Board 12: CAREER: Characterizing Latent Diversity Among a National Sample of First-Year Engineering Students

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Allison Godwin, Ph.D. is an Assistant Professor of Engineering Education at Purdue University. Her research focuses what factors influence diverse students to choose engineering and stay in engineering through their careers and how different experiences within the practice and culture of engineering foster or hinder belongingness and identity development. Dr. Godwin graduated from Clemson University with a B.S. in Chemical Engineering and Ph.D. in Engineering and Science Education. Her research earned her a National Science Foundation CAREER Award focused on characterizing latent diversity, which includes diverse attitudes, mindsets, and approaches to learning, to understand engineering students' identity development. She has won several awards for her research including the 2016 American Society of Engineering Education Educational Research and Methods Division Best Paper Award and the 2018 Benjamin J. Dasher Best Paper Award for the IEEE Frontiers in Education Conference. She has also been recognized for the synergy of research and teaching as an invited participant of the 2016 National Academy of Engineering Frontiers of Engineering Education Symposium and the Purdue University 2018 recipient of School of Engineering Education Award for Excellence in Undergraduate Teaching and the 2018 College of Engineering Exceptional Early Career Teaching Award.

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Introduction

Students often have limited perceptions of what it means to be or think like an engineer. Often this perception stems from social norms and the culture of engineering that emphasizes particular values and roles that engineering includes. The result of this culture is that only particular types of students are recognized as an engineer, and the process of educating engineers homogenizes rather than diversifies students' skills and potential for innovation. This process of homogenization develops engineering graduates that are more alike in their problem-solving approaches, ways of thinking, and identities as engineers than as unique innovators [1]– [3]. Students who do not conform to this mold of "being an engineer" are often alienated from engineering, do not develop engineering identities, and leave engineering, which reduces the much-needed human potential for innovation [4], [5].

Most diversity literature focuses on the intent to increase access and provide equitable experiences to students who are often marginalized in engineering (i.e., women, students of color, students with visible and non-visible disabilities, and students in the LGBTQ+ community). However, our work begins to address a gap in the literature about students' underlying attitudes, mindsets, and beliefs (what we call latent diversity in this work) that are often ignored as legitimate ways of being in engineering. Our prior work from a pilot qualitative study showed how students value the diversity of thought in engineering; however, they acknowledged how certain ways of thinking and being in engineering are privileged in an engineering classroom, despite what is valued in the workforce [6]. These findings also provided pilot data to developing the constructs measured in the CAREER survey described briefly in our project overview.

Project Overview

This project examines the incoming attitudes and beliefs students hold about particular ways of being, thinking, and knowing that are associated with engineering as well as how engineering culture and education may shape specific students' identities and belonging in engineering. This paper describes the first stage of this study focused on characterizing incoming engineering students' latent diversity and then understanding how students' experiences in engineering shape latent diversity. The results of this work can uncover particular ways in which engineering education sends messages about who students are as engineers, who they can become, and if they belong as engineers. Understanding how latent diversity may inform these areas of identity development can provide answers to why talented students from traditionally underrepresented groups may not choose or stay in engineering. It can also provide a better understanding of the mechanisms that homogenize students' ways of being, thinking, and knowing and offer new ways to educate engineering students to promote engineering identity development and novel problem-solving approaches.

This CAREER project addresses three research questions:

> **RQ1)** What kinds of diversity of thought, innovation mindsets, and attitudes are present in engineering students?
> **RQ2)** How do undergraduate students with latent diversity form engineering identities within an engineering community of practice over time?
> **RQ3)** What support, both inside and outside of the classroom, can be provided to promote inclusion of students with latent diversity in engineering?

This executive summary describes the results in answering the first research question of characterizing students' incoming latent diversity. We developed an instrument for measuring students' latent diversity from a review of the existing literature as well as interviews with undergraduate students. A detailed description of this process can be found in [7]. This survey measured students' epistemic beliefs, innovation self-efficacy beliefs, STEM role identity constructs, motivation, personality, and background factors such as race/ethnicity, gender identity, sexual orientation, ZIP code, and parent(s) level of education. Students responded to items measuring their attitudes and beliefs on a 7-point anchored numeric scale. We administered 3,855 paper and pencil surveys to 32 ABET accredited institutions to understand students' latent diversity. These schools were recruited from a list of ABET institutions that had a first-year engineering program that was stratified by size of engineering enrollment into small, medium, and large schools. We recruited a third of the sample from all strata to gather a nationally representative sample of engineering schools. Most of the students completed the survey in the fall semester of 2017; however, one institution administered and returned the survey in the spring semester of 2018.

