Investigating inclusive professional engineering identity developmental patterns of first-year engineering majors: A person-centered approach

Mary Elizabeth Lockhart[1]

Karen Rambo-Hernandez[1,2]

Rebecca Atadero[3]

[1]Department of Teaching, Learning and Culture, Texas A&M University, College Station, TX, USA

[2]Department of Educational Psychology, Texas A&M University, College Station, TX, USA

[3]Department of Civil and Environmental Engineering, Colorado State University, Fort Collins, CO, USA

Correspondence: Mary Elizabeth Lockhart, Department of Teaching, Learning and Culture, Texas A&M University, College Station, TX, 77843-4232, mlockhart@tamu.edu

Abstract

Background

The lack of diversity within engineering degree programs and occupations has been an ongoing concern for decades. National engineering programs have placed a high priority on broadening participation in engineering and making the engineering culture more inclusive. Specifically, the cultivation of engineering students' Inclusive Professional Engineering Identities (IPEIs)—or the value these individuals place on diversity and their willingness to act inclusively within engineering contexts—might be one way to address this long-standing lack of representation.

Purpose

Rooted in theoretical contexts regarding professional identity development, the purpose of this study is to uncover developmental patterns of first-year engineering students' IPEIs and factors that influence IPEI cultivation.

Methods

This study built upon the previous variable-centered research findings regarding IPEI development. Specifically, the person-centered approach of Random Intercept Latent Transition Analysis (RI-LTA) was utilized. RI-LTA allows for the detection of different, meaningful groups of individuals demonstrating similarities on the construct and investigating these groups for probabilistic changes over time.

Results

Four IPEI groups of students emerged with IPEI developmental patterns that were not always stable. Student IPEI classifications differed significantly across gender and students' levels of engineering identity. Furthermore, a series of intervention experiences instigated an even more malleable nature to student IPEIs.

Conclusions

Engineering students' IPEIs demonstrate some likelihood to change over time, with intervention experiences enhancing the likelihoods for changes to occur. Continuing to investigate factors influencing the positive cultivation of students' IPEIs is fundamental to broadening participation in engineering and making the engineering culture more inclusive.

Keywords

engineering education, identity, inclusivity, diversity, person-centered

1 Introduction

Racialized and gendered inequalities exist and are persistent within science, technology, engineering and mathematical (STEM) fields, particularly engineering. Indeed, the lack of diversity within engineering degree programs and occupations has been an ongoing concern for several decades (Lichtenstein, 2015). Despite tremendous efforts, only small gains have been documented in the proportion of students from systemically marginalized groups within engineering (e.g., students who are Black or Latino/as, White women, indigenous) graduating with engineering degrees and prepared to enter the engineering workforce (National Science Foundation, 2021).

The typical engineering culture has been described as privileging certain forms of knowledge and ways of interacting that are based upon the majority (i.e., White cisgender and heterosexual men), cultivating a *chilly* climate for individuals with other identities, and promoting competition over collaboration—weakening efforts to promote inclusivity (Foor et al., 2013; Leydens & Lucena, 2017; Lezotte, 2021; Seymour & Hewitt, 1997; Walton et al., 2015). In response, noting that degree attainment in many engineering disciplines is not representative of demographics within the United States (National Science Foundation, 2021), national engineering programs and initiatives have placed a high priority on broadening participation in engineering and making the engineering culture more inclusive. Specifically, the cultivation of engineering students' Inclusive Professional Engineering Identities (IPEIs)—or the value these individuals place on diversity and their willingness to act inclusively within engineering contexts—may be one way to address the long-standing lack of representation within engineering as these students have the potential to be changemakers and alter the trajectory of engineering culture (Atadero et al., 2017; Rambo-Hernandez et al., 2021).

The primary goal of helping engineering students cultivate strong IPEIs is to broaden engineering culture's perceptions of who can be or is an engineer (Atadero et al., 2017)—especially for those about to enter the field. Rooted in theoretical contexts regarding professional identity development, in this paper we seek to uncover developmental patterns of first-year engineering students' IPEIs and factors that influence IPEI cultivation within students.

1.1 Lack of Diversity in Engineering

The lack of diversity within the engineering workforce in the United States is concerning. As of 2021, the engineering workforce was only 5% Black, 9% Latino/as, and 16% women of all races; proportions far below the representation of these identities in the broader population of the

United States (Fry et al., 2021; National Science Foundation, 2021). Many explanations have been proposed regarding the lack of diversity and need for inclusion of underrepresented groups in engineering degree programs and occupations. Researchers have noted an exclusionary or privileged process regarding who is introduced to engineering practices and/or knowledge, which begins in early childhood (Lezotte, 2021). Children from the non-majority group in engineering (i.e., children who are not White boys) lack non-stereotypical engineering role models, have inequitable access to engineering resources and often have lesser access to engineering preparation programs such as engineering camps, after school programs, or similar experiences (Baldwin, 2009; Bensimon & Dowd, 2012; Leydens & Lucena, 2017; Lezotte, 2021).

Furthermore, the culture of engineering education itself has been a proposed explanation for the lack of diversity in the profession (Rambo-Hernandez et al., 2021). Noting that much of the engineering curriculum and environment is geared towards White men, unintentional additional barriers to diversity and inclusiveness within engineering are perpetually introduced into the field. Engineering curricula that value certain experiences and/or skills at the expense of others suggest that a dominant or privileged group (i.e., White men in engineering) defines what constitutes worthwhile engineering knowledge and that students will be successful only if they reproduce this same type of knowledge (Lezotte, 2021; Tierney, 1991). Teaching toward and focusing the curricula on the dominant culture can have many negative consequences and introduces norms and values into the field that are reflective of the dominant culture, thereby hindering inclusiveness (Ong et al., 2020; Seron et al., 2016; Seymour and Hewitt, 1997; Seymour & Hunter, 2019). Moreover, as most of the curricula, values, and norms are man-centered, this breeds the question as to if being a man compared to a woman or other gender (or White-man compared to any other status) in engineering influences one’s value of diversity and willingness to act inclusively within engineering contexts. For instance, engineering faculty tend to value certain dispositions and skills in first-year students such as having experience with engineering software, specialized equipment, or STEM camps and using these as experiences as "weed out" strategies (Lezotte, 2021). However, each of these experiences or skills, as stated previously, have been found to be inequitably accessible to children from non-majority groups in engineering. Thus, inclusiveness in engineering is hindered.

