provide five Faculty Learning Community meetings to provide continued support, assess the usability and feasibility of the implementation of the new program, and assess its effectiveness in enabling teachers to promote and deliver ELEs in their STEM classrooms.
5. Using lessons learned through the pilot, develop a PD manual and materials for scaling the program for future iterations and further research.

The intended outcome of the work is to assess the program's ability to increase educators' capacity to create ELEs in STEM classrooms and increase students' interest in pursuing further STEM courses and programs to prepare them for engineering, particularly among students in rural communities. The design, development, research design and work to date for this project will be discussed below and details of the PD delivered will be presented at ASEE.

Design

The SEEE program diverges from traditional models of independent and separate STEM content and equity instruction. In the program, engineering design content is embedded with equitable thinking, understanding, and practice related to classroom practices and pedagogy. The engineering content, INSPIRES (***IN***creasing ***S***tudent ***P***articipation, ***I***nterest & ***R***ecruitment in ***E***ngineering and ***S***cience), was co-developed by the PI of the grant and is aligned to the Next Generation Science Standards. To date over 250 teachers have completed INSPIRES PD and over 6,000 students have received instruction in classrooms using the curriculum. This project combines components of INSPIRES with an equity model called NEIR, which stands for Normalize (N), Empower (E), Inclusive (I), and Relevant (R).

NEIR was developed by the co-PI in collaboration with STEM faculty researchers and practitioners and based on decades of experience in creating equity to improve student academic outcomes. Over time, four constructs and a supporting program improvement process emerged through this work and were developed through trial and practice. The refinement of the constructs was informed by multidisciplinary research, and reviewed, revised, and supported by academics, business leaders, professional associations, and national nonprofit organizations[12]. The resulting model simplifies and synthesizes hundreds of strategies addressing social-emotional development, systemic biases, and community and cultural influences that intersect with student and educator lived experiences. The NEIR model is a unifying model that accounts for seemingly diverse constructs[13]. By creating conceptual order, the NEIR model helps practitioners integrate multiple interconnected theoretical frameworks into an operational practice that creates customizable ELEs to meet the needs of any child. The model is based on two core beliefs:

1. Students are assets in the classroom. This belief replaces the traditional deficit model where the teacher is all-knowing and students absorb their instruction with a focus on the contribution of the whole child (assets and challenges) to the classroom experience. The unique gifts of each teacher and student should be brought out and utilized within the classroom and school.
2. An intersectional approach that recognizes that we each hold multiple identities. When we focus on one element of who we are (females vs. males for instance), we may inadvertently create stereotypes that reinforce the very biases we are trying to dispel. Recognizing the whole child means understanding that we all hold multiple assets and challenges that cumulatively make us each unique individuals that contribute to the classroom and the world.

Addressing the unique characteristics of each child in a classroom using an equity lens requires a conceptual model to help teachers select effective strategies among the myriad available. That model consists of four indicators of an ELE: Normalize, Empower, Inclusive, and Relevant (NEIR).

Normalize provides an educational environment that connects to lived experiences that are common, typical, customary, and/or routine for the student or teacher. The theoretical model underpinning a normalizing school, classroom, or program experience is based on research related to a "Sense of Belonging," which is predictive of students' retention and persistence through college[14-15]. Rainey et al.[16] extended the literature on sense of belonging to women and underrepresented students in STEM. Without a sense of comfort or familiarity, underrepresented minority students are forced to adapt the values and norms of dominant culture to "fit in"[17-18].

Empower refers to a mindset that all students are assets in their classroom and are individually responsible for and recognized for their own learning and the learning of others. Freire studied the concept of empowerment in school environments and educational settings 50 years ago[19]. He found that an educational system can either liberate marginalized students or maintain systems of oppression that fail to give students a voice and opportunity to control their educational destiny. Intrapersonal student empowerment is predicted by equitable power use, positive teacher-student relationships, and a sense of community in the classroom[20]. Empowering students entails building their self-efficacy, agency in their learning, and resilience in schools[21].

Inclusive refers to classrooms or school settings where educators are aware of and responsive to the ways that students are marginalized by our current education system and educators' and students' implicit biases. Several theories support the concept of creating an inclusive and welcoming environment. Most prominent is "school climate," which is generally described as the quality and character of school life and reflects the norms, goals, values, interpersonal relationships, teaching and learning practices, and organizational structures that shape the quality and character of a school[22]. A recent literature review recognized no less than six theoretical frameworks that inform research and speak to its multi-dimensionality[23]. All six developmental theories stress the importance of strong social bonds between teachers and students.

Relevant refers to students' experience of learning, "relatedness" with their teachers, and their connections to their parents, community, and cultural experiences. Research has long documented that teaching theory or abstract ideas can be demotivating to students, while establishing relevance to local cases, everyday applications, and newsworthy events can be very motivating[24-25]. Work-based, case-based, and problem-based learning have all been efforts to address traditional classroom-based learning, the antithesis of situated learning. For engineering, problem-based and experiential learning captures the general notion of learning by doing and applying theory to practice. Relevancy allows for continuous reanalysis of curricular content, its impact on experience and the impact of experience on content. It also promotes social and emotional growth for students and teachers who can better relate learning to their lives.