We digitized the paper-and-pencil survey responses in the spring semester of 2018. The data cleaning process involved removing indiscriminate responses by looking for large sections of repeated answers and comparing the answers on questions that should have different answers within the data for a final number of 3,711 participants. Factor analysis was conducted on the data to confirm construct validity and understand the quality of measurements before characterizing students' underlying attitudes, beliefs, and mindsets. To characterize the patterns and relationships between the multiple effective dimensions in the paper, we used Topological Data Analysis (TDA), a relatively new statistical technique (2009) to map complex multidimensional data [8]-[10]. Shown below in Table 1, we describe the national characterization of latent diversity for each group identified in the TDA map. Our future work focuses on recruiting additional students to participate in longitudinal interviews over the next three years. This data collection will include bi-annual interviews with students with attitudes in different parts of the map (indicating different incoming latent diversity) as well as journaling activities to understand how latent diversity informs students' identity trajectories and development throughout their engineering education.

National Characterization of Latent Diversity

We used Topological Data Analysis (TDA) to understand the data structure of the students' responses. A total of 17 factors were used in the TDA—described in Table 1. These factors were chosen from a more extensive list of measures because they had the highest measurement reliability (reducing error in the model) and had high variation in responses (distinguishing among students). This statistical technique resulted in a "map" that formed six progressions within the data that we labeled as groups, A-F. See the documentation by Godwin et al. [10] for a description of how this analysis was conducted and the researcher decisions made to develop the final mapping. The radar chart shown in Figure 1 provides a more in-depth characterization of each group.

Table 1. Factors used in TDA characterization.

Factor	**Factor Label**	**Factor Description**
Mathematics Interest	Math_Int	Students' interest in understanding and learning more about mathematics. One of three constructs used to measure mathematics identity [11].
Mathematics Performance/Competence	Math_PC	Students' beliefs about their ability to understand and do well in mathematics courses. One of three constructs used to measure mathematics identity [11].
Mathematics Recognition	Math_Rec	Students' beliefs that others see them as the type of person that can-do mathematics. One of three constructs used to measure mathematics identity [11].
Physics Interest	Phys_Int	Students' interest in understanding and learning more about physics. One of three constructs used to measure physics identity [12].
Physics Performance/Competence	Phys_PC	Students' beliefs about their ability to understand and do well in physics courses One of three constructs used to measure physics identity [12].
Physics Recognition	Phys_Rec	Students' beliefs that others see them as the type of person that can-do physics. One of three constructs used to measure physics identity [12].
Engineering Interest	Eng_Int	Students' interest in understanding and learning more about engineering. One of three constructs used to measure engineering identity [13].
Engineering Performance/Competence	Eng_PC	Students' beliefs about their ability to understand and do well in engineering courses. One of three constructs used to measure of engineering identity [13].
Engineering Recognition	Eng_Rec	Students' beliefs that others see them as the type of person that can-do engineering. One of three constructs used to measure engineering identity [13].
Conscientiousness	Ocean_NC	Part of the Big 5 personality measure. High conscientiousness indicates a desire to do a task well, and to take obligations to others seriously [14].

Factor	Factor Label	Factor Description
Neuroticism	Ocean_Neu	Part of the Big 5 personality measure. A measure of emotional stability; those with high neuroticism tend to be prone to psychological stress [14].
Belonging in Engineering	Bel_Fac1	Students' feeling of belonging in the field of engineering [15].
Belonging in Engineering Classroom	Bel_Fac2	Students' feeling of belonging in engineering classrooms [15].
Motivation Controlled Regulation: Instructor	Motiv_CR1	Students' external motivation to be a good student in the eyes of their instructor [16].
Motivation Controlled Regulation: External Pressures	Motiv_CR2	Students' external motivation to perform, engage, and complete academic tasks based on external factors defined by the environment [16].
Motivation Autonomous Regulation: Enjoyment	Motiv_AR2	Students' internal motivation to perform, engage, and complete academic tasks based on enjoyment and fulfillment [16].
Epistemic Beliefs	Epis_Fac4	Students' beliefs about differences in knowledge in engineering classes and the field of engineering [17].