The suggested reasons for the lack of diversity within engineering programs and professions are quite broad in scope and likewise remedying the situation is complex. One way that engineering educators can help shape the future of engineering culture is through how they prepare engineering students before the students enter the profession. If students adopt a broader view regarding who is and can be an engineer, demonstrate a high value for diversity within engineering, and be willing to act inclusively in engineering settings then perhaps these students can help drive change as they enter the profession. Thus, cultivating students' IPEIs—or their valuing of diversity and willingness to act inclusively in engineering contexts—has the potential to instigate future cultural change within engineering and broaden participation within the field.

1.2 Inclusive Professional Engineering Identity Conceptualization (IPEI)

The conceptual framework of an individual's Inclusive Professional Engineering Identity (IPEI) is rooted in the professional engineering identity theory (Atadero et al., 2016; Rambo-Hernandez et al., 2021; Casper et al., 2021). Consequently, understanding the professional engineering identity theoretical conceptualization is fundamental to understanding the IPEI. We want to highlight that in discussing the conceptualization of an individual's *professional engineering identity*, we are not alluding to their *engineering identity*—or view of themselves as an engineer—which we distinguish as a different construct as discussed later in the manuscript (see *Distinguishing Professional Engineering Identity from Engineering Identity*). The conceptualizations of the *professional engineering identity* construct and the *engineering identity* construct are not equivalent, nor have they been justifiably tested and unified within the engineering literature. Consequently, we approach the constructs independently.

Much of the work regarding professional engineering identity development can be traced back to Ibarra's (1999) conceptualization of one's professional identity (Atadero et al., 2016; Burleson et al., 2021; Casper et al., 2021; Eliot and Turns, 2011). According to Ibarra (1999), one's professional identity is defined as the combination of attributes, beliefs, values, motives, and experiences in terms of which people define themselves in a professional role, such as engineering. Eliot and Turns (2011), building upon Ibarra's theories, defined professional identity as one's personal identification with the duties, responsibilities, and knowledge associated with a profession such as engineering.

Ibarra (2004) suggested that the development of a professional identity is comprised of three basic processes: engagement with professional activities, developing social networks, and sense-making. Accordingly, professional identities are believed to be formed over time through varied experiences and meaningful feedback that enable individuals to obtain insights about their central and enduring preferences, talents, and values (Ibarra, 1999). This process has been related to the formation of a self-narrative that one constructs and revises over time through interactions with external forces (e.g., peers, faculty, employers) and internal forces (Eliot and Turns, 2011). With this, it has been postulated that one's professional identity is more adaptable and malleable early in one's career (Ibarra, 1999).

The conceptualization of one's Inclusive Professional Engineering Identity adopts this framework of professional engineering identity. Further, the IPEI conceptualization augments traditional professional identity development theory by focusing not just upon the duties, responsibilities and knowledge associated with the engineering profession as defined by the traditionally dominant culture in engineering (e.g., the White cis heteropatriarchy), but upon the duties, responsibilities, and knowledge associated *with a more inclusive vision of* the engineering profession. In other words, the IPEI explicitly conceptualizes engineering as a profession that benefits significantly from diverse perspectives, inclusive practices, and the pursuit of equity in both designs and workplaces (Atadero et al., 2016; Rambo-Hernandez et al., 2021; Casper et al., 2021). Casper and colleagues (2021) posited that engineering students' attitudes toward diversity must go beyond a general appreciation of diversity and be specific to the context of engineering if students are to act on those attitudes and enact inclusive behaviors in their engineering courses and professional practice. Thus, central to one's IEPI is the value they place on diversity (reflecting "knowledge") and their willingness to act inclusively (reflecting "duties and responsibilities") within engineering contexts (Rambo-Hernandez et al., 2021).

Given that IPEI is rooted in professional identity theory and in conjunction with Ibarra's (1999) theoretical perspective on professional identity development, it reasons that an engineer's IPEI might be more adaptable and formable early in their career, such as early in their collegiate tenure. First-year engineering students are beginning to navigate and negotiate their roles between students and professional engineers and, simultaneously, are revising their IPEI narrative. At this point, they are early in their journey of conceptualizing who an engineer is and what an engineer does which makes investigating IPEI development, cultivation and factors influencing its development within first-year engineering students a ripe platform to contribute to the knowledge-base regarding diversity and inclusion within engineering. Indeed, these students are at a critical junction where they have the potential to alter the trajectory of the engineering culture for future generations.

1.3 Current IPEI Development Research Practices

Literature specific to students' IPEI development, especially early in their collegiate tenure where their professional identities are potentially most malleable, is scarce. Most of the literature regarding IPEI development and/or efforts to strengthen young engineers' value for diversity in engineering contexts have included variable-centered analytical approaches. A few of these are discussed below.

In an effort to augment engineering students' interpretations of who is an engineer and enhance their value for diversity, inclusion and equity within engineering contexts (e.g., their IPEIs), Atadero and colleagues (2016) curated a set of six interventions for first-year engineering students. Activities were specifically designed to include small steps engineering faculty could make to their engineering curriculum to promote the development of students' IPEIs (Atadero et al., 2016). Examples of such intervention experiences included: student trading cards and a guest lecture on the "nature" of engineering (Atadero et al., 2016; Barker et al., 2014). Three groups of first-year engineering students participated in the study—two intervention groups and one control group—each measured on five occasions throughout their first semester. Using variable-centered multilevel modeling approaches, Atadero and colleagues (2016) sought to provide trajectories of each group's IPEI. Results from the study were inconclusive—suggesting an initial increase for both intervention groups' IPEIs in comparison to the control group, followed by a statistically significant decline in one intervention group's IPEI over time.

Noting the lack of instruments with strong validity evidence to measure students' IPEIs, Rambo-Hernandez and colleagues (2021) first composed a two dimensional (reflecting two primary constructs), four-factor scale with two factors per dimension. The two primary constructs measured as a reflection of students' IPEIs were their value of diversity and willingness to act inclusively within engineering contexts. The scale inquires about why students should value diversity. This construct is measured by the two primary sub-constructs of (a) fulfilling a greater purpose and (b) serving customers better. The willingness to act inclusively is also measured by two sub-constructs—their willingness to (a) act inclusively in teams and (b) challenge discriminatory behaviors. These two primary constructs of valuing diversity and willingness to act inclusively are reflections of components of the professional identity Eliot and Turns (2011) established as an elaboration of Ibarra's (1999) theory. Specifically, the valuing diversity construct aligns with the knowledge component, and the willingness to act inclusively aligns with beliefs about duties and responsibilities in engineering contexts (Eliot and Turns, 2011).

