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Student Success in 4-D (SS4D): Toward a Holistic Understanding of Engineering Student Success in Motivation, Curricular Attainment and Experiential Opportunities across Educational Stages

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Work in Progress: Toward a Holistic Understanding of Engineering Student Success in Mechanical Engineering across Educational Stages

Abstract: This WIP paper will present our results to date in conducting a multimethod single case study, which is appropriate for deeply understanding multiple stakeholder perspectives within a bounded environment, in our case, the Department of Mechanical Engineering at Pennsylvania State University. The in-progress goal of our team in Mechanical Engineering at this large, research-focused institution, is to reconceptualize student success that enfolds four dimensions. These dimensions have been previously siloed in engineering education literature, though even within these groupings, engineering education researchers typically focus on one phenomenon at a time: motivation; attainment; experiential opportunities; and success across career stages. This project is underway and, in this work-in-progress paper, we share preliminary findings from our qualitative investigation of thriving in online Master of Science Mechanical Engineering students.

Motivation: Numerical metrics, such as degree conferrals, grade point average (GPA), and job placement rate are often metrics used by universities, colleges, and departments as a proxy for measuring the success of students and programs alike. However, these numbers are limited: For example, if a student graduates with a 4.0 GPA but has low conceptual understanding, should that be considered success on the part of the student, the department/university, or neither? If a student graduates on time but is not psychologically well because of a hostile environment, should that be counted as success on the part of the student, of the department/university, or of neither? We would posit in both these situations, certain entities can measure victory while the holistic story is more nuanced, with the student underserved in many perspectives. Therefore, the overarching research question that will be launched by this project is: ***How can and should holistic engineering student success be measured?*** Given that very little progress in diversifying engineering at either the undergraduate or graduate levels has been accomplished in the past decade despite attention and funding [1], we suggest that if a new way to assess success of students were to be developed, we may be able to measure and identify where students are not thriving, and to develop more effective and strategic interventions. This is particularly important as students and departments alike recover from the pandemic, which has adversely affected student well-being [2,3], retention [4], and learning [5-7] at the undergraduate and graduate levels [8,9], especially for marginalized groups [10-12].

The goal of this project is to reconceptualize metrics of student success. This conceptualization enfolds four dimensions that have been previously siloed in engineering education literature, though even within these groupings, engineering education researchers typically focus on one phenomenon at a time: Motivation (success could be measured by thriving [13,14], well-being [15,16], belongingness [17,18] grit [19,20]); Curricular Attainment (success could be measured by metrics like GPA and completion rates [21,22], conceptual understanding [23], transfer of skills across applications [24,25]); and Experiential Opportunities (success could be measured through understanding in authentic project based learning [26,27]; obtaining internship experiences [28,29] and undergraduate research [30], and job placement rates). The fourth dimension of success is considering success over time *across career stages*. This project is funded via a seed grant from Pennsylvania State University with the goal of understanding and translating findings for departmental initiatives and pursuing research into metrics of success.

Research Design and Timeline: Overall, this research project is designed as through a phenomenographic [31,32] multimethod single case study methodology [33], which is appropriate for deeply understanding multiple stakeholder perspectives within a bounded environment, in our case, the Department of Mechanical Engineering at Pennsylvania State University. Formal case study methodology must incorporate multiple streams of data. Table 1 shows the multiple streams of data, data analysis methods, and utility of that stream of data in understanding facets of success. We started with the investigation of students in our online MSME program since that project a) had IRB approval; b) was already underway; and c) was aligned with long-term goals of our department [34]. Therefore, the parts of the study for which preliminary results are reported correspond to the row outlined in boldface and shaded in Table 1.

