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Work in Progress: Facilitating a year-long research course sequence for undergraduate transfer students within a NSF S-STEM scholarship program

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Introduction

Science, technology, engineering, and mathematics (STEM) students transferring into 4-year from 2-year institutions have been reported to change their majors more often, and graduate at slower rates, than the students that enrolled directly at the 4-year institution [1, 2]. In addition, studies have shown that these transfer students have more difficulty establishing their social network and navigating the 4-year institution system [3,4]. To improve the matriculation rates of transfer students, the National Science Foundation (NSF) allows transfer students to be supported through their Scholarships in Science, Technology, Engineering and Mathematics (S-STEM) program.

The Student Pathways in Engineering and Computing for Transfers (SPECTRA) program is a newly funded S-STEM program in South Carolina, expected to run through 2026. The program is envisioned to provide a streamlined academic pathway for transfer students from 2-year programs within South Carolina into Clemson University, and provide programming to aid their academic success and social integration. To achieve this, SPECTRA will create cohorts of students at two community/technical colleges (Spartanburg Community College and Trident Technical College) and then support that cohort as they transitioned together into Clemson University [5]. This cohort would then be mentored in how to navigate Clemson University's academic environment, utilizing available programming such as academic tutoring, field trips to see local engineering companies, *etc*. A unique component of the SPECTRA program is the requirement that scholarship recipients at Clemson University enroll in two semesters of research, in addition to their participation in social and academic programing. These 1-credit research courses are designed by the graduate student fellows who have either completed their MS degrees, or finished their qualifying exams for an engineering or computing program. By providing the cohorts with a shared mission of a successful research experience and emphasizing the need to learn skills from each other [6], the transfer students expected to form a community of practice [7,8]. Prior research has also shown that introducing transfer students to research expanded their perspective of STEM pursuits [9].

Through this Work in Progress (WIP) paper, the experience in designing and facilitating these research courses while matriculating through their graduate programs is documented by the authors. Specifically, the design constraints of the research courses, the topics developed for the 2021-2022 cohorts and the envisioned assessment are discussed.

Developing a research course that could engage students authentically from a range of engineering and computing majors

SPECTRA scholarship recipients represent a variety of engineering and computing program offered by Clemson University. While requested to develop a 1-credit research course that can allow these transfer students to authentically contribute, the graduate students affiliated with SPECTRA are restricted on the scope of research topics. The authors worked with both the SPECTRA faculty and their own research advisors to refine the topic for their research course after selection as a SPECTRA graduate student fellow. The authors found that the scoping of the research courses to be challenging, however, since they wanted to strengthen the undergraduate students' identities as engineers, equipping them with the skills needed for research and allow time for these students to conduct their research. The research opportunities offered in 2021-2022 aligned with the dissertations of the two fellows enrolled in the fields of civil and bioengineering. Below are the abstracts for 'Reimagining Transportation Infrastructures in Clemson University' and 'Human Factors of Clean Eating Globally' offered in the 2021-2022 academic year.

Abstract for research course option 1 for 2021-2022 SPECTRA Scholarship Recipients: 'Reimagining the Transportation Infrastructures of Clemson University'

'Reimagining the Transportation Infrastructure of Clemson University' is designed to introduce undergraduates to quantitative research methods and comparative analysis fundamentals. Scholars will identify how (if) there are interactions between expanding traffic capacity and a community's quality of life. Scholars will initially address the following questions: (1) How can we accommodate the increasing transportation demands while maintaining safety for residents?; (2) What can be done to improve the parking experience of faculty, staff and students on a university campus?; (3) Is it feasible to implement solar-panel parking lots on the university campus? Enrolled scholars will be expected to form hypotheses, participate within the research process (including field work) and disseminate their work at the end of the year. Part of the research process will include learning how to apply empirical theory to observations.

Abstract for research course option 2 for 2021-2022 SPECTRA Scholarship Recipients: 'Human Factors of Clean Eating Globally'

Human factors contribute to usability and design of an instrument. Eating utensils, while found in most homes, are of varied design based on resources, culture, and utility. This also contributes to variations in reprocessing utensils for safe reuse. Utensils in this study will include plastic, wooden, electronic, and metal utensils. The purpose of this research course is to define the key human factors for reprocessing and usability of eating utensils and to determine the most ideal usability factors and design globally. By way of example, the US Food and Drug Administration guidelines identify human factors engineering as essential for maximizing the likelihood that reprocessed medical devices will be safe and effective for the intended users, uses, and use environments. Therefore, incorporating human factors engineering into device design and reprocessing methods, applying regulatory standards, and launching a successful product can be achieved. In this course we will aim to answer questions such as: (1) What factors contribute to instrument usability?; (2) What factors contribute to instrument design?; (3) What are basic procedures for reprocessing devices for safety and reusability? ; (4) How do we use computer software in decision making for a practical application?

