

Board 281: Fidelity and Transferability of an Ecological Intervention to Transform Engineering Representation at Scale

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Research Scholar at the University of Pittsburgh. Dr. Z.'s research program focuses on examining the impact of intersectional oppression on historically excluded groups & creating culturally relevant interventions to enhance their well-being. Within this framework, he studies academic persistence and mental wellness to promote holistic healing among BIPOC. He earned Bachelor's degrees in Psychology & Sociology, a Master's degree in Learning Science-Educational Psychology Track, and is a Ph.D. in Counseling Psychology from Indiana University. In addition to work, Dr. Z. loves reading, discovering new music/art, outdoor activities, time with friends and family, and living a holistically full life.

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Anne-Ketura Elie earned a BS degree in 2019 in psychology from the University of Florida, Gainesville, Florida.

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Gerard Dorvè-Lewis, University of Pittsburgh

Gerard Dorvè-Lewis (he/him) is a higher education PhD student and scholar at the University of Pittsburgh. His broad research interests include emerging adulthood, equity and social justice in higher education, first-generation college students, Black students, and student success. Prior to beginning his doctoral journey, he worked full-time in student affairs at the University of Florida where he also earned his bachelor's and master's degrees in Family, Youth, and Community Sciences.

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Maricela Bañuelos received her Sociology B.A. from the University of California, (UC) Santa Barbara in 2016, and graduated with Summa Cum Laude. She received her master's in Educational Policy and Social Context from UC Irvine in 2020 and is currently pursuing her Ph.D. in Sociology at UC Irvine with an emphasis in Chicano Latino studies. Maricela was awarded the Ford Pre-Doctoral Fellowship in 2021, to support her doctoral research on issues of access and persistence in higher education. Her research centers the social mobility of first-generation college students, low-income students, and underrepresented students of color.

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Matthew Bahnson is a Matthew Bahnson completed his Ph.D. in the Applied Social and Community Psychology program in at North Carolina State University. His previous training includes a B.A. in Psychology from the University of Northern Iowa and an M.A. in Social Sciences from the University of Chicago. Matthew's research focuses on sociocultural inequality in engineering graduate education with the intention of increasing diversity, equity, inclusion, and justice in STEM graduate education. He is currently a research scientist in engineering education with the STRIDE Lab at Purdue University.

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Dr. Christian D Schunn, University of Pittsburgh

Dr. Christian D. Schunn is a professor of Psychology, Intelligent Systems, and Learning Sciences and Policy at the University of Pittsburgh. He is also a senior scientist at the Learning Research and Development Center. He received his Ph.D. in Psychology.

Beverly Conrique, University of Pittsburgh

Beverly Conrique is a PhD student at the University of Pittsburgh. Her research seeks to understand social psychological and ecological influences in two topical areas: U.S. politics and education. Her research in education focuses on understanding how people's experiences in educational domains are shaped by their subjective understandings of themselves and their social environment. She is also passionate about social justice and service work, both in her research and in her professional roles.

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Carlie is a doctoral student in the Louise McBee Institute of Higher Education at the University of Georgia (UGA). She earned a bachelor's degree in Psychology from UGA (2017) and a Master of Education in Higher Education Administration from Georgia Southern University (2021). She has higher education experience in business affairs and academic advising. She researches structures that contribute to underrepresentation in STEM majors and is currently a Graduate Assistant for the UBelong Collaborative.

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Jacqueline (Jacki) Rohde is the Assessment Coordinator in the School of Electrical and Computer Engineering at the Georgia Institute of Technology. Her interests are in sociocultural norms in engineering and the professional development of engineering students.

Fidelity and Transferability of an Ecological Intervention to Transform Engineering Representation at Scale

Abstract

We report on an ongoing effort to contextualize and test an ecological belonging intervention in first- and second-year engineering courses. As a part of an *NSF IUSE: EDU Program, Institutional, and Community Transformation* track grant, this intervention targets women, Black, Latinx, and Indigenous students to support self-efficacy, belongingness, growth mindset, and identity as avenues to address academic equity gaps that persist in engineering despite increasing enrollment within engineering among these groups. We frame these as *equity gaps* because they derive not from any deficit of the students themselves but rather from systemic issues of marginalization that make students feel as if they do not belong. The ecological belonging intervention focuses on common engineering-course-specific student experiences of struggle and is delivered by instructors early in the term. Through shared narratives and self-reflection, students learn that struggle in engineering courses is normal and surmountable. Our prior work indicates that this message may serve as a protective mechanism for Black, Latinx, and Indigenous students' belonging and, subsequently, individual grades in their courses. As we continue to develop and study the intervention, we share our processes and additional findings in this paper. First, we report on our initial efforts to assess fidelity in the implementation of the intervention by course instructors and the impact of the intervention on instructors. Second, we report on our continued research studying the efficacy of the intervention on student outcomes.

