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BOARD # 418: NSF-ITEST: Evaluating the Impact of a STEM-focused Advanced Manufacturing Program on Rural Middle School Students' STEM Content Knowledge Development

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Introduction

Interest in STEM (Science, Technology, Engineering and Mathematics) subjects among U.S. students is on the decline despite a growing national need to fill critical positions in these areas. According to the 2024 *Condition of Education* annual report released by the National Center for Education Statistics (NCES), mathematics achievement among middle and high school students has seen a significant decline in recent years [1]. It was reported that the percentage of fourth grade students that were proficient (as defined by the National Assessment of Education Progress - NAEP) in mathematics decreased from 41% in 2019 to 36% in 2022. Similarly, the NAEP proficiency in mathematics for eighth grade students decreased from 34% to 26% over the same period [1]. Declines were also reported in science proficiency among 4th-grade students (38% in 2015 compared to 36% in 2019) but remained relatively steady for 8th and 12th-grade students. While some of these losses have been attributed to the Covid-19 pandemic, achievement in these subjects had been trending downward even before the onset of the pandemic [2].

The decline in mathematics and science proficiencies is even more pronounced among students in rural school districts who face unique challenges that limit their ability to provide STEM opportunities for their students, including insufficient funding, lack of access to professional development for rural teachers, technology gaps and proximity to resources [3], [4], [5]. Some studies [4], [5], [6] have suggested that one of the most effective ways of overcoming STEM access issues in rural areas is to employ a community-based approach where partnerships are formed between rural school districts and community stakeholders including community colleges, local industry and higher education institutions. Hartman et al. [5] asserts that collaborative partnerships that bridge formal and informal learning experiences represent an important mechanism for addressing access and equity in rural settings.

The objective of this study was to investigate the impact of an engineering design elective course focused on advanced manufacturing processes and technologies on the science content knowledge of rural middle school students.

Project Description

This STEM-focused program is part of a four year NSF-ITEST project designed to provide underserved rural middle school students (grades 6-8) with an opportunity to explore STEM subjects and STEM career opportunities in the advanced manufacturing industry. The goals of the STEM program, referred to as DeSIRE (Developing STEM Identity in Rural Audiences through Community-based Engineering Design) are to improve students' STEM content knowledge and

STEM career awareness, thus increasing their interest in pursuing STEM careers, particularly engineering. The DeSIRE program leverages strategic partnerships between academia, a rural school district and local industry to engage middle school students in authentic engineering design experiences through a 3-part engineering design elective course, near-peer mentoring by undergraduate engineering students in the Women & Minority Engineering Program (WMEP) at NC State University and by participating in supplemental STEM enrichment activities through a Saturday Academy and Summer Program offered by the NC Mathematics and Science Education Network Pre-College Program (MSEN). Participants enter the DeSIRE program as sixth graders and end as eighth graders having completed a total of three elective courses (one course each year) by the end of the program.

Engineering Design Elective Course

A three-part engineering design elective course was developed by the project team in consultation with local STEM industry professionals and implemented in two rural middle schools in the same school district. Each year students take the grade-level specific course as part of their regular elective rotation. In these courses, students participate in hands-on, project-based learning activities related to advanced manufacturing. Students have engaged with various technologies including DIY robotics kits, Raspberry Pi computing, and Arduino microcontrollers to simulate real-world manufacturing production environments. Course topics and activities are aligned with three segments of the local advanced manufacturing industry represented by our six industry partners: food production, pharmaceuticals and energy systems.

The DeSIRE project began in earnest in 2020 during the Covid-19 pandemic with the creation of course content with input from subject matter experts employed in STEM fields near the schools. Because NC schools required remote learning, the elective course was adapted from its original in-person format to an online version for the first year of implementation. A shift back to in-person instruction occurred in the following school year. The course was first implemented with 6th graders with a new grade level course being added each year of the project. The data analyzed for this paper represent students enrolled in 2020-21 as sixth graders and completed the course cycle as eighth graders in 2022-23.

Theoretical Framework

The theoretical framework for the DeSIRE project is self-determination theory (SDT) which asserts that individuals are inherently drawn to grow, master challenges, and integrate new experiences as they continually develop and refine their own sense of self [7]. The DeSIRE project provided such an avenue for the development of STEM identity through the core concepts of SDT-autonomy, relatedness, and competence. Environments that support students' psychological need for autonomy, relatedness, and competence provide the ideal setting for encouraging social and

cognitive development [7] [8]. Ryan and Deci [7] define autonomy as the level of control that one perceives to have over one's behavior and successes; while, relatedness is defined as the longing to feel connection with others and be included in a social group, and competence is the level of ability or success that an individual believes he possesses when attempting a task. In this project, students were empowered to develop the elements related to SDT through the real-world engineering design challenges.

Methodology

This paper highlights findings related to only the student knowledge domain of the project. The following research question was explored:

> To what degree does the engineering design-focused program impact students' science content knowledge?