In the Rambo-Hernandez and colleagues' (2021) study, the research team applied a variable-centered multilevel modeling technique to a subset (approximately 30%) of the data used in the current study. By applying such modeling techniques to compare intervention and control groups ratings on the four IPEI factors over time, the results revealed no differences between the two groups on three of the four IPEI factors (Rambo-Hernandez et al., 2021). However, intervention students did demonstrate a small but statistically greater positive slope over time in their value of diversity to promote a healthy team environment relative to comparison students (Rambo-Hernandez et al., 2021). Therefore, the authors concluded that further study was needed in assessing and following students' IPEI development and the factors influencing it.

As noted previously, professional identity development is believed to occur over time and be quite individualistic as people consistently revise and construct their professional identity narratives (Ibarra, 1999; Eliot and Turns, 2011). Conventional longitudinal modeling approaches, such as the ones utilized in the previously noted studies, though useful, assume that individuals come from a single population and that a single growth trajectory can adequately approximate that entire population (Jung & Wickrama, 2008). If multiple populations exist within a sample but a single population is assumed—like in the variable-centered approaches used in the previously noted studies—then these variable-centered approaches would likely reveal minimal change in the construct under investigation such as the IPEI (e.g., for some populations IPEI trajectory grew while others declined, so overall the trajectory appeared flat). Hence, it is appropriate and necessary to consider other modeling techniques that do not make such assumptions about a single population. Examining data from these additional perspectives can expand and enhance research practices regarding identity development and allow these inquiries to be more individualistically focused. Person-centered analytical approaches treat individuals as unique and holistic entities, and work to maintain the entirety of their response in the analysis—something variable-centered approaches lack (Godwin et al., 2021).

Person-centered quantitative methods are quite applicable to modeling identity development (e.g., IPEI development) as they are capable of detecting different, meaningful groups, or classes, of individuals demonstrating similarities on the construct; importantly not constricting the entire population to follow the same trajectory and allowing for the individualistic approach to the investigation (Jung & Wickrama, 2008; Luyckx et al., 2008b;

Meeus et al., 2012). These classes can then be investigated over time for probabilistic transitions of individuals between classes and predictors of such transitions, which yields tremendous insight into identity development over time. Godwin and colleagues (2021) noted the importance of initiating person-centered investigations within the field of engineering education and called for such analytical approaches to be embraced as a way of conducting more interpretive and inclusive quantitative research within the field that elaborates and expands upon existing knowledge.

The goal of this study is to build upon the previous research findings regarding IPEI development and cultivation within first-year engineering students by utilizing a person-centered quantitative approach. Ultimately, this will provide insight into how IPEIs develop over time within engineering students and various factors contributing to, or hindering, its cultivation.

1.4 Distinguishing Professional Engineering Identity from Engineering Identity

Within engineering education literature, much discussion has been made regarding "professional engineering identities" and "engineering identities." Given that the operationalization of students' IPEIs is situated within professional engineering identity theory, we desire to differentiate the constructs of "professional engineering identity" and "engineering identity," and examine how "engineering identity" provides a useful investigative tool into students' IPEI cultivation.

As described previously, "professional engineering identity" theory is concerned with the knowledge, duties, and responsibilities of the engineering profession (and the desire or willingness of a person to take on those roles) and serves as the foundational work for the newer IPEI framework. In contrast, the conceptualization of "engineering identity" can be traced back to Gee (2000), a linguist, who attempted to provide a bridge from traditional identity theory posited by Erickson (1959) into education. Gee (2000) loosely defined identity as a "kind of person" one is in any given context.

Many recent studies seeking to measure "engineering identity" have been built upon the grounded model of science identity put forward by Carlone and Johnson (2007) who utilized Gee's definition of identity within their Recognition dimension of science identity (Carlone & Johnson, 2007; Chemers et al., 2011; Gee, 2000; Godwin, 2016; Godwin et al., 2013; Melo et al., 2017; Revelo et al., 2019; Rodriguez et al., 2018). These recent studies measuring engineering identity have, thus, simultaneously carried forward Gee's (2000) definition of identity as being a "kind of person" into the field of engineering. This self-identifying as an engineering kind of person has proven to be central in various research studies investigating "engineering identity" (McCave et al., 2014; Owen & Rolfes, 2015; Rodriguez et al., 2018; Tonso, 2014; Trytten et al., 2015), especially in regards to engineering persistence.

Prior research has established that students who identify with engineering and develop a strong internalization of their engineering identity are more likely to persist in the engineering fields (McCave et al., 2014; Owen & Rolfes, 2015; Rodriguez et al., 2018; Tonso, 2014; Trytten et al., 2015). Furthermore, Lockhart and Rambo-Hernandez (2023) applied a person-centered methodological analytical approach to a group of first-year engineering majors and discovered three distinct classes of students existed demonstrating similarities on the engineering identity construct. Students' "engineering identity" classifications were found to be stable over time, demonstrating no significant probabilistic transitions from one engineering classification to another over engineering students' first academic year (Lockhart & Rambo-Hernandez, 2023). This was quite similar to findings from other person-centered studies regarding the related construct of science identity. Though person-centered investigations in science identity are also scarce, Robinson and colleagues (2018, 2019) also found a primarily stable nature to a three-class solution of undergraduate science majors with only the lowest class showing any variability in identification over time (Robinson et al., 2018; 2019).

Given that those who deeply internalize their "engineering identity" are most likely to persist in engineering and that these identities are stable across students' first-year (Lockhart & Rambo-Hernandez, 2023), exploring the relationship between students' "engineering identities" and their IPEI development patterns may be an important step toward building an engineering workforce dedicated to inclusivity and diversity.

1.5 Present Study

The current study is a part of a larger, grant-funded study focused on cultivating Inclusive Professional Engineering Identities within engineering majors. Variable-centered analytical approaches have provided little insight regarding how IPEIs are cultivated within undergraduate engineering students, the variables influencing this cultivation, or if students' IPEIs can change over time (providing support for the malleable nature of this professional identity).