We hypothesize that the intervention is most effective when instructors follow the intervention protocol, share their stories of struggle authentically, and effectively facilitate small group discussions. We created an observation protocol to help assess the fidelity of intervention implementation in classroom settings. Graduate student research team members observed six classes in which the instructors conducted the intervention. The observation protocol consisted of 15 quantitative items such as "facilitator shares a personal story" that observers rated on a 3-point scale: "did not observe," "needs improvement," and "accomplished well." Qualitative questions ($n = 13$) assessed additional aspects such as notes on the instructor-facilitator's body language. Qualitative interviews with instructors have also provided insight into faculty perspectives on intervention fidelity. With this data, we investigate how onboarding to the intervention impacts instructor beliefs, how instructor beliefs shape implementation, and the impact of facilitating the intervention on instructors' mindsets, attitudes, and practices. Further, the research team is using this information to improve facilitator training (e.g., ensuring implementers perform essential intervention tasks) and to check the observation protocol captures all of the essential observation aspects (clarifying what "adequate engagement" means).

Our research on the efficacy of the intervention on student outcomes continues across two lines. In the first, we seek to identify short-term impacts on course grades (i.e., individual work, final grade) and continued enrollment in engineering courses. Initial analyses have found limited direct impact on course grades, with more impact on individual assignment grades and continued enrollment. The second line seeks to identify the relationships between theoretically important psychosocial constructs such as belongingness, self-efficacy, interest, and engineering recognition (identity) in preparation for future longitudinal assessments of change following the intervention.

Introduction

Our ecological intervention research received funding from an *NSF IUSE: EDU Program, Institutional and Community Transformation track grant (NSF IUSE 2111114/2111513)*. Faculty at the University of Pittsburgh (Pitt), Purdue University, and the University of California, Irvine (UCI) collaborate on the project entitled “Collaborative Research: Course-based Adaptations of an Ecological Belonging Intervention to Transform Engineering Representation at Scale.” The brief ecological intervention implementation uses one class meeting and has erased gender and race-associated inequity in academic achievement in introductory STEM courses [1]. The intervention is contextualized [2] for each course at each university and has been successfully tested with enthusiastic faculty involvement in the first and second years of the grant project. In our current year (third year), we have focused further on implementation processes (i.e., materials, training) and have begun to address fidelity issues in intervention implementation. Continued research on efficacy and mechanism functions demonstrates a wide range of positive impacts the ecological intervention has on students and continued enrollment in engineering courses.

Project Description

Our project adapts prior social-belonging interventions [3], [4], [5] by addressing challenges common in specific engineering course contexts and providing instructor training to deliver authentic challenges as part of a social “icebreaker” activity during class time in the first week of classes [1].

The Ecological Belonging Intervention (Base Form)

The ecological belonging intervention in base form closed demographic performance disparities in prior research [1], [6]. Based on prior social belonging interventions to teach students that college adversity is normal and surmountable [4], the ecological approach in our adaptation instills the same message within the social ecology of the classroom rather than at the individual level. Specifically, previous social belonging intervention research used lab-based settings, while the ecological-approach delivers the intervention in context, in the courses with known demographic disparities in academic performance. Intervention materials such as student narratives (referred to as stories) of struggle are developed and adapted based on focus groups of participants drawn from past sections of the target course [2]. Further, the course instructors deliver the adapted intervention rather than a researcher. In delivering the intervention, instructors also engage with students about their struggles and challenges while supporting peer discussion around overcoming adversity.

The ecological intervention establishes a classroom norm for a) adversity in the course as common and normal and b) struggles with adversity in the course tend to be surmountable with time and appropriate effort. Instructors deliver the intervention in five parts in one class period: 1) instructors verbally normalize adversity in college, surmountability of adversity, and adversity specific to the course; 2) students reflect and write down challenges they experience in college and how they change with time; 3) instructors present first-person narratives attributed to past students who encountered and overcame adversity in the course; 4) student peer groups share their experiences with, and discuss adversity in college; 5) in summary, the instructor leads class-based discussion based on group identified topics (For a complete guide to the intervention see [1] and the adaptation [2], [7].