Table 1: Description of data streams, utility, analysis methods

Stream of Data	Purpose	Analysis Methods
Statistical analysis of Departmental metrics, GPA, time to degree completion from undergraduate programs	Analyze broad patterns in student experiences and traditional metrics of success as context for other metrics of success	Quantitative descriptive and longitudinal statistics
Artifact analysis of conceptual learning and transfer of concepts in ME 320 (Undergrad Fluids) classroom	Considers success in a local coursework environment related to homework scores and final grade in the class; ability to translate conceptual understanding from core course to project-based applications	Qualitative characterization of formative and summative assessments via homework and exam problems for conceptual understanding; analyze senior design and lab projects that focus on heat transfer concepts using artifact analysis methods [35,36]
Surveys of Motivation and Success with Current undergraduate and online & Resident Grad Students	Considers success as well-being with respect to motivation and affective (psychological) dimensions	Data collected using validated survey instruments available in literature; Analyzed through Descriptive statistics; regression; correlational statistics
Interviews: n = 5 ME alumni in industry	Understand how alumni characterize success through and out of their programs; retrospective attributions of success into, through, and to next steps after undergrad	Interviews collected using semi-structured interview protocols [37]; interview data transcribed and analyzed using thematic qualitative analysis using open- and axial coding methods through a constructivist paradigm [38]
Interviews: n = 5 ME alumni in academia		
Interviews: n = 20 Online MSME Student exit interviews	Understand how current MS and PhD student characterize success in their current stage as it relates to their undergraduate preparation, transition into graduate school, and to their current and future goals	
Interviews with Current MS (n = 10) and PhD Students (n = 10), and Postdoctoral Scholars (n = 5) in ME		

Methods: Interviews with n = 20 graduating online MSME students were conducted over the course of two years as part of the exit interview protocol for our online MSME degree. Exit interviews are required for graduating students as part of program improvement purposes, but in recent years we have been increasingly interested in understanding not just which features students appreciated/struggled with in their program, but whether and how they learned to thrive in their program. Our semi-structured exit interview protocol was designed to collect both types of data (evaluative and research), building on prior expertise in our research team in conducting graduate-level engineering education research and research pertaining to online learning.

To ensure that participants did not feel power dynamics or pressure to participate, and to ensure that they would give their accurate perceptions on the program, the interviews were

conducted over Zoom by a faculty member who is affiliated with the MSME online program, trained in educational research methods, but is not student-facing such that she represented a neutral party in the interviews. At the end of each exit interview, students were told about the research project, informed that they would receive an email invitation to participate, and reassured that the program requirement of the exit interview was satisfied regardless of whether they chose to make their data further available for research. A total of 20 students consented to participate. All participants were employed in a full-time engineering-related position during at least two semesters in the program, with 85% of participants having at least half of their degree paid for by their companies.

Interviews were transcribed by a professional transcription service and cleaned for accuracy. The lead author conducted the initial analysis of the transcripts using thematic analysis methods through a constructivist framework, grounded in a modified version of Spritzer's Workplace Thriving Theory that has recently been published by our research team for engineering graduate students in residential settings [39]. In the framework, there are three dominant domains that are important for thriving: Context Features, Agentic Behaviors, Produced Resources, and the development of hidden competencies that serve to facilitate a connection between agentic behaviors and produced resources. By employing this theoretical framework to the study, we are able to understand the ways in which thriving in online engineering graduate students compare with residential (traditional) graduate students. Data were further analyzed by the research team using NVIVO qualitative data analysis software, and procedures, codebook development, and interpretation of findings were discussed to consensus in weekly meetings.

Findings to Date: Findings to date show that while, in general, the types of issues affecting the online Mechanical Engineering master's students were similar to those of resident graduate students documented in prior work, the ways in which they manifested were quite different. These differences were due to the situatedness of the online MSME graduate students, who for the most part held full-time jobs in the engineering industry, with many of them having families and children, and traveling for their careers in addition to balancing their coursework and research in the online MSME program. Unlike resident students, who resi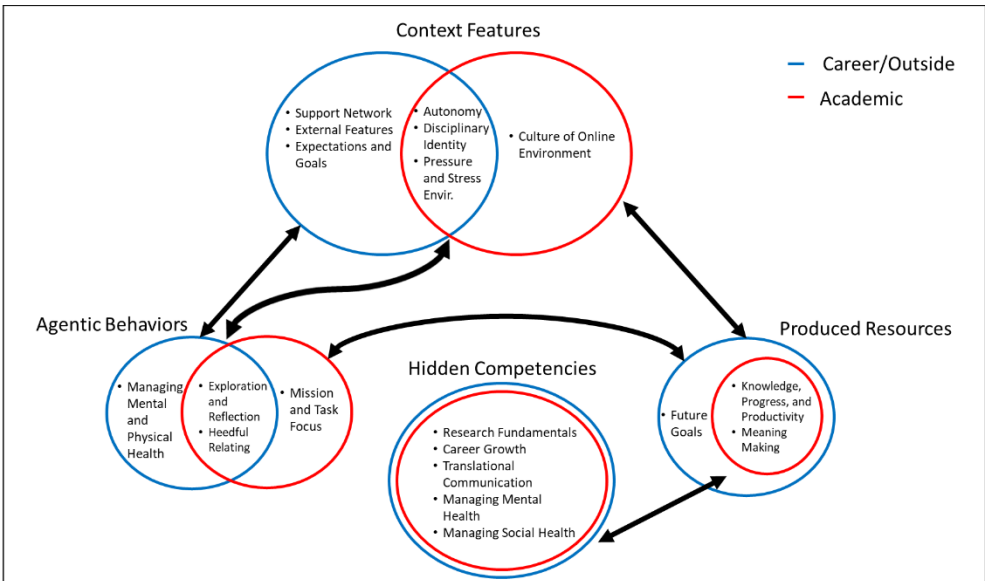de primarily in an academic context, for online MSME students to thrive, they delineated between factors that affected them in a career or outside-academic context, and those that affected them in ways directly related to the university, as depicted in Figure 1. As an example, the code "support network" within the theme "Context