The SEEE program is based on the hypothesis that the four NEIR constructs, when integrated fully with any quality curriculum, pedagogy, and resources, creates ELEs in classrooms that benefit all students, including those overlooked, underrepresented, and in the margins. Implemented with an improvement process that supports systemic change, the NEIR model advances quality STEM content and pedagogy by integrating a significant third variable (measurably identified, increased equity in a classroom environment) required for the education equation to sum to academic success for all students.

Develop

To develop the NEIR-ED (NEIR-Engineering Design) program, the PI and co-PI convened an advisory board in quarterly meetings over two years. The board included national experts in engineering education, STEM education, project evaluation, and the field of engineering. The engineers represent both individuals from rural communities and historically underrepresented populations (female and African American). Together, the group prepared the integrated content, assessments, and reflections, which led to the design of a 3.5-day NEIR-ED PD workshop.
Following the design phase, the PIs identified rural high schools to participate in the workshop that covers the following: (details and examples will be provided at the ASEE conference)

- Knowledge of engineering core ideas;
- Practices and pedagogical knowledge and skills to teach engineering design in a way that integrates science and mathematics principles;
- School and classroom environmental factors that are required for engineering design learning to take place for all students; and
- Strategies that teachers can use to customize, prioritize, and assess their STEM instruction and support ELEs that can improve academic outcomes for all students.

Secondary schools in the two districts selected for the pilot were asked to identify 3-4 STEM teachers to participate. While the target was 20 teachers, the team recruited 14 teachers largely because the rural schools only had one or two STEM teachers each, low support from administrators, and limited engagement with community stakeholders. In addition, recent discussions in the media about the term equity caused distrust among teachers that was difficult to overcome.

The PI and Co-PI delivered the NEIR-ED workshop over 3.5 days during August 15-18, 2022 for the 14 teachers representing both traditional STEM courses (math, chemistry, robotics) and career and technical education programs. Following the PD, the team scheduled five faculty learning community (FLC) meetings, setting expectations for attendance and assignments. The project team also selected university engineering students from rural communities who are participating in the initial NEIR training. They are providing additional support to the STEM classroom teachers. In addition, they will:

1. Participate in FLCs to provide student perspective on the challenges in the classroom
2. Be available for calls and questions related to implementation of content throughout the semester and between FLC meetings.
3. Serve as a role model and example for students in the class and serve as a resource for the school and its community
4. Learn from teachers about the field of education.

Research Design

The SEEE project lays the groundwork for further research and development by (1) identifying indicators of successful model implementation, (2) assessing the feasibility of implementing the curriculum in rural STEM classrooms; and (3) collecting initial data on the program's effects on the classroom environment and students' engagement and interest in engineering To gauge the usability, feasibility, and promise of NEIR-ED, the team is employing an iterative cycle of testing and revision over the project's two years. The research team will measure the effects of the

program on the instructional practices of the STEM teachers and on about 300 11th- and 12th- grade students enrolled in STEM classes during the pilot phase. The study's research questions relate to the quality of the NEIR-ED program's content, feasibility, usability, and sustainability and student impact, and will guide data collection and analysis.

Work to Date

The grant team has learned through the program design process about the challenges of aligning engineering design content and equity in education, and the questions that arise when moving away from traditional education models, such as how to measure outcomes, teamwork, and problem-solving ability.

Initial research findings suggest that the NEIR-ED PD was positively received by teachers, has had positive effects on teacher's perceptions of their knowledge of practices for creating equity in STEM classrooms, and has influenced their classroom practices. There was an improvement in the teachers' perceptions of their knowledge from the pre-PD survey to post-PD (p value =.054). (*I am knowledgeable about ways to increase equity in my STEM classroom).* A final survey will measure additional impact (if any) on teachers' self-reported knowledge and beliefs.

In September 2022, research staff interviewed eight of the 14 teachers who participated in the workshop. Overall, teachers rated the delivery and content of the workshop highly. All shared that they would recommend the training to others. Two observed that the workshop would be best suited to new teachers and teachers who are willing to change or seeking a new perspective. All also felt that the workshop content was well aligned with their students' needs, with two noting that the workshop would be more suited to some students (e.g., students in general classes rather than Advanced Placement). Among the workshop's strengths, the teachers highlighted the focus on engaging students and the quality of the workshop instruction. Even though the interviews were conducted at the start of the school year, five of the teachers shared specific examples of how they are applying lessons learned from the workshop in their classes.

Prior to the training, I considered design challenges as only appropriate for science classes, but now I understand that design challenges also work for math and that it is OK to take the time to let math students try things out…. Now I am using a lot more shorter games on math skills in the classroom as a brain break and to encourage a game mindset and help students understand that they don't have to get the right answer all the time.

The teachers also shared ideas for strengthening the workshop. Three felt strongly that including the word equity in the name of the program and the organization could deter teachers from participating. Four noted a need for more clarity, particularly early in the workshop, on the training's goals and purpose.

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