Research Questions

Our project includes seven overarching research questions around two main topics: 1) ecological belonging intervention effects on students and 2) research on scaling and transformation of the intervention. These have been presented in previous reports [2], [7].

Intervention Effects on Students

RQ1 (the course contexts): *How do students, with a focus on minoritized students (i.e., Black, Latinx, and Indigenous, women and non-binary students), describe their lived experiences in courses that show demographic-based achievement differences?*

RQ2 (the immediate effects on students): *How does the ecological belonging intervention change students' feelings of belonging in the course, their disciplinary-based growth mindset, and perceptions of academic norms in the course, major, and engineering overall?*

RQ3 (the broader effects on students): *What effect does the intervention have on short- and long-term academic success as measured by achievement (course-specific, overall GPA) and choice (retention, engineering career pathways)?*

Research on the Scaling and Transformation Approach

RQ4 (context effects on onboarding strategies): *What are the key disciplinary and institutional factors that demand adaptation to the onboarding strategies?*

RQ5 (impact of onboarding strategies on instructor beliefs): *What are the effects of the onboarding strategies on instructor beliefs that are key to intervention implementation?*

RQ6 (impact of instructor beliefs on intervention implementation): *What are the instructor beliefs most critical to implementation (initial and sustaining implementation) of the intervention?*

RQ7 (impact of implementation on instructors): *What impact does implementing the intervention have on instructors' mindsets, attitudes, and practices?*

Intervention Fidelity and Instructor Implementers

This report focuses on our aims relating to *Research on the Scaling and Transformation Approach*, specifically, we address implementation and fidelity issues in relation to our instructors who deliver the intervention [See [7] for a full description of our instructor recruitment, remuneration, and training procedures]. We also present an overview of in-process and current studies addressing our research questions, which add to work we have already published [2], [7], [8], [9]. Addressing fidelity is important to understanding the impact of the intervention on students, as outlined in our research questions under *Intervention Effects on Students*.

Evaluating fidelity of implementation, sometimes termed “treatment integrity,” is defined as “the act of monitoring whether all elements of an intervention...were implemented as originally intended” [10] and forms a central concern in psychosocial intervention research. For example, fidelity challenges can explain lack of replication in otherwise well-designed studies, and a lack of fidelity can prevent the accurate understanding of treatment mechanisms, or produce biased evaluations of treatment effects across populations and contexts [11]. Furthermore, low fidelity reduces statistical power by introducing an unmeasured variable that increases background variability, making true effects harder to detect. These consequences can result in students receiving reduced benefits from the intervention, and researchers reporting untrustworthy effect sizes [12].

To address fidelity, researchers are urged to develop a clear implementation protocol that emphasizes the rationale for specific parts of the intervention; to institute training for implementers prior to the intervention that discusses how to handle planned and unplanned events that may occur; and to observe interventions to measure fidelity and produce fidelity calculations [13]. In doing this, researchers should utilize a multi-perspective multi-method approach to assess fidelity (for example, both expert observations of implementers as well as surveys of student recipients to assess treatment receipt) [14]. Additionally, implementor competence (e.g., body language, warmth, ability to engage with participants) should be assessed [15]. Finally, fidelity assessment data should be used for corrective adjustments to training and materials in an iterative feedback loop [15]. As the intervention continues to scale-up, maintaining high fidelity increases our opportunity for broad real-world effects in eliminating inequitable outcomes in engineering.

Observations of Instructor Implementation

Our process to develop an implementation fidelity protocol began among members of the research team including members who had developed the initial faculty training, as well as those who had implemented the intervention in their own classrooms. We first created a timeline of actions that make up the delivery of the intervention. We then used this timeline to discuss the specific factors that impacted the quality of each action within the intervention protocol, including average duration, and or conditions that could affect the quality of the intervention like tone of voice, body language, student engagement, and classroom interruptions. For each event on the timeline of intervention steps, we added items to the observation protocol to rate the quality of the delivery of the intervention using a 3-point scale: "did not observe," "needs improvement," and "accomplished well." The observation protocol consists of 15 quantitative items such as "facilitator shares a personal story." For 13 items that required more in-depth qualitative assessment, such as notes on the instructor-facilitator's body language, the items provided space for observers to record their notes. We totaled the quantitative items, which we determined to be an instructor's fidelity score and contextualized that score based on the information provided in the qualitative assessment. Together this data and analysis was used to inform the research team on fidelity levels.

