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Using Design-based Research Methods to Scale in an Expanding Intervention

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In this *work-in-progress* paper, we share the methodological decisions we made to support research within the ongoing implementation of a large-scale, five-year NSF Scholarships in STEM (S-STEM) project. Our purpose in sharing our current situation is to gain feedback from colleagues experienced with projects of this size and type on how to effectively make midstream corrections to design-based methods in ways that maintain research and project fidelity. During the 2019-20 academic year, the first year of the project, we created tools and procedures for data collection and analysis that we piloted in Spring 2020 with the first cohort of students to participate in the S-STEM program. With regard to supporting undergraduate students, the plan for this multi-year, grant-funded project is to scale each year, along with increasing the size of participant cohorts, through the fifth and final year of the project. As a two-person research group within the project team, we had been concerned about our ability to collect and analyze the amount of data we might potentially have available. That is not the current situation. Although plans were to support up to twenty students in year 1, 52 students in year 2, 70 students in year 3, 88 students in year 4, and 113 students in year 5, our first cohort had only six student participants.

Highlighted by this emergent issue with recruitment, we were concerned about how our research designs would fare on implementation. Participant numbers are intended to continue to grow each year of the project, placing additional demands on our small research team and our chosen methods, so we piloted initial tools and procedures that we felt would provide consistent research throughlines during the project lifespan as participant numbers increased, while also giving us useful iterations of formative feedback about participants' needs and their experiences in the program. At the time, we felt it important to create methods that would remain manageable for a single graduate assistant researcher to implement data collection and prepare data for analysis by the research team each semester. While our tools and procedures have allowed us to analyze pilot data, participant numbers have not scaled in the second year, with a similarly small cohort of students. We find ourselves at a point where we have the capacity to collect additional data and address emergent questions that have resulted from our formative analysis.

As a work in progress,, we are seeking feedback from researchers who have experience with large-scale, multi-year implementations, especially in the context of making revisions to research design. We chose design-based methods to construct our tools and plan our implementation, having selected them for their applicability in situations where plans may need to be revised based on formative iterations of reflection [1]. Now that we find ourselves with the need to make changes, we are uncertain how to effectively integrate new research questions, collect and analyze data, and communicate findings in ways that: (1) maintain consistent attention to established throughlines while; (2) integrating adaptations to the original research design that may result in changes to program implementation. We are wondering how we can revise what we have designed into a process that integrates added focus on emergent questions, while remaining fidelitous to overarching project goals during an ongoing implementation. We are also seeking guidance on how to address potential impact to the reliability and validity of our current measures for data collection.

project background

The purpose of our S-STEM project is to connect transfer student pathways from state technical colleges to Engineering and Computer Sciences programs at a Research I university in the southeastern United States. It is our hope that, by creating and improving these pathways, we can facilitate more students achieving their academic goals. Cohorts of participating students begin at the technical colleges, guided by a doctoral student mentor who engages program participants in applied research and shepherds them through their transition to the university. As S-STEM participants, students receive scholarship support and become part of a program designed to support their particular needs. To develop these cohorts, project interventions build on the conceptual and operational themes of communities of practice [2], [3], using cognitive apprenticeship strategies [4], [5] to support student cohorts and create programming aspects to enhance transfer students' enculturation to the university, completion of STEM-related degrees, and placement in the industrial workforce. Students engage in a year-long course-based research experience in their first year at the university but can participate in that opportunity each additional year prior to graduation. Table 1 displays the primary interventions of the S-STEM program, with sources for data collection and analysis.

TABLE 1
PROGRAM INTERVENTIONS

Intervention	**Data Collection**	**Data Analysis**
need-based scholarship	institutional data related to retention, achievement, and attainment	quantitative analysis to define current state and determine trends in grade changes over time
revised coursework	course curricula; classroom observations; student achievement data; student interview data	thematic and organizational coding to determine emergent patterns and differences in institutional contexts
cohort experiences	survey, interview and observation data of student participants; artifacts from virtual environment supporting cohort interactions	mixed methods analysis to determine descriptive trends, identify relationships and networks, and expose areas of contextual significance

Transfer students who are accepted to and engage in the S-STEM program and consent to participating in research data collection are our primary research subjects, with graduate students, staff, and faculty involved in the S-STEM program as the remaining participants. Each cohort of students is analyzed as its own case as well as comparatively and collectively with other cohorts. Individual students provide essential feedback about their engagement with and feelings about their STEM-related coursework, the S-STEM program, and their academic experiences in general. Of particular focus in our data collection procedures is mathematics anxiety, as our funding proposal highlighted mathematics knowledge as an area of high institutional need related to STEM transfer students. The primary questions guiding our work are

shown in Table 2. As existing throughlines in our work throughout the first two years of the project, we hope to maintain these questions as we consider integration of emergent concerns.