The primary goal of the present study is to apply person-centered analytical methods to investigate the developmental patterns of the IPEI within subgroups of engineering students over their first semester and variables impacting changes to those patterns. Specifically, we operationalize IPEI by observing students' value of diversity (e.g., knowledge) and their willingness to enact inclusive behaviors (e.g., duties and responsibilities) within the engineering profession and contexts. Furthermore, a student's value of diversity within engineering contexts is measured specifically as their desire to (a) fulfill a greater purpose, and (b) to serve customers better. Students' intentions to enact inclusive behaviors within engineering contexts is measured specifically as their desire to (a) promote healthy behaviors on teams, and (b) challenge discriminatory action. The specific research questions (RQ) and sub-question (SQ) addressed in this study include:

- RQ1: How many different probabilistic classes/groups of first-semester engineering students exist who demonstrate similarities on the IPEI construct?
- RQ2: Do first-year engineering students demonstrate changes in their IPEIs over time, or are their IPEIs stable?
    - SQ2.1: If engineering students' IPEIs demonstrate change, which IPEI factors(s) are students' most likely to change on, and when does this occur?
- RQ3: Is there a statistically significant difference in engineering students' initial IPEI classification due to gender or the level of internalization of their engineering identity?
- RQ4: Does gender or engineering identity status influence students' IPEI classification stability over time, or their standing on the underlying IPEI construct?
- RQ5: Do intervention experiences influence students' IPEI classification stability over time, or their standing on the underlying IPEI construct?

The first two authors of this paper are White women with formal training in educational psychology—specifically measurement and statistics. With no formal training in engineering, they approach questions in the engineering context as observers—not members—of the engineering community. The first author is a postdoctoral research associate whose work is primarily related to the development and cultivation of various STEM identities within students and the impact of such identities on student persistence in STEM. She approaches this work with quantitative, person-centered methodologies in an attempt to more accurately describe the individualistic nature of these various role identities and their developmental trajectories within students. The second author is an educational psychology faculty member. Her work related to engineering education uses quantitative approaches to describe the impacts of educational interventions on student-level outcomes and students' change relative to outcomes of interest, especially outcomes or contexts related to performance and persistence of students who have been historically underrepresented.

The third author of the paper is a White woman and engineering faculty member with formal training in the field of structural engineering. For this author the topic of the research holds a different type of personal significance. The overall research project that contains this study was inspired by the third author’s frustration that although a variety of identity-based professional organizations and support structures exist for students from systemically marginalized backgrounds in engineering, these external supports do not change the ways these students are treated by majority students (e.g., White men) in academic settings. At the onset of the study, the third author admittedly approached the research as a person who had experienced marginalization due to her gender in engineering but had limited understanding of the way gender interacted with the other privileged aspects of her identity and the intersectional experiences of students experiencing other types of marginalization. During the course of the project the entire team experienced shifts in their ways of understanding the world, and the team acknowledges that some aspects of the project would likely have been conducted differently if the project was to start over now.

2 Methods

2.1 Participants and Procedures

Participants for this study were all first-year engineering students from two large, R1, public universities within the United States. Students were enrolled in an introductory engineering course over one semester. The study was reviewed and approved by the Institutional Review Board and participant consent was obtained through the online Qualtrics survey platform.

The larger study for which this study is situated utilized a quasi-experimental design where students in the intervention group participated in several experiences not usually facilitated within engineering classrooms. Such intervention experiences included the incorporation of several diversity and inclusion activities into students' traditional first semester engineering courses facilitated by engineering faculty. Two of such activities included in all intervention sections were, (a) the dean' talk (Bennett & Sekaquaptewa, 2014) and (b) an interactive theater sketch (Finelli & Kendall-Brown, 2009). In the dean's talk, the dean of each college (who was a White man in both instances) gave a talk during one of the early class meetings to establish egalitarian norms for students in the college (Bennett & Sekaquaptewa, 2014). In the interactive theater sketches, students watched a theater sketch that illustrated a dysfunctional engineering study team of three. Students were then guided by trained facilitators to identify some of the problems on the team. They were then given the opportunity to volunteer to be the fourth member of the study team to try to address the dysfunction as the actors reran the sketch. Other activities included an engineering panel of purposefully diverse (race, gender and age) engineers (utilized in all but two sections) and reflective writing assignments to foster sense-making (conducted in all sections and tailored to the course content; Barker et al., 2014; Bennett & Sekaquaptewa, 2014; Mohd-Yusof et al., 2014).

The courses with the intervention sections were determined by the schedule and by the length of time the campus had been involved with the grant efforts. Due to the scale-up nature of the larger project from which this study resides, the first campus had been implementing interventions in some sections for the previous two years. In the year of the current study, because of the scale-up nature, all sections from this campus participated in the interventions—data from comparison sections were collected in previous years but not included here due to differences in year of collection. Therefore, the control data came from the second campus, which was in their first year of implementation. Specifically, at this campus, intervention sections were selected based on when the sections were taught to simplify scheduling the interventions, such as the dean's talk. Comparison students at this campus were also first semester engineering students who were enrolled in otherwise identical engineering courses taught by the same faculty members. Specifically, at the second campus, three faculty members each taught an equal number of comparison and intervention sections at this campus.

Students' IPEIs were measured on four different, equally spaced, occasions during the Fall 2017 semester. The first measurement occasion occurred before any interventions. Information was gathered and evaluated from a total of 810 student participants. Thirty-one participants were removed from the analytic sample after basic data cleaning practices such as removing students with a non-response on a variable utilized as a covariate—for which the analytical method would automatically exclude these participants. To maintain the integrity of the data and accuracy of the analyses, an additional 96 participants were removed from the analytic sample who did not complete survey measures at the first timepoint and at least one of the other three timepoints. A total of 683 student participants were retained. Demographic information for the analytic sample is as follows: 33%/67% split between the two campuses, 74% self-identified as men, 93% White, and 82% participated in intervention experiences throughout the semester. The large percentage of men and White students in the analytic sample is representative of undergraduate engineering programs and provides further rationale for using person-centered methodologies where participant scores are not all regressed to the mean.

The statistical technique used in this study afforded the opportunity to include all 683 participants in the analysis. Analyses were conducted to assess differences between those who participated at all four timepoints and those who did not. Pearson's Chi-Squared Test of Independence revealed no significant differences between completers and non-completers based on gender (p = .853) or intervention participation (p = .419). Mann-Whitney U Tests using the Bonferroni correction revealed that there were no significant differences on any of the four measured IPEI variables (see *Measure)* at any of the four timepoints between the two groups (*ps* = .18 to .91). These results suggested that data may be missing at random and imputation may be a valid means of retaining missing data, such as in the use of the full information maximum likelihood estimation method (Little & Rubin, 1987).