The data source used to measure knowledge changes over time for students were the NC End-of-Grade (EOG) science tests for grades five and eight which are a part of the state's standardized testing program. These multiple choice assessments assess students' knowledge of science content outlined in the NC Essential Science Standards. Assessments are given to all NC students in grades five and eight in the final few weeks of the school year. In this study, the fifth grade EOG served as the baseline for students' knowledge of science prior to taking the DeSIRE course while the eighth grade EOG served as the final measure after taking the three-part engineering course.

Bayesian ordinal regression was performed using EOG scores to determine the impact of the program on students' science content knowledge, particularly understanding whether the number of years students participated in the DeSIRE program had an effect on 8th grade end-of-grade (EOG) test scores. Because EOG tests are scored on an ordinal scale (i.e. "Not Proficient", "Level 3", "Level 4", and "Level 5") and are the dependent variable, it was determined that ordinal regression was the most appropriate analysis method to ascertain whether a relationship exists between a predictor variable (time in DeSIRE) and EOG scores, while accounting for 5th grade test scores as students' starting scores.

Results and Discussion

Analyses show that, overall, the DeSIRE program improved students' chances of reaching higher proficiency levels by the 8th grade regardless of their 5th grade EOG score. As seen in Figure 1, models showed that students who participate in more years in DeSIRE, increased their probability of scoring higher on the EOG (i.e. Level 4 or 5) in 8th grade, while decreasing the probability of scoring lower (i.e. Level 3 or Not Proficient).

The highest probability of growth was seen with students who scored Level 4 in 5th grade, where students who participated in two years of DeSIRE were five times more likely to earn a Level 5 score in 8th grade, compared to those with no years in DeSIRE. It was also found that students who scored "Not Proficient" in 5th grade were three times more likely to earn a Level 4 EOG score with just one year of DeSIRE participation. Even with one year of participation, the probability of students scoring higher than their 5th grade year increases. These findings support DeSIRE's significant impact on student's science-based knowledge and growth in EOG science test scores.

It is also important to note that the analyses accounted for students' gender and ethnicity, neither of which were shown to have any significant relationship to EOG test scores. Another particularly interesting finding was that the specific school that a student attended had no significant effect on 8th grade test scores despite the fact that the DeSIRE class was taught by two different teachers with different teaching philosophies and there were two completely different learning environments. The lack of a significant relationship with schools suggests that the positive impacts of DeSIRE could be similarly observed if implemented in another school.

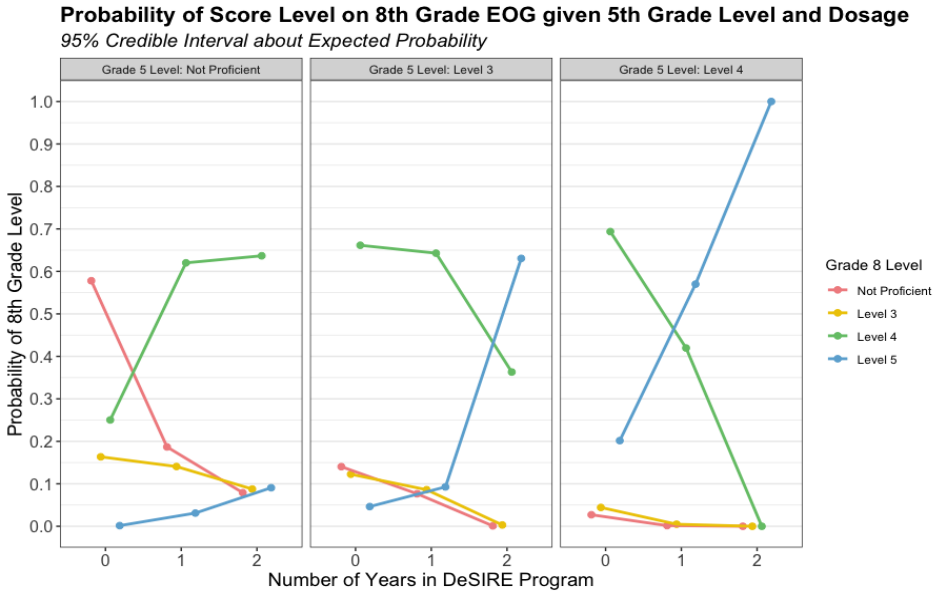

Figure 1. Models of Probability of 8th Grade EOG Scores Based on Years in DeSIRE

Conclusion

Ultimately, the findings of the study showed a positive impact of the DeSIRE project on student participants' science content knowledge. The DeSIRE project's success highlights how effective, targeted educational initiatives have the propensity to impact students in rural communities. By bolstering student opportunity to explore STEM content and careers, the project was able to move the needle on student STEM knowledge. As educators and policymakers look for ways to

bridge the opportunity gap inherent for rural underserved students, DeSIRE can serve as a design blueprint for other programs.

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