

## **Developing an Engineering Design Course for Rural Middle School Students: Implementation Strategies and Lessons Learned**

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## **Abstract**

In early 2020, a research collaboration between the College of Engineering and the Friday Institute for Educational Innovation at North Carolina State University (NCSU), the NC Mathematics and Science Education Network Pre-college Program (MSEN), a rural school district in NC, and the local advanced manufacturing industry began. The goal of this Innovative Technology Experiences for Students and Teachers (ITEST) project was to create community-based engineering design experiences for underserved middle school students (grades 6-8) from rural NC aimed to improve their cognitive (STEM content knowledge and career awareness) and non-cognitive (interest, self-efficacy, and STEM identity) outcomes, and ultimately lead to their increased participation in STEM fields, particularly engineering. The project leverages strategic partnerships to create a 3-part, grade-level specific Engineering Design and Exploration course that engages middle school students in authentic engineering design experiences that allow them to research, design, and problem-solve in a simulated advanced manufacturing environment. Shortly after receiving university approval to begin the research process, progress was halted due to an unprecedented global health crisis. The school district was closed for several weeks as administrators and teachers prepared to transition to remote learning. In addition, the district experienced unexpected teacher and administrator turnover. In the wake of such uncertainty, the project team has pivoted their research design to work more closely with industry partners while still maintaining an active relationship with the school district as they rebuild. This paper will describe the challenges faced, strategies employed, and lessons learned during the course development and implementation process.

## **Introduction**

It has been well documented that the current shortage of individuals with the requisite technical skills to enter the STEM workforce is threatening U.S. global competitiveness in these fields. Compounding the problem is the lack of equal access to high quality STEM programming in K-12, which disproportionately affects underserved students in rural areas. STEM education disparities threaten the nation's ability to close education and poverty gaps, meet the demands of a technology-driven economy, and maintain preeminence in scientific research and technological innovation (Department of Education, 2016). According to the 2003-2004 U.S. Census, 19.3%, or 60 million people reside in rural areas. In addition, 56% of all operating public school districts and one-third of all public schools are located in rural areas (Provasnik, et al., 2007). Despite these numbers, this population has been largely overlooked as a potential source of STEM talent (Hartman, Hines-Bergmeier & Klein, 2017; Harris & Hodges, 2018). Rural school districts face unique challenges that limit their ability to provide STEM educational opportunities for their students, including insufficient funding to support STEM initiatives, lack of access to professional development for rural teachers, technology gaps and proximity to resources (Elam & Solomon, 2012; Peterson, Bornemann, Lydon & West, 2015; Hartman et al., 2017). Underrepresented minorities (URMs), in particular, living in remote rural areas face the additional challenge of attending schools with moderate to high rates of poverty (Provasnik et al., 2007). If we are going to meet STEM workforce demands now and in the future, we must invest resources in rural

communities and provide the support needed to assist them in developing targeted, relevant and engaging STEM educational programs that motivate students to pursue STEM careers.

The goal of this four-year project is to create community-based engineering design experiences for underserved middle school students (grades 6-8) from rural NC aimed to improve their cognitive (STEM content knowledge and career awareness) and non-cognitive (interest, self-efficacy and STEM identity) outcomes, and ultimately lead to their increased participation in STEM fields, particularly engineering. The paper will report on preliminary findings for the planning and implementation of the 6th grade course.

## **Program Description**

This four year project is a collaboration between the College of Engineering and the Friday Institute for Educational Innovation at NCSU, the MSEN pre-college program, a rural school district in NC, and the local advanced manufacturing industry.

The program consists of three parts: 1) 3-part Engineering Design elective course for grade levels 6-8 in which rural middle school students engage in engineering design experiences closely tied to local advanced manufacturing technologies and practices, 2) Mentoring component whereby undergraduate engineering students from the Minority Engineering Program (MEP) at NCSU and STEM professionals from industry serve as mentors to the middle school students during the course and 3) In-depth STEM Experiences where students engage in supplemental STEM enrichment activities outside of the classroom such as industry and university tours. In addition, a subset of students will participate in a Saturday Academy and summer camp.

***Engineering Design Elective Course.*** Project staff collaborated with middle school educators from the rural school district and local industry representatives to develop the content for the 6th grade Engineering Design elective course. Course content was aligned to the NC Standards for Curriculum and Instruction and care was taken to ensure that the advanced manufacturing concepts were appropriately adapted for this age group.

***Mentoring.*** Nine undergraduate students from the MEP were recruited in the fall of 2020 to serve as mentors to the middle school students during the sixth grade course. The undergraduate students were required to participate in virtual training sessions prior to interacting with the middle school students. These training sessions were designed to familiarize the student mentors with strategies to appropriately and effectively interact with this student demographic, facilitate small group discussion and assist the middle school educators in teaching engineering design principles.

***In-depth STEM Experiences.*** No supplemental STEM experiences have occurred prior to the preparation of this paper.

## **Challenges & Strategies**

***Implementation Delays and Modifications Due to COVID-19.*** The initial implementation plan included teachers and researchers co-creating the new, face-to-face middle school courses during the summer of 2020, with an anticipated launch date of fall 2020 for the sixth grade course. Due to uncertainty amid COVID-19, the sixth grade course launch was ultimately postponed until mid-spring 2021, and the course format was adjusted from continuous face-to-face instruction to a

hybrid of virtual and face-to-face instruction on a rotating basis. Also, as will be discussed in the next section - equitable access to high-quality teachers - the teachers joined the project in mid to late fall respectively and did not have the content expertise to co-create the new courses on the pre-established timeline. Finally, the baseline data source - 5th grade statewide Science Test - was not collected in the spring of 2020 due to COVID, thus the team did not have any pre-intervention participant data for Year 1. To overcome these challenges, the research team completed an IRB amendment detailing the following three changes: (1) allowing participants to complete the approved permission, assent, and consent forms virtually using university-sponsored Qualtrics Forms; (2) changing the format of focus groups/interviews from in-person to virtual focus groups using the university-sponsored password protected Zoom platform, and (3) changing the baseline data collection from the 5th grade statewide Science Test to the 5th grade statewide Science Released Exam. The first two changes align with social distancing procedures. The third change is due to a lack of 5th grade statewide End-of-Grade (EOG) Science Test administration or scores for spring 2020. As such, the researchers planned to use the released exam as a proxy for 5th grade EOG.