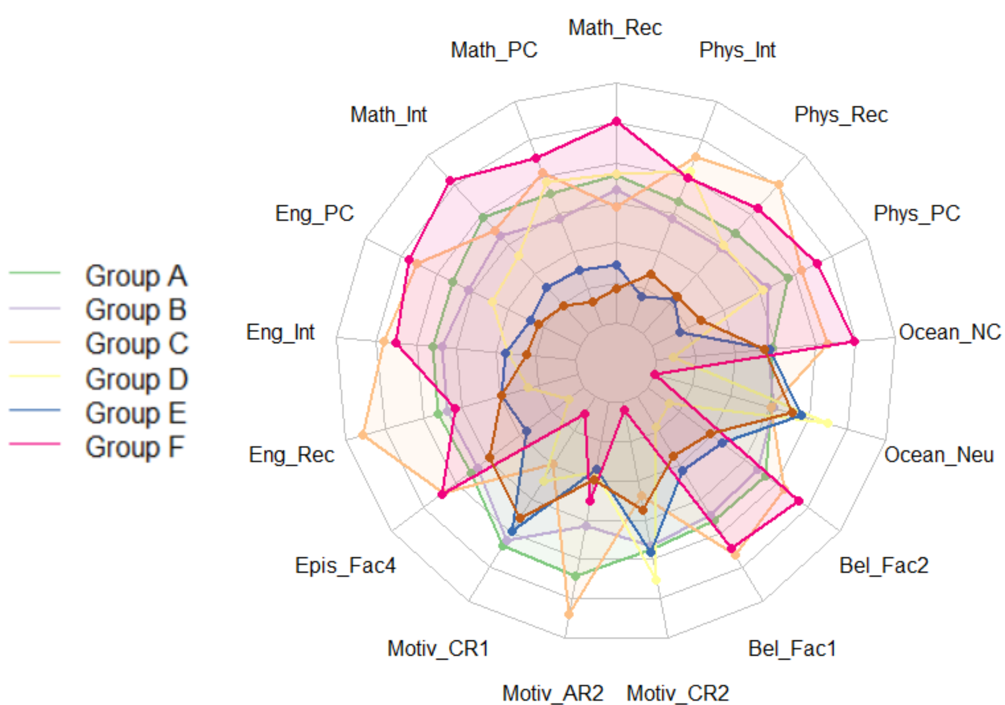

Figure 1. Standardized group means from the grand mean for results from TDA analysis.

In Table 1, we describe a preliminary set of findings of the distinguishing characteristics of each of the identified groups. We are still working to understand how these results connect to students' experiences and practices in engineering.

Group A (Green)
There were 1085 students in group A. This group had moderately high responses on all of the constructs; however, their most defining features were their 1) high controlled regulation (CR1) and autonomous regulation (AR2), 2) strong interest in mathematics, and 3) strong performance competence beliefs in physics. Both external and intrinsic factors motivate these students. For example, students in group A indicated that they cared about the instructor's perception of them as a student, as well as having fun in engineering. These students felt confident in their abilities to 1) understand physics inside and outside of the classroom, 2) overcome difficulties they may experience while learning physics, and 3) enjoy learning math.

Group B (Purple)
There were a total of 702 students identified in group B, which consisted of four sub-progressions (i.e., B1-B4). Similar to group A, this group had moderately high responses on all of the constructs included in the analysis. The most defining features of this group were their 1) high controlled regulation (CR1), 2) strong engineering interests and recognition, and 3) moderately high epistemic beliefs similar to those of Group A. External factors motivated these students regarding their instructors' perception of them as a student. In addition to their motivation beliefs, these students believed there is variability in what a person knows about engineering in a course or the field of engineering. These students enjoyed learning about engineering topics and felt recognized as an engineer by their instructor, peers, or family.