2.2 Measures

2.2.1 Valuing Diversity and Enacting Inclusion in Engineering (VDEIE)

Students' IPEIs were measured using the VDEIE scale developed by Rambo-Hernandez et al. (2021). Please see Appendix A for specific items. The instrument measures students' IPEIs by evaluating two constructs critical to the IPEI – Valuing Diversity and Enacting Inclusive Behaviors. Valuing Diversity is represented by the two primary factors of fulfilling a greater purpose (VD1) and serving customers better (VD2). A high score on VD1 indicated the engineering student perceived valuing diversity aligned with a strong inward desire for purpose and fairness in their work. A high score on VD2 indicated the engineering student believed customers could be better served if diversity is valued. Furthermore, the Enacting Inclusive Behaviors construct is represented by the two primary factors of promoting a healthy work environment (IB1) and challenging discriminatory behaviors (IB2). A high score on IB1 indicated the engineering student would take measures to ensure every team member was included and valued and sought to have a variety of skills represented on the team. A high score on IB2 indicated that the engineering student would call out any type of discriminatory behavior while working on a team. Each factor included between four and five items rated on a scale of 1 (strongly disagree) to 7 (strongly agree). Confirmatory factor analysis (CFA) results of the VDEIE with the analytic sample revealed good global model fit statistics ($X^2(113) = 285.682, p < .001; RMSEA = .047; CFI = .950; SRMR = .036$) with ranges of the standardized factor loadings per the four factors as follows: VD1: .641 to .850; VD2: .668 to .793; IB1: .671 to .734; IB2: .653 to .889. Cronbach's alpha was further used to assess the internal consistency of the IPEI items for each of the four measurement occasions (T1-T4). Results revealed good internal consistency of all four factors across all four measurement occasions with Cronbach's α ranging from .84 to .90 for VD1, .82 to .92 for VD2, .80 to .90 for IB1, and .90 to .94 for IB2 (Kline, 1999).

2.2.2 Engineering Identity

The Identity as a Scientist instrument developed by Chemers and colleagues (2010) was adopted and modified specifically for engineering to reflect a student's self-identification as an engineer. Participants' engineering identity was measured using three of Chemers and colleagues' (2010) original six identity items. Items were rated on a scale of 1 (strongly disagree) to 7 (strongly agree). Participants indicated their level of agreement with three statements. "In general, being an engineer is an important part of my self-image." "Being an engineer is an important reflection of who I am." "I have come to think of myself as an engineer." Thus, a higher scale score indicated a greater degree of self-identification as an engineer. CFA results of the engineering identity scale with the analytic sample revealed saturated global model fit indices and standardized factor loadings of .82 and higher. Cronbach's alpha was further used to assess the internal consistency of the identity items for each of the four measurement occasions (T1-T4). Results revealed good internal consistency of the instrument with Cronbach's α = .84, .89, .92 and .92 for T1, T2, T3 and T4, respectively (Kline, 1999).

2.3 Data Analytic Strategy

Factor scores for each of the four VDEIE factors were first calculated per each participant as an average score on the factor. These factor average scores represented the four primary variables to be investigated over time and reflected a student's standing on the underlying IPEI latent construct.

To assess the research questions and sub-questions, the new person-centered analytical technique of Random Intercept Latent Transition Analysis (RI-LTA) was utilized to examine how probabilistic classes/groups of students who demonstrated similarities on the construct (i.e., Inclusive Professional Engineering Identity statuses) varied in systematic ways over time. RI-LTA allows us to capture various subgroups of students demonstrating similarities in their IPEIs and track their IPEI developmental patterns over time. This methodology also affords us the opportunity to investigate how various factors (i.e., intervention status, gender, engineering identity) influence these groups' IPEI developmental patterns in different ways. It is similar to regular Latent Transition Analysis (LTA), which according to Muthén and Asparouhov (2020) is unnecessarily restrictive. Regular LTA is a single-level modeling approach. RI-LTA, alternatively, reflects a multilevel modeling approach of separating the between and within-subject variation (Lockhart & Rambo-Hernandez, 2023; Muthén & Asparouhov, 2020). By considering time as the within-level and student as the between-level, the latent class transitions are represented on the within-level (Lockhart & Rambo-Hernandez, 2023; Muthén & Asparouhov, 2020). The between-level captures much of the variability across students which yields more accurate classifications (Lockhart & Rambo-Hernandez, 2023; Muthén & Asparouhov, 2020). The alternative RI-LTA model typically fits the data better with both smaller and larger sample sizes as long as $n \geq 500$, leads to more accurate estimates of the transition probabilities (e.g., developmental patterns), reduces the probability of individuals staying in the same class, and reduces the need for Mover-Stayer modeling (Muthén, 2021; Muthén & Asparouhov, 2020).

To begin investigating the research questions and related sub-questions of this study, model building techniques were employed. The 5-step procedure proposed by Nylund (2007) for LTA was combined with suggestions for RI-LTA procedures from Muthén (2021) into four primary steps: basic model identification, model invariance testing, covariate inclusion, and distal outcomes.

2.3.1 Step 1: Basic Model Identification

To begin investigating RQ1, RQ2 and SQ2.1, and in accordance with best practice methodology using RI-LTA, a model building approach was employed to identify the RI-LTA model that best fit the data (Muthén, 2021). Various RI-LTA models with different numbers of classes were estimated. Model fit indicators such as loglikelihood (LL), Akaike information criterion (AIC), Bayesian information criterion (BIC), entropy (classification accuracy), and class size were used to aid in the selection of the most appropriate model. Higher loglikelihood values, lower AIC and BIC values, entropy values closer to 1.00 with a .70 cutoff (Clark, 2010; Fonseca & Cardoso, 2007; Ramaswamy et al., 1993) and reasonable class sizes containing at least 5% of the sample (Shanahan et al., 2013) were used as indicators of a better model fit (Muthén, 2021). After a baseline model was selected, the appropriateness of the lag 1 assumption was tested. A lag 2 model (where the first measurement occasion was allowed to directly influence the third measurement occasion and so on) was estimated and compared to the lag 1 model using global model fit indices. Next, a lag 3 model (where the first measurement occasion was allowed to directly influence the fourth measurement occasion) was estimated and compared to the lag 1 model using global model fit indices.