Communicating the utility of research work to students in a range of engineering/computing majors

To select the specific SPECTRA research course they preferred to enroll, the students used a Qualtrics survey. This survey included an open textbox for the students to provide comments to the SPECTRA administrators. Some of the undergraduates that used this textbox expressed concern that they did not see strong alignment with the proposed topics and their own majors. Of the 2021-2022 SPECTRA cohort, only one scholar was majoring in the same field as the two graduate fellows offering the research courses.

To articulate the value of these research experiences more clearly, the authors took the following steps at start of the fall academic term. First, they set up consultations with faculty in departments facilitating each major (or intended major) programs of the enrolled SPECTRA scholars that term. In these meetings, the authors provided an overview of their research course scopes along with their perceptions of the utility of the research activities for each major. The faculty were then asked to provide feedback on how the fellow could both communicate the utility of the research course or improve the utility by altering the course activities or scope. This approach followed the value creation framework proposed by Wenger *et al*. [10]. The authors wanted each undergraduate scholar to identify the benefits of partaking in the course, including the benefits of expanding their network, and utilization of foundational engineering and computing courses to contribute to a research project. To increase the potential value, the authors changed their initial course structure to allow time for industry professionals and faculty researchers to speak to the enrolled students. Finally, the authors intentionally took time within lectures to highlight the skillsets the scholars utilized that day.

Embedding Foundational Research Skills into Framework of Research Course Structure

Since the SPECTRA scholars do not typically have prior research experience, each research course offered in 2021-2022 integrated foundational research skill development, and an overview of the research process for enrolled students. Using prior published work on pre-research programs and the materials developed for the 'Research Foundations' program offered at Clemson, the authors included a series of modules within a Canvas portal for the enrolled students: (1) What is research, and who are researchers; (2) What can you expect to do as an undergraduate research assistant; (3) Basic safety training and Responsible Conduct of Research training; (4) Documenting your research in laboratory notebooks; (5) Finding research articles and building a reference library; (6) Reading research articles and understanding the peer review process; (7) Writing an abstract for conference submission, (8) Disseminating research at conferences or seminars; (9) Tips for time management; (10) Creating your resume to apply for research positions. The ability to utilize developed pre-research course materials allowed the graduate students more time to focus on scoping their research topics with their dissertation advisors.

Initiating Research by Scholars

Research projects were initiated in parallel to the student's development of foundational research skills. The scholars were initially given a broad prompt that encouraged critical thinking. For example, the students enrolled in 'Human Factors of Clean Eating Globally' were prompted: *'Analyze 3-5 utensils in your home. Describe the utensil dimensions and explain the significance of each dimension. What are these utensils used for and why do these dimensions benefit these functions? How can these utensils be repurposed? Re-design these utensils for a community with limitations such as arthritis, children without prior experience, etc.'* This prompt challenged the scholars to think about how the utensils were developed according to usability standards and were used to help the scholars prepare for discussions. While the initial activities were general, these assignments also provided the scholars with foundational knowledge prior to solidifying their team's research questions. For example, one of the first activities of the 'Reimagining the transportation infrastructures of Clemson University' research course was a field data collection. The field observation allowed students to observe traffic phenomenon of bottlenecking, and collected congestion data to use as inputs in the traffic simulation.

Characteristics of enrolled SPECTRA scholars in research courses

Undergraduates supported by SPECTRA scholarships are referred to as 'scholars' to increase support their identities as members of the SPECTRA program and as undergraduates having academic talent. The scholars enrolled in the research courses self-identified as majoring or intending to major in a range of programs (civil engineering, computer information systems, computer engineering, computer science, electrical engineering, industrial engineering or mechanical engineering) (Figure 1). During Spring 2021, 57% of the scholars are in the mechanical engineering major, while the other majors are about 14% or lower. During Spring 2022, the cohort grew for computer engineering and computer science majors. Most enrolled scholars had junior or senior standing.