It should be noted that even with these pivots, the team continued to experience additional ad hoc challenges throughout Year 1. For example, the student assent and parent consent process was significantly delayed due to several compounding factors including not being able to send students and families consent forms prior to the course start, students having low or no tech access at home, and families preferring paper consent forms. The research team worked with the teacher to provide paper copies; however, implementing paper consent required the teacher to scan and email the completed forms to the team, which often lengthened the consent process and delayed data collection. Other unintended challenges included school maintenance issues requiring further school delays and closures and not receiving consent from one teacher. To maximize their time, the research team shifted focus from items outside their locus of control to items that were in their locus of control, such as planning future deliverables and publications, and providing recommendations to improve the project's transition to a remote environment. Some of those recommendations included (1) a website video to introduce the project to the schools and engage families and students; (2) an enhanced web presence to engage with students and families online, and (3) monthly industry spotlight videos to students to build program momentum. The research team also presented regular research Q&A talks to student cohorts within the first day of their course beginning with the goal of boosting research participation.

***Equitable Access to High Quality Teachers.*** Teachers are an essential partner in the collaborative model. Securing high-quality teachers in rural districts is a persistent challenge in the literature (Goodpaster, Adedokun, & Weaver, 2012). Data shows rural districts are more likely to have trouble attracting and retaining a cadre of credentialed teaching faculty (Monk, 2007). On par with the literature, teacher turnover was a major challenge experienced by the project team. Teacher turnover impacted the project in several ways. First, it delayed the one-week teacher professional development workshop that was slated for summer 2020 as the two teachers initially earmarked to teach the courses transitioned to new schools, and principals were tasked with recruiting replacement teachers. Recruitment took most of the fall semester and the two new teachers joined the project in mid and late fall, respectively.

In response to the implementation delay and phased hiring of the teacher leaders, the research team reoriented and took a different approach to collaboration. The team relied more heavily on

feedback from industry partners during the summer. They proceeded with the first day of that professional development workshop, which was a virtual session with industry representatives. In an email, the lead professional development facilitator succinctly articulated the rationale for preceding with the meeting. With his consent, this quote is included below:

*“[O]ur DeSIRE model is based on an industry-driven course curriculum and lesson plan input. My vote is to maintain our time-line planner and work with the Industry-leaders to complete the planning of the curriculum and lesson plan "as a draft." This way we begin to forge our relationship and be prepared to launch in the fall with the selected teachers and integrate their input. This approach can buy time for the school leaders in the teacher search.”*

Once the new teachers were hired, it became apparent that neither teacher was a STEM expert and required substantial training and support to implement the intervention. To respond to teacher needs, the team modified the professional development training model from one continuous week of training to a phased training program for the teacher leaders throughout the fall and spring. The team implemented a series of five customized mini sessions for each teacher throughout the fall and spring terms, to acclimate them to engineering fundamentals, tools, and activities. The research team is currently engaging in extensive documentation of the teacher training and course development process, and plans to continue documentation through the implementation to assist with implementation fidelity for research/evaluation purposes and program scaling purposes. Eventually, the team plans to develop a framework for course design and implementation which would serve useful for other rural districts seeking to create and sustain similar projects.

## **Lessons Learned**

***Lesson #1: Understand that relationships are the currency of research.*** It is vital to build relational trust among all the partners involved with the project. The research team benefited greatly from engaging in authentic and mutually beneficial working relationships with both the industry representatives and the teachers who were tasked with implementing the program. Moreover, the project’s success or failure is dependent on buy-in from the institutional gatekeepers, teachers. We advise future researchers to incorporate relationship building in their project planning process and spend adequate time listening to their partners and gaining their perspective. Their insights can be critical to both developing curriculum, and the investment in the long-term relationship is truly invaluable.

***Lesson #2: Create resources that are not personnel-dependent.*** As mentioned previously, rural districts suffer from high teacher turnover. Early on, the project experienced both the loss of a district leader who helped shepherd the grant, and two teachers that were ear-marked to teach the course. Future research teams would benefit from creating resources that stay at a school or district level, and are not personnel focused. Resources need to be detailed and specific so that any school personnel can take it and implement it, if needed.

***Lesson #3: Be flexible and willing to pivot.*** At several turns, the team was willing to make adjustments that better fit their current needs as circumstances. For example, the team developed strategies to build program interest and momentum virtually such as creating a welcome video for parents and planning virtual industry spotlight videos. The team also gained consent and data using virtual platforms such as Qualtrics, Zoom, and scanning technologies. Throughout the iterative

pivoting process, the team discovered the importance of documentation. With so many shifting elements, it became imperative to document the process closely for fidelity.

## Summary

This paper described the challenges faced during the planning and implementation of a STEM-focused program largely designed for in-person interaction during a pandemic. While there were numerous challenges, the ability to remain flexible and adapt enabled the project team to move the program forward. The next steps will involve integrating the best practices and lessons learned from this year into the second year of the project in order to continue to provide high impact STEM educational experiences for underserved rural students.

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