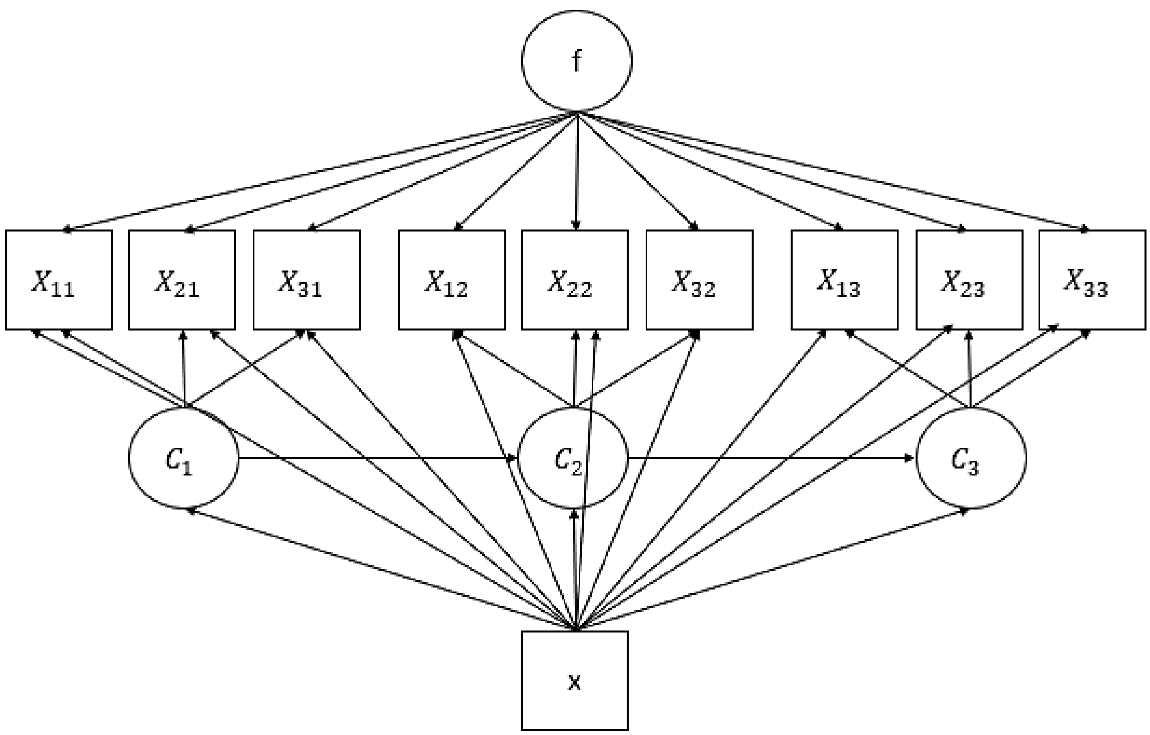
2.3.2 Step 2: Model Invariance Testing

Before addressing RQ1, RQ2 and SQ2.1, the invariance across time and groups assumption of the established baseline model with appropriate lag needs to be investigated to determine if any model misspecifications exist that should be accounted for in a new baseline model. For examining the time invariance assumption, one indicator was freed and allowed to vary across all time points. This method was repeated for each indicator. Global model fit indices for each of these models were compared to the fully invariant model to determine if partial or full invariance held across time.

To examine measurement invariance across genders and campuses, a flexible modeling approach outlined by Muthén (2021) was utilized. Specifically, a direct effects model where the grouping variable acts as a covariate and directly influences the latent class variables and latent class indicators (see Figure 1) was compared to a main effects model where the grouping variable (i.e., gender or campus) acts as a covariate and influences the latent class variables and the random intercept (see Figure 2). The direct effects model does not allow the covariate to influence the random intercept as this yields a nonidentifiable model (Muthén, 2021). The selection of the main effects model as the better fitting model would indicate measurement invariance held across the grouping variable as the random intercept captured most of the measurement non-invariance that was time-invariant (Muthén, 2021; Muthén & Asparouhov, 2020). Therefore, the selection of the main effects model as the superior model would be desirable for invariance testing across genders and campuses.

Figure 1

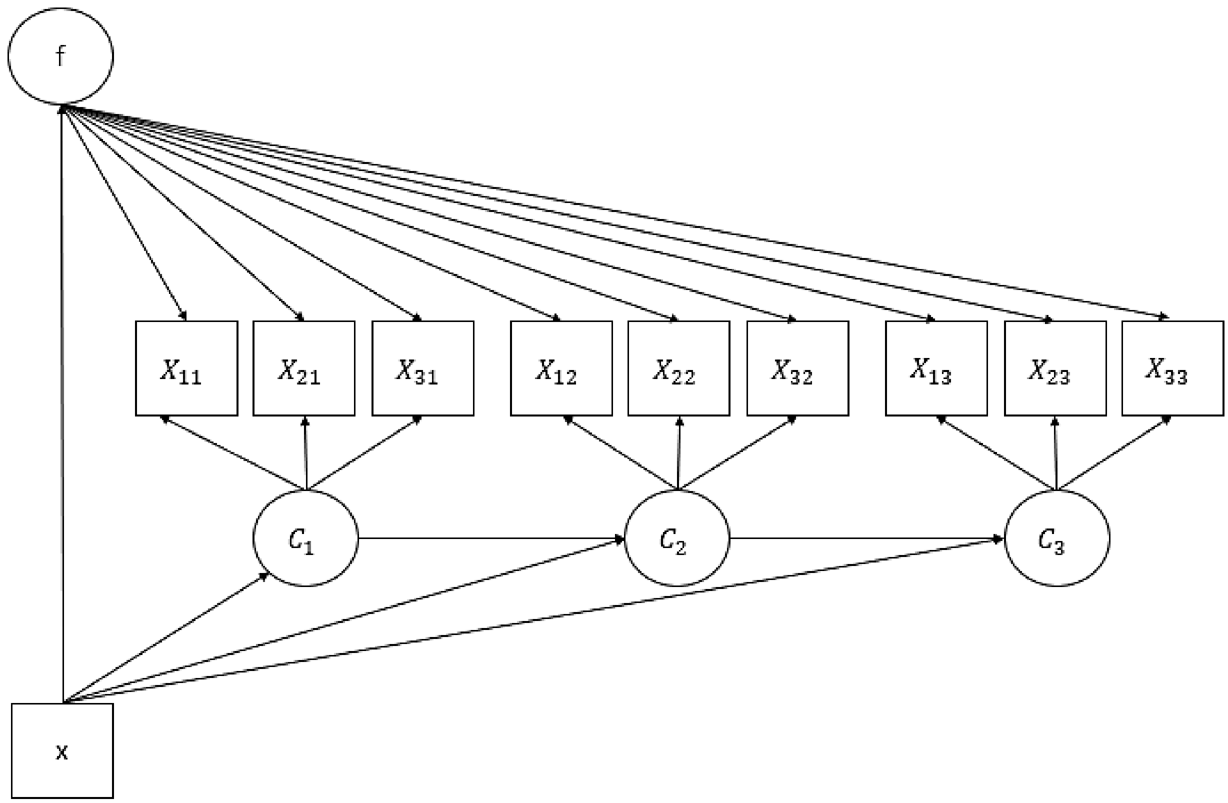
Direct Effects RI-LTA Model: Covariate Influences the Latent Class Indicators and Latent Class Variables



Note. RI-LTA = Random Intercept Latent Transition Analysis; *f* = *Random intercept factor;* X_{it} = *Continuous l*atent class indicator, *i,* at time *t*; C_t = Latent class variable at time *t*; *x* = Grouping variable acting as a covariate.