TABLE 2
RESEARCH QUESTIONS

Primary Research Questions	**Quantitative & Qualitative Data Sources**	**Analysis**
How does participation in S-STEM program activities by low-income technical school transfer undergraduates in Computing and Engineering influence their retention, achievement, and degree attainment at University?	Ongoing institutional data for grades in pre-transfer and Univ. coursework, program enrollments, and graduation information; participation in S-STEM cohort and mentorship activities	Internal: annual collection and analysis using institutional data Internal: formative semester review of course-related artifacts and achievement data, observations, and interviews
What are faculty and mentor participants' beliefs about their involvement with the design and implementation of program activities and how do they change across engagement with S-STEM?	Formative iterations of survey and interview data from faculty participants at technical schools and University related to their experiences with program design and implementation	External: annual evaluation by external evaluator Internal: formative semester survey and interview data collection and analysis with faculty and Fellows
What are student participants' beliefs about their interactions with program activities and how do they change across engagement with S-STEM?	Formative iterations of survey data from student participants during pre- and post-transfer coursework; interview data from transfer student participants concurrent with cohort and mentorship activities during pre- and post-transfer periods	Internal: formative pre- and post-semester survey and mid-semester interview and observation data collection and analysis focused on participant engagement and their values, attitudes, and beliefs
How do student participants' perspectives change regarding their professional goals and identities across engagement with S-STEM?		

In our initial design for data collection and analysis, each fall and spring semester of their participation, students in the program at all institutions would complete early and late semester pre-and-post style surveys. Once they were selected and agreed to participate, we would interview a subset of the students one-time, mid-semester, continuing to interview the same group in following semesters. Graduate students, staff, and faculty in the program would also participate in one survey per semester. Opportunities for observation would come from program activities as well as the undergraduate course that provides the structure for the cohorts to interact with focused, program-specific research experiences.

Each year, the number of students participating in the five-year implementation was designed to accumulate to a proposed total of over 300 students, with potentially half of those students in the program in the fourth and final years. Our research team would need to scale our efforts to maintain project fidelity and effectively conduct our research. We chose design-based research and development methods to create an iterative design and implementation loop of formative assessment and maintain a consistent research goal toward summative evaluation of fidelity across the span of the multi-year project [6], [7]. With design-based methods intended for this type of implementation work, we hoped to use these opportunities for formative reflection to refine our data collection and analysis methods while continuing to ask questions. We still feel that these methods are applicable toward the issue of scale, but given our current situation, our attention has turned to the flexibility in our research that design-based methods are intended to support.

Last year, we completed the pilot implementation of our tools with the initial cohort of students in the early months of the COVID-19 pandemic and our forced move to using online tools to support remote interactions. Currently, school-year implementation in the second year of the project has ended, along with data collection, until August 2021. The pilot cohort is in their second year at the university while a second cohort has transferred to the university and another group has engaged at one of the collaborating technical colleges, with the intent being that they will apply to the university and the S-STEM scholarship program.

years one and two

The 2019-2020 academic year was the first year of the S-STEM program and was only implemented at the R1 university to which the students from technical colleges would transfer, as the cohort-driven program activities had yet to be designed and implemented at the technical colleges. Student participants were still recruited and selected from the target population: transfer students in Engineering and Computer Science from two of the technical colleges in different regions of the state. The intention then was that cohort experiences at the technical colleges would begin August 2020.

Fall 2019, six students began the program in the pilot cohort. They had not been together as a group prior to August 2019 and engaged in the S-STEM program activities without the benefit of cohort-based learning experiences during their last year at their technical colleges. Given this difference, we treated them as a pilot group for testing certain survey and interview questions as they had not engaged in certain program activities. Their data would not be sequestered, but would be carefully considered in light of this difference in their experiences as new cohorts provided their feedback.