Prior to the first observation, the graduate student research team members team who would be conducting the observations met to ensure familiarity with the observation protocol and create guidelines for conducting the observations. To minimize disrupting the classroom environment and be as unobtrusive as possible, we notified all instructors before their classroom was observed. Observers were instructed to arrive early, sit in the back of the classroom, and not participate in any of the class activities.

To date, six observations have been conducted. This data, as well as data from interviews with instructors related to implementation assist in answering RQ4 (*context effects on onboarding strategies*). We found that while a majority of instructors implemented the intervention with minor changes or errors, some instructors needed further support in understanding the importance of delivering each piece of the intervention with fidelity. For example, we observed some faculty who rushed through the protocol and student stories of struggle very quickly without reading the story attribution and without giving adequate time for students to process the stories. While this implementor was aiming to ensure there was ample time for students to ask questions at the end of the class session, this disconnected the students from fully understanding the messages that each of the stories delivered. This haste in the delivery of this key aspect of the intervention did not allow students to connect with the stories from their peers who had previously completed the course and had experienced the same classroom environment. These observations also clarified

that one of the issues that instructors were encountering was balancing the competing pressures to meet course objectives and complete the intervention along with those pressures all instructors face inside and outside of the classroom during the first week of instruction.

Refining Instructor Onboarding and Training

Based on our initial set of observations, we have taken several steps designed to increase implementation fidelity. Though we have kept the same format and number of asynchronous and synchronous training sessions as described previously [7], the content of two of the three training sessions as well as the implementation script we provide to instructors have been revised.

Specifically, the “How-To” training video was revised so that it more effectively highlights how each intervention activity conveys and reinforces the intervention’s core message, thereby influencing how students perceive and frame their struggle. The training video features a team member guiding viewers through the intervention process and explores both the practical mechanics within the classroom and the supporting social-psychological theory of each intervention activity. By explicitly discussing the interplay between the intervention activities and psycho-social theory, we emphasize the importance of adhering precisely to the instructions in the facilitator implementation packet for maximum impact.

For example, the revised training video emphasizes the power of reading stories of struggle from former students in helping current students reframe their own struggles. Implementers are instructed to slowly read each story, identify the student by name, and emphasize both the challenge they faced and how they overcame that challenge. This is important because it provides current students with evidence that former students who were ultimately successful struggled along the way. Thus, if a current student encounters a challenge, they'll be better equipped to see it as normal rather than as evidence that something is uniquely wrong with them.

Additionally, the revised training video underscores the significance of associating each story with a student’s name as the selection of stories intentionally includes a variety of names that signify different genders, races, and ethnicities. This diversity serves to normalize the idea that all students, irrespective of their identity, encounter challenges and, importantly, overcome them. This training video now more directly emphasizes that the intentional inclusion of varied identities conveys the universal nature of overcoming obstacles in education. It communicates that every student has the capacity to overcome challenges, which allows current students to challenge any unspoken stereotypes associated with their identity group, thereby disrupting the effects of stereotype threat. The script that we provide to instructors to implement the intervention now carries this same revised information. To do this, we added a column within the script that provides instructors with the social-psychological underpinnings of each of the aspects of the intervention.

To support instructors in balancing the competing demands of their positions in relation to the fidelity of intervention delivery, we also revised the synchronous training session. Specifically, we revised one of the scenarios for discussion that we present so that it allows instructors to discuss these issues and develop strategies that they might use to quell these pressures during the class session in which they are delivering the intervention.

Instructor Interviews

As part of our research, instructors who implement the intervention participate in semi-structured longitudinal qualitative interviews about their experiences with the intervention. These interviews are designed to address RQs 4 - 7 and assist us in addressing these areas of our research.

Preliminary thematic analyses of qualitative data identified core beliefs instructors hold about their responsibilities to students' development, students' perspectives, and the impact of the intervention on faculty. Briefly, instructors discussed their responsibilities towards students in ways that reflected the first-year course where the intervention was implemented: transition into college, independence, skill development, and supportive educational environments, while monitoring and encouraging progress within the course. Similarly, instructor perceptions of students revolved around instilling knowledge and confidence in students while recognizing students face many struggles common to the transition into college and struggles specific to introductory engineering coursework.