Figure 2

Main Effects RI-LTA Model: Covariate Influences the Random Intercept and Latent Class Variables



Note. RI-LTA = Random Intercept Latent Transition Analysis; *f = Random intercept factor;* X_{it} *= Continuous l*atent class indicator, *i,* at time *t*; C_t = Latent Class Variable at time *t*; *x* = Grouping Variable Acting as a Covariate.

After invariance was established, RQ2 and SQ2.1 were addressed by examining transition probabilities obtained through the validated, baseline model. Odds ratios greater than one with a significant, non-symmetric 95% confidence interval (centered at 1.00) indicated that the odds of transitioning from a particular class to another at that timepoint were significantly greater than the odds of remaining within the same class. This would suggest that students' IPEIs were malleable and capable of changing.

2.3.3 Step 3: Covariate Inclusion

After the establishment of the new invariant baseline model, optional covariates can be incorporated into the RI-LTA framework one at a time in various ways to assess the degree to which they influence the transitions of individuals from one classification to another (see Muthén, 2021 for more information). Specifically for the purposes of this study in addressing RQ3, RQ4 and RQ5, we seek to determine the grouping effects that gender, engineering identity, and intervention status have upon the transitions of students from one IPEI classification to another over time—portrayed as a main effects model.

2.3.3.1 Engineering Identity. Before addressing RQ3 and RQ4 and in conjunction with the findings from our previous work (e.g., Lockhart & Rambo-Hernandez, 2023) regarding first-year engineering students engineering identity, a three-class RI-LTA model was produced that yielded good entropy (.861). The three classes presented various levels of engineering identity labeled as: 1 = lowest, 2 = moderate, and 3 = highest. Given previous findings that though participants might experience slight deviations in their average engineering identity scores as time persists, their engineering identity classifications were stable across time, it was decided to introduce the more stable classifications as a grouping covariate in the baseline RI-LTA model for this study. This would help to determine the influence of students' levels of their internalization of their engineering identity on their IPEI development pattern over time.

2.3.3.2 Grouping Effects. The effects of different grouping variables (i.e., gender) on student IPEI classifications were addressed next. First, to investigate RQ3, student posterior probabilistic classifications produced by the validated baseline model were used to investigate the relationship between initial IPEI classifications and different levels of the grouping variables (e.g., man or woman, engineering identity classification). Proportions of participants in each IPEI classification at Time 1 were compared across levels of the grouping variable and analyzed for systematic differences using Pearson Chi-Squared Test of Independence at the standard α=.05 significance level.

Next, to begin addressing RQ4 and RQ5, the grouping variables of gender, engineering identity status, and intervention status were introduced one at a time as a covariate into the RI-LTA validated baseline model as a main effects model, synonymous with the main effects models described previously (see Figure 2). The degree to which the grouping variable influenced the probabilistic transitions of individuals from one IPEI classification status to another over time were observed. Significant odds ratios signified that the odds of transitioning between classes were significantly different for one-level of the covariate (e.g., intervention) than the other (e.g., control) and, thus, that the grouping variable impacted the developmental patterns of certain IPEI classes. Lastly, the effects of the gender, engineering identity, and intervention status covariates on the underlying latent factor, f, in the related RI-LTA main effects model were observed at the standard $\alpha = .05$ significance level. The significance of this value reflects the significant influence of the grouping variable on the underlying IPEI construct.

2.3.4 Step 4: Distal Outcomes (not incorporated in this study)

According to Muthén (2021), an optional fourth step regarding the inclusion of distal outcomes into the invariant baseline model with appropriate covariate inclusions can be done. This is accomplished in a similar fashion as LTA utilizing a “dot method” in Mplus (see Muthén, 2021 for more information). The research questions addressed in this study only incorporate the use of the first three steps outlined previously. As this study represents one of the first to employ this newer RI-LTA method, we have included a brief description of this step for readers.

STATA 17.1 (StataCorp, 2021) was used for all descriptive and correlational studies. RI-LTA models were estimated with Mplus Version 8.7 (Muthén & Muthén, 1998 –2021) using the maximum likelihood estimation method with robust standard errors (MLR), the default estimator for RI-LTA. Missing data were handled through the use of the full information maximum likelihood (FIML) method, default to Mplus. All non-nested models were compared using BIC values with lower values indicating a better model fit. Nested models were compared using BIC and loglikelihood values with lower BIC and higher loglikelihood values indicating a better model fit. Where appropriate, formal Chi-Square Difference Tests were applied using the Satorra-Bentler Correction at the standard $\alpha = .05$ significance level (Muthén, 2021).

3 Results

The present study ($n = 683$) was analyzed under the RI-LTA framework with continuous variables, which was an adequate sample size to yield reliable results with $T \geq 3$, and $N \geq 500$ (Muthén, 2021). IPEI variable distributions demonstrated univariate $|\text{skew}| < 2$ and kurtosis < 6 deeming the MLR estimation method adequate for handling any slight deviations in normality (Curran, West & Finch, 1996; Hancock & Mueller, 2013; Muthén & Muthén, 1998 – 2021). Descriptive statistics and a correlation matrix for study variables are provided in Appendix B.

Upon first inspection of the correlation matrix, VD1 and VD2 demonstrated correlations between .68 and .76 at each timepoint. Consequently, consideration was given to the collapsing of these two factors into a single factor. Confirmatory factor analysis was used to compare the proposed 4-factor model (AIC = 28283.07, BIC = 28541.08) with all original variables at time-point 1 to the related 3-factor model (AIC = 28440.60, BIC = 28685.03) where the two valuing diversity factors were collapsed. With lower AIC and BIC values, combined with previous validity findings by Rambo-Hernandez and colleagues (2021), it was decided to retain the 4-factor model.