Figure 1: Preliminary Themes and Subthemes Affecting Thriving for Online MS Students

Features" is one that is common in graduate education literature. For resident students, this typically relates to a students' ability to develop, seek out, and nurture strong bonds with others in graduate school to support them in a period of time that is typically isolating. However, for our online MSME students, the support network code most often referred to colleagues at work, or managers, that allowed them the flexibility to work on coursework or exams during deadline seasons, or to students' families in supporting them through the time-intensive coursework by taking on more family labor.

Important differences between the experiences of residential and online graduate students can also be seen in the "Agentic Behaviors" theme. The coding for the theme "Agentic Behaviors" indicated few (out of the 20) participants exhibited behaviors relating to engagement with the university and peer community in graduate school. As shown in Figure 2, more participants exhibited behaviors associated with codes that focused on their course and career interests, research experiences, and individual well-being practices, rather than pursuing a support network through the university (e.g., joining student clubs).
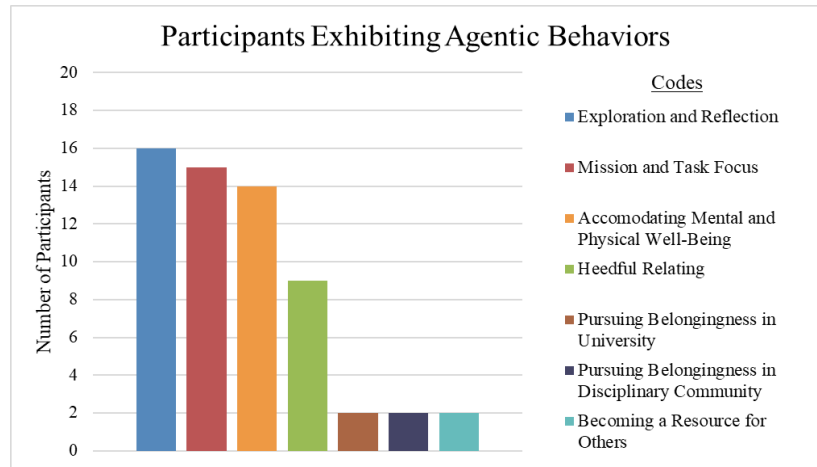

Figure 2: Participants Exhibiting Agentic Behavior Codes

Another theme that manifested differently was the "Future Goals" subtheme within the "Produced Resources" theme. While prior work indicates that resident graduate students consider their future goals being everything outside of graduate school, the online students had much clearer goals with respect to promotion or advancement in their company. Many students had pursued a Master's degree in order to earn the knowledge and credentials to move into technical leadership or management positions, and saw those goals coming to fruition as they were nearing completion of their MS degrees. Alternatively, some participants produced new future goals after they had explored new technical areas in their graduate coursework and research, and decided to pivot in their careers in part because of their new education.

Conclusions and Future Work: This WIP paper discusses an ongoing initiative by the Mechanical Engineering Department at Pennsylvania State University to measure success holistically, incorporating motivation, curricular attainment, experiential opportunities, and success over time. In this paper we present preliminary results articulating how thriving is different for online graduate students than for typical resident graduate students on which most of the literature is based. While the honing of codes, relationship between themes, and contribution to theory and literature in graduate engineering education is still ongoing, the results from this phase of the study show that we are making promising progress in re-envisioning what thriving looks like holistically. As our team continues to weave together multiple data sources, we will continue to take the perspective that grades and degree completion are only one part of student thriving and success and seek to promote that perspective to other engineering education researchers and practitioners.

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