During interviews, instructors discussed the impact of the intervention on beliefs about their abilities as instructors, and connection to their students. Instructors reported that delivering the intervention helped them be more authentic in the classroom. Leading the intervention and sharing their own story of struggle enabled these instructors to overcome their fear of vulnerability in teaching, allowing them to be more open and genuine with students. Increased vulnerability seemed to allow instructors to find a closer connection with students than they reported they had in past instances when they had taught the same class.

Instructors also reported feeling enhanced self-confidence in their abilities as instructors, which for some translated positively to their research work. Finally, after the intervention, instructors felt students were more engaged in the course as compared to students whom they had taught in the same course previously. They shared that students seemed to speak more openly, actively participated more in class discussions, and showed increased attendance during office hours. Instructors attributed this to improved communication and engagement between them and their students. While preliminary, these insights demonstrate the potential positive effect of the ecological belonging intervention on both students and the instructors who implement the intervention in their courses.

Overview of In-Process Studies

The project team currently has four journal articles under review, two that focus on RQ1, one that addresses the utility of our student survey to answer RQs 2-3, and one that is a preliminary analytical step to addressing RQs 2-3 in a new course where the intervention has been implemented. An additional manuscript is in the advanced development stage and focuses directly on the broader effects of the intervention on students, RQ3. Below we provide a brief overview of each of these studies.

Coding-Specific Challenges - RQ1

Focus groups at Purdue (n=3) and UCI (n=3) were conducted to discuss student struggles in MATLAB-dominated programming courses that were required as part of the introductory engineering curricula at both institutions. In addition to the generation of context-specific narratives or stories for the intervention for each of these courses, the research team conducted a secondary analysis to thematically characterize the types of challenges faced by students across these two courses. Briefly, we used thematic analysis to identify four themes in the challenges participants discussed about learning a programming language within the course-specific context. The themes were: 1) developing coding-specific skills; 2) group work and peer comparison; 3) engaging and demonstrating knowledge; and 4) gendered experiences or expectations. In the first theme, students described their experiences navigating course resources, teaching themselves using outside references, engaging in frustrations while troubleshooting, and feeling like they had

not yet developed a “coding mindset.” Although these struggles were mentioned in the focus groups, the actual coding-specific skills were not the predominant challenge that students faced. In contrast, a significant portion of the challenges arose through peer comparison, in which students who had limited prior experience with coding felt like they were perpetually behind their peers, despite the supposedly introductory nature of the course (Theme 2). Other challenges arose from team conflicts, gendered interactions, and course logistics that stymied students’ ability to engage and demonstrate their knowledge (Themes 3 and 4).

While perhaps unsurprising, these results highlight the commonality of challenging experiences in programming-based engineering courses. The results also highlight the potential opportunities for counter-messaging to normalize experiences of struggles and affirm students’ belonging in engineering. Without being prescriptive, the article offers considerations for faculty as they develop and instruct introductory MATLAB-based courses to avoid potentially isolating environments and account for the diversity of prior experiences and perspectives to learning that students bring with them to the classroom [16].

Struggle Transitioning into Engineering Majors - RQ1

We also conducted focus groups with 3rd and 4th year women engineering students at Pitt, to identify challenges associated with the transition into an engineering major to develop discipline-specific stories for interventions in courses students complete during their second year. Due to the timing of these focus groups, and although it was not the focus of the protocol that was used to conduct the groups, the impact of remote instruction during COVID-19 on participants’ sense of belonging was prevalent across groups. The impact of the pandemic was discussed not only in the groups themselves but was represented in the artifacts that are collected as part of each group. For instance, representations of students during remote instruction were a large part of what they highlighted during the journey map exercise when they were asked to draw and write about memorable experiences they have had during their journey as undergraduate engineers. These experiences related to remote instruction were also well documented during an exercise where students created good and bad cards in which they shared three challenges they had during their transition into their major during their second year and three good things that resulted from their transition experiences.