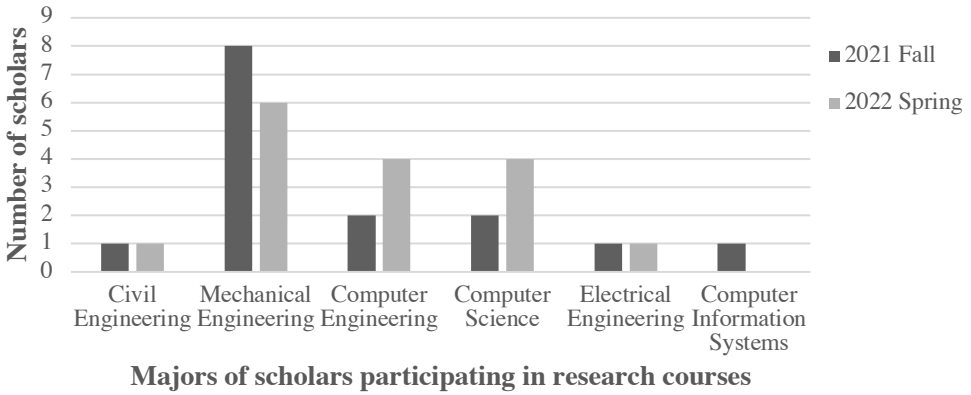

Figure 1: Distribution of majors of scholars participating in the 2021 Fall and 2022 Spring Creative Inquiry classes associated with the SPECTRA program.

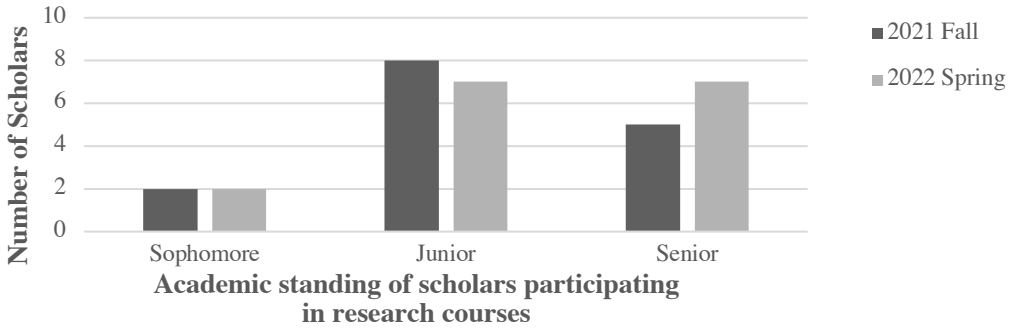

Figure 2: Distribution of academic class standings for SPECTRA scholars participating in the 2021 Fall and 2022 Spring Creative Inquiry classes.

Future Work- Assessment of the Implementation

During the Spring 2022 term, the authors distributed a survey among scholars to understand their perception of interdisciplinary work and expectations for their participation in an undergraduate research course. The following is an example question provided in the survey:

> *"Greenville-Spartanburg International Airport (GSP) hosted a demonstration of an advanced all-electric, automated vehicle in the airport in 2020. Suppose you were responsible for putting together a team to study and develop the prototype all-electric automated vehicle in GSP. What engineering or computing disciplines would your team members need to have experience in? What characteristics do you want your teammates to have?"*

The question was adapted from [11] and will be used to evaluate the collaboration between students. The instrument was designed to measure the scholars' ability to identify and value the contribution of multiple disciplines both inside and outside of engineering. In addition, an assessment was designed and will be provided to students who completed the required two semesters of research course participation to understand the scholars' value of this experience. Through the Canvas platform, the undergraduates will be asked to respond to the following prompts using open textboxes.

1. *Why did you initially apply to join the SPECTRA Scholarship program at Clemson University?*
2. *Why would you recommend that other transfer students participate within the SPECTRA program?*
3. *What are the top three skills or pieces of knowledge that you gained while participating within the undergraduate research experience?*

4. *How do you anticipate utilizing the skills grained in your research experience in your chosen engineering or computing majors?*
5. *Do you feel better prepared to participate in research projects at the course of this class? Please elaborate on why you chose your answer.*

The student responses will be used to generate a best-practices and suggestions document for subsequent SPECTRA fellows as they develop their research courses.

Conclusions

This WIP documented the development and planning of the undergraduate research courses offered to the 2021-2022 SPECTRA scholars at Clemson University. It offered insight into the considerations and challenges experienced by the two fellows in designing courses. In addition, we describe our evaluation instruments and analysis plan.

Acknowledgments

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