In Spring 2020, we were able to pilot our tools with the first cohort of students. We also invited all students to interview, rather than select a sample to interview, as would be our process if cohort numbers were to scale as intended. With the arrival of the second cohort to the university, we went from six to twelve total students, well below the number of students planned for in our proposed budget. We continued with the same tools, noting but not yet choosing to pursue

questions of recruitment, with pre- and post-semester surveys and mid-semester interviews using our existing protocols.

Table 3 displays our existing plan for internal assessment, along with the addition in italics of two new groups of participants (i.e., Technical College students who may or may not transfer to our university) originally not part of our plans for data collection and analysis. Given concerns from project leadership, advisory board members, and the external evaluator, we are hoping to integrate questions about recruitment. Potentially bringing new theory and practice in this area into our current research has left us with questions about how to effectively address emergent concerns in the context of our tools and procedures.

TABLE 3
INTERNAL ASSESSMENT PLAN

Participants	**Fall/Spring Methods**	**Analysis Methods**
S-STEM scholarship students at University	Pre- and Post-semester survey; Individual interview	• Demographic data used for organization and context; • Likert results analyzed for descriptive statistics; • Open-text responses coded through thematic qualitative analysis and intercoder reliability; • Integrated mixed method analysis to confirm evidence and contribute to common themes
Graduate Assistant Fellows	Post-semester-survey; Individual interview	
Project Leadership	Post-semester-survey; Individual interview	
Creative Inquiry (CI) students at Technical Colleges who apply to target university	*Pre- and Post-semester survey; potential interview*	
Qualified CI students who do not apply to target university	*Post-semester survey; potential interview*	

Table 4 displays themes resulting from analysis related to our original research questions through the first two years of the project. We were pleased with the results from our survey questions with respect to the design of our instruments for new and returning student participants. We had been able to remain fidelitous to our research questions and uncover potential themes for our ongoing analysis.

TABLE 4
INTERNAL ASSESSMENT RESULTS

Participants	Fall/Spring Methods	Analysis Themes
S-STEM scholarship students at university	Three semesters of survey and interview results: • Spring 2020 - pilot • Fall 2020 • Spring 2021	Self-efficacy and professional identity; Project and coursework engagement; Communities of practice
Graduate Assistant Fellows	Post-semester survey • Fall 2020 • Spring 2021 Individual interviews • Spring 2021	Communities of practice; Cognitive apprenticeship; Student engagement

The low number of participants in the first year did not greatly concern us, as we had no delusions about creating any grand new theories from our findings with the initial cohort of six participants. We wanted to pilot our instruments and design our collection and analysis methods that, although we only had a few participants and a small amount of information at the time, would be useful for a large data set involving more than 300 individual participants. Even as we discussed preparing for interviews, we did so believing that we may not have the capacity to interview each participant but would try to do so with this first group of students to test our measures. The addition of new participants into our ongoing research is needed, given problems that have emerged in the implementation design with regard to recruitment of students into the program.

What does concern us is the apparent problem recruiting the number of students that the project is designed to support. Anecdotally, before the second year, our collective project team did try to chalk some of it up to the disruption and resulting stressors from the COVID-19 pandemic. In that light, we felt that perhaps we could continue with the implementation we had designed for the pilot. The 2020-2021 academic year brought additional changes to program personnel, further complicating implementation of both research and program efforts. The emergent issues of recruitment, personnel change, and the ability to remain connected through COVID-19 restrictions have become acutely important to our ongoing project.

Our choice to use design-based methods has provided this opportunity for us to reflect on our procedures and revise them in response to findings that have emerged from three iterations of formative reflection, while maintaining our goals for research and development. As researchers new to the Engineering Education community, sharing our work-in-progress provides us with the chance to connect with new colleagues who can advise us.

closing

Our intent with this work-in-progress paper is to share our current status and invite interested colleagues to provide feedback about our pilot analysis work and our plans for future data collection and analysis. Our particular concern is how to effectively integrate emergent issues

into the research design of the ongoing implementation. As the primary researchers on the S-STEM project, we are also new to the ASEE community, and would like to hear from colleagues who have experience with large-scale, multi-year implementations. We invite you to share your experiences and expertise with us as we consider our next steps in this ongoing project.

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