The extensiveness of the discussion of the pandemic on these women’s early experiences led us to focus a study on this area. Through a robust analysis process that involved multiple rounds of coding of all the pieces of data collected during these focus groups, we found that women who experienced remote instruction in their second year experienced a serious reduction in their ability to build bonds and belonging as they transitioned into their majors. In contrast, women who experienced remote instruction in their third year and had established bonds and belonging in their engineering major were able to lean into these relationships and use the time to reflect on their futures as engineers. However, we also found that participants who had challenges prior to COVID-19, regardless of class year, experienced a heightened intensity of these issues and additional barriers during remote instruction. Given the continued presence of online instruction, the implications for generating and maintaining belonging for women in engineering underscore the criticality of cultivating supportive and meaningful connections to support women through their engineering journey. This is especially important, as their gender identity can put women at risk of additional barriers and further marginalization [17].

STEM Learning Engagement - RQs 2-3

As part of our research, we seek to clarify the modus operandi of the intervention, identifying psychological and behavioral constructs that moderate or mediate its effects. A major construct theorized to link the intervention to increased performance in STEM courses is STEM learning engagement. While learning engagement is notoriously challenging to measure, our research team has developed and iteratively refined an incisive series of scales to assess this multifaceted construct. These scales are theoretically grounded in the affective-behavioral-cognitive (or ABC) model of learning engagement that currently predominates in the engagement literature, contributing to the construct validity of the scales. Furthermore, the content validity of the scale items were assessed by conducting extensive cognitive interviews using a sample of 16 undergraduate STEM students. The sampling frame used stratified maximum variation procedures to recruit seven engineering students and nine students from either chemistry or economics, and deliberately oversampled Black, Latinx, and Indigenous (BLI) students ($n=6$) and students who identified as a minoritized gender ($n=7$) from the different STEM fields. Data from this process was used to further refine the scales, resulting in stronger content validity and applicability across STEM contexts.

The research team then investigated the factor structure of the scale, and consequently, the structure of STEM learning engagement in undergraduate contexts. The data for this analysis was acquired from field trials in three diverse institutional contexts, encompassing six different courses (introductory first-year engineering, advanced first-year engineering, microeconomics, macroeconomics, organic chemistry, general chemistry), and 1,827 students. Our analyses revealed unexpected, but consistent patterns in the structure of STEM engagement across these contexts. Specifically, the structure of undergraduate STEM learning engagement is primarily shaped by places, or modes, of engagement rather than by affective, behavioral, or cognitive aspects. Distinct factors emerged for focusing during exams or tests, studying prior to exams or tests, engaging behaviorally and in deep cognitive ways during course lectures and recitations or labs, and finally, where applicable, separate factors emerged for cognitively engaging in group projects and spending time working on group projects. While these structures were robust across disciplinary contexts, the within-factor item structure varied based on the particular context of the course, highlighting similarities across STEM, as well as important differences in how students engage in various disciplines. As a result, the research team has produced transferable and robust, but flexible, pools of items from which project researchers and STEM scholars may choose in order to measure STEM learning engagement in varied contexts. This permits the research team to more adequately explain the often-heterogeneous effects of psychosocial interventions, to better tailor such interventions for diverse students and fields, and to illuminate the mediators and moderators that link the intervention to increased disciplinary persistence and course performance. Furthermore, this work has advanced our understanding of engagement beyond the traditional ABC model, and identified further opportunities for instructors to diversify the modes by which different students may engage with STEM learning [18].

Early Engineering Identity - RQs 2 - 3

Research has demonstrated the importance and utility of engineering identity in understanding the career trajectories of undergraduate students. To build upon this work, we have used our pre-intervention survey data from a first-semester required engineering course ($n = 834$) to investigate the structure of psychosocial variables as they contribute to very early career engineering identity. We investigate the utility of self-efficacy, interest, belonging, race-related belonging, and gender-related belonging to predict engineering identity using path analysis, a form of structural equation

modeling. Self-efficacy, interest, and belonging demonstrate important aspects of engineering identity as well as academic performance and career trajectory in engineering. We have included race- and gender-based belonging in preparation to assess aspects of the intervention that may function differently for women and BLI students in a predominantly white institution in a college with predominantly white men students. The reported path analyses are preparatory to investigate changes in the relationship of these variables following the intervention at the end of the first semester. We propose that race and gender belonging self-efficacy, and interest will be associated with belonging, and that self-efficacy, interest, and belonging will be associated with engineering identity. The initial path analyses are presented here at ASEE 2024 [19]. We find strong support for the proposed model and have identified differences in the model function for BLI and Women students. As we continue these analyses, we will engage in longitudinal path analysis to identify differences in engineering identity associations and the ability of the model to predict continued enrollment into the second semester of required engineering courses.