Group C (Light Orange)
Group C was the smallest of the groups identified. This group had tightly clustered responses on the dimensions used in the analysis, but there were only 25 students identified in Group C. The most defining features are their 1) high autonomous regulation (AR2), 2) strong engineering and physics recognition beliefs, and 3) high beliefs about their sense of belonging in engineering as a field. These students were intrinsically motivated to learn about engineering because it was fun; felt recognized as an engineer or physics person by their instructors, peers, or family; and felt a sense of belonging in engineering as a whole.

Group D (Yellow)
There were 37 students identified in group D. The most defining features were their 1) high controlled regulation (CR2), 2) personality (high neuroticism and low conscientiousness), and 3) low beliefs about their sense of belonging in both engineering as a field and in the classroom. These students were motivated to learn engineering because of a sense of obligation, rather than because they felt it is fun or rewarding. These students lacked a sense of belonging in engineering, got upset easily, and were less organized than their peers; in some cases, these behaviors could make them less successful as an engineer. Our future work includes understanding how students in this group progress through engineering.

Group E (Blue)
There were 199 students identified in Group E. The most defining features were their 1) moderately low beliefs about their STEM role identities (i.e., interest, performance/competence, and recognition), 2) controlled regulation (CR1 and CR2), and 3) and high neuroticism. External factors motivated these students. For example, students in Group E indicated that they were concerned about their instructors' perception of them as a student and felt motivated out of obligation to the program requirements than by their internal motivation. These students were more confident in their ability to understand engineering and mathematics concepts than physics concepts. Similar to group D, these students had low emotional stability and may sense stressors more keenly than their peers. This group is also one we are interested in monitoring as this project progresses.

Group F (Pink)
There were 57 students identified in Group F. The most defining features were their 1) high mathematics role identity for all constructs (e.g., high interest, performance/competence, and recognition), 2) controlled regulation (CR1 and CR2), 3) high sense of belonging in both engineering as a field and in their classroom, and 4) high neuroticism. These students were motivated by internal. These students felt confident about their abilities to understand mathematics, felt recognized as a math person, enjoyed mathematics, and felt a sense of belonging in engineering as a whole and their classroom. Similar to group D and E, these students had low emotional stability.

Our findings-to-date show the broad range of latent diversity among students entering engineering programs. This work highlights the importance of understanding the complex attitudes, beliefs, and mindsets that students bring with them into the engineering classroom, even from day one. The process of educating these students may support particular attitudinal profiles while alienating others. These findings will inform the types of strategies we develop to help educators support diverse mindsets in engineering classrooms.

Future Work

We used the data progressions from our TDA to identify and recruit students who are attitudinally and demographically diverse for a narrative inquiry of how students navigate their pathways in engineering and develop identities as engineers. Each participant will be longitudinally interviewed and asked to complete journal entries over the next three years of their undergraduate education. To date, we have recruited twenty-five students to complete the first and second round of in the 2018-2019 academic year. Since we are using a narrative analysis approach, we asked students to share stories of their background, their pathway to engineering, and their experience as a first-year engineering student at their institution. The second interview focused on journey maps of their experiences in engineering over the most recent semester. These stories will allow us to understand their experiences and investigate how students with different attitudes, beliefs, and mindsets may feel more or less like they can become engineers through an engineering education pathway. We will also use their narratives to understand how to foster an innovative mindset in the engineering classroom. These findings will inform the educational plan to develop an inclusive pedagogy to support latently diverse students.

Impact of the Proposed Work

This work impacts the engineering education community by 1) identifying alternative approaches to understand how to support latently diverse students, 2) employing a new statistical method used for complex datasets, and 3) highlight narratives of latently diverse students to understand how they develop their identities as engineers and feel a sense of belonging in a culture that historically privileges certain schools of thought. In our prior work, we highlighted the need for educators to begin recognizing relevant and inclusive ways of being an engineer, but we did not explicitly state how to practice inclusivity in the classroom [6]. Therefore, our work will focus on not only understanding general trends in the data but what works for supporting a diverse range of students in engineering. More importantly, this work impacts how we support the individual needs of learners and cultivate innovation in the classroom.

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