Belonging and Retention - RQ 3

In another path analysis, we utilize survey data from a second-semester required programming course to test the relationships between help-seeking attitudes, belonging, and continued enrollment in engineering courses during the fall term following participating in our intervention. The survey data comes from a second-semester first-year required MATLAB-based course from the 2022 and 2023 intervention cohorts. These analyses assist in our understanding of the mechanisms of the intervention by identifying how students' attitudes about struggle and help-seeking change following the intervention. Ultimately, we seek to understand how help-seeking contributes to belonging and a resulting increase in continued enrollment in engineering after the first college year. Students' willingness to seek help influences their beliefs about how normal it is for students to seek help in engineering classes and boosts feelings of belonging in the class. Students also expressed feeling safe to be wrong in association with higher belonging in the class. In addition, gender and race/ethnicity related to students' feelings of belongingness with women and BLI students scoring lower on average than their peers. Feelings of belonging for students who participated in the intervention significantly predict their enrollment in engineering in the fall term of the second year beyond their grade point average (GPA). This work is in preparation for a journal publication and will be reported in greater detail in future publications.

Current and Future Work

As we enter the fourth year of our grant, we are poised to further engage in robust tests of the intervention [RQs 2 -3]. In this work, we will continue to refine and test our theory of action. In this past year, we piloted the intervention in a second first-year engineering course at Purdue, and together with the data we are collecting on the first first-year course where the intervention has been implemented we will begin examining the effects of multiple intervention doses on students (i.e. receiving the intervention multiple times across semesters related to different aspects of struggle contextualized in courses versus at only one point in time). In the past year, we also piloted out second-year engineering discipline-specific intervention at Pitt with contextualized stories specific to the transition into each discipline. In the coming year, we will begin scaling up this work to additional courses in our pilot disciplines and begin to test the efficacy of the intervention in these courses. We will also begin analyzing the effects of the intervention on first-year engineering students at UCI, which is an HSI and AANAPISI institution, to test the robustness and replicability of our findings in this context, and to investigate the unique effects of tailoring the intervention with similar content to a unique campus context. Additional survey validation work

on the novel scales developed for this project will also continue, and studies using our STEM learning engagement constructs on intervention outcomes in engineering will be conducted.

Our efforts to address and study RQs 4-7 will continue. Having revised and refined our instructor onboarding and training processes, we will continue to train and work with new faculty partners and will continue to observe intervention implementation and improve our efforts to support instructors in this work through interactive refinement of our materials. We will also begin to more comprehensively analyze our instructor interview and survey data and expect that we will develop several journal articles addressing instructor beliefs and mindsets related to their engagement with the intervention and its implementation [RQs 5-6], and how implementing the intervention changes instructor mindsets, attitudes, and practices [RQ 7].

We are also continuing our work studying RQs 2-3 with a comprehensive, longitudinal set of interviews with students. To this date, we have interviewed the initial cohort of students whose classrooms were part of our intervention during year one of the grant (treatment/control Spring 2022) at Purdue four times and are poised to interview them for the fifth time (Fall 2024) as they entire their fourth college year and are beginning to consider their post-degree aspirations and plans more fully. An analysis of a portion of this data is being presented in a Work in Progress paper at ASEE 2024 [20]. We are also continuing to follow our second cohort of students at Purdue (treatment/control Spring 2023) and will interview this group for the fourth time in Fall 2024. Lastly, we have begun to interview students at UCI and are following a cohort there (treatment/control Fall 2023) who we will interview for the third time (Fall 2024) when they are in their second college year. This work is designed to allow us to understand not only how the intervention relates to the student experience but also how participating in the intervention relates to career goals, aspirations, and early career trajectories. We are also addressing how and where students at the intersection of race/ethnicity and gender diverge in their experiences, identity development, and meaning-making. We will continue to develop studies leveraging these interviews and will be developing our first mixed methods study to leverage our qualitative interview data and our quantitative data sources from students. Lastly, we are currently developing a journal article that examines our focus group processes [RQ 1] and how it allows students who have completed one of our target courses previously to discuss their challenges and their resolutions to them in ways our student participants are served and affirmed.

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