3.1 Basic Model Identification and Invariance Testing

RI-LTA models for 2, 3, 4, and 5-class solutions were produced. Results are provided in Table 1.

Table 1

RI-LTA Model Results for Different Numbers of IPEI Class Solutions

Class Model	AIC	BIC	Log-likelihood	Entropy
2 Class	21557.46	21715.89	-10743.73	0.85
3 Class	20961.81	21197.19	-10428.90	0.88
4 Class	20409.25	20748.73	-10129.62	0.88
5 Class	20085.30	20556.06	-9938.65	0.89

Class sizes are provided for each RI-LTA model at every timepoint in Table 2. All models converged. Class intercept estimates and standard errors of the different RI-LTA models are provided in Appendix C.

Table 2

RI-LTA Model Results for Individual Class Sizes of Different IPEI Class Models

Individual Classes	**Class Sizes (proportions)**

	Time 1	*Time 2*	*Time 3*	*Time 4*
	2 Class Model			
Class 1	.16	.19	.21	.19
Class 2	.84	.81	.79	.81
	3 Class Model			
Class 1	.81	.77	.75	.77
Class 2	.10	.10	.12	.09
Class 3	.08	.13	.13	.14
	4 Class Model			
Class 1 (MH)	.10	.10	.11	.08
Class 2 (HM)	.15	.16	.12	.13
Class 3 (HH)	.04	.07	.10	.10
Class 4 (MM)	.71	.67	.68	.70
	5 Class Model			
Class 1	.05	.06	.06	.04
Class 2	.04	.08	.09	.10
Class 3	.15	.15	.12	.12
Class 4	.04	.04	.05	.04
Class 5	.71	.67	.68	.69

Note. MH = Medium-High, HM = High-Medium, HH = High-High, MM = Medium-Medium

To address *RQ1: How many different probabilistic classes/groups of first-semester engineering students exist who demonstrate similarities on the IPEI construct?* RI-LTA class models were compared. AIC and BIC decreased substantially as more classes were introduced into the modeling framework while loglikelihood increased. Entropy remained consistent across each model. In noting class size changes between models, the 5-class solution had seven classes across time with 5% or less of participants residing within a class. In combining these results, it appeared likely that a model misspecification existed that needed to be resolved as the introduction of more classes improved model fit but provided insufficient class sizes (Muthén, 2021; Shanahan et al., 2013). Since the 5-class model had numerous classes containing less than 5% of participants, it was not selected to serve as the baseline model. The 4-class model demonstrated substantially lower AIC and BIC and higher LL than the 2 or 3-class solutions. It also demonstrated sufficient class sizes except for one class at timepoint 1 that held only 4% of the data. Notably, this class grew to containing 10% of participants by timepoints 3 and 4.

Accordingly, the 4-class solution was chosen to serve as the baseline model and was investigated for model misspecification as selection criterion suggested four IPEI classes/groups existed.

Next, the lag 2, 4-class model was tested (BIC = 21133.09, LL = -10351.17) and compared to the baseline model. With a higher BIC and lower loglikelihood value, the lag 2 model did not show an improved fit over the baseline model. Next, a lag 3, 4-class model was tested (BIC = 21157.18, LL = -10392.59) and compared to the baseline model. With a higher BIC and lower loglikelihood value, the lag 3 model did not show an improved fit over the baseline model. The lag 1 baseline model was retained for invariance testing.

To examine the time invariance assumption of the baseline model, one indicator was freed at a time and allowed to vary across all time points. Model results are provided in Table 3. The fully invariant, baseline model presented higher loglikelihood values and lower BICs than either of the three VD1, VD2, or IB1 noninvariant models. However, the loglikelihood for the IB2 noninvariant model was slightly higher than the baseline model and its BIC was lower than the baseline model. Due to the nested nature of these models, a Chi-Square Difference Test was applied using the Satorra-Bentler Correction. Results were significant (*adjusted* $X^2(12) = 74.97$, $p < .001$). This indicated that constraining IB2 to be invariant across time was too restricting and, thus, the variable should be freed.

Table 3

Model Results for Testing the Invariance Across Time Assumption

	BIC	Loglikelihood	Number of Free Parameters	Scaling Correction Factor
Fully Invariant	20748.73	-10129.62	75	1.64
VD1 Noninvariant	20807.58	-10119.90	87	1.64

VD2 Noninvariant	20801.11	-10116.70	87	1.70
IB1 Noninvariant	20786.24	-10109.20	87	1.59
IB2 Noninvariant	20740.64	-10086.40	87	1.72

Note. VD1 = Value Diversity to fulfill a greater purpose, VD2 = Value Diversity to serve customers better, IB1 = enact Inclusive Behaviors by promoting a healthy work environment, IB2 = enact Inclusive Behaviors by challenging discriminatory behaviors.

To examine possible model misspecification as related to invariance across groups (gender and campus), a direct effects model was compared to a main effects model using BIC. The gender main effects model produced a lower BIC (20788.01) than the related direct effects model (20852.25). Similarly, the campus main effects model also produced a lower BIC (20802.54) than the corresponding direct effects model (20807.48). Thus, the main effects model for both gender and campus were superior to their direct effects counterparts. Measurement invariance was upheld across gender and campus under the RI-LTA framework.

Model misspecification seemed to be due solely to the non-invariance of IB2. The 4-class RI-LTA model with IB2 being non-invariant was chosen to serve as the new baseline model. We now moved to answering *RQ2: Do first-year engineering students demonstrate changes in their IPEIs over time, or are their IPEIs stable? and SQ2.1: If engineering students' IPEIs demonstrate change, which IPEI factors(s) are students' most likely to change on, and when does this occur?* by examining transition probabilities obtained through the validated, baseline model. Time and class specific intercept values, standard errors, and proportions are provided in Appendix D. For ease of interpretability and noting class intercept values on the four factors, the classes have been labeled as MH (Medium-High), HM (High-Medium), HH

(High-High) and MM (Medium-Medium) for their relative standings on the primary Valuing Diversity (VD1 and VD2) and the Enacting Inclusive Behaviors (IB1 and IB2) constructs. For example, a class with the MH label represents a class of students who measured at a medium level on VD1 and VD2, and at a high level on IB1 and IB2 (see Appendix D for reference). As can be noted in Appendix D, none of the classes presented "low" intercept values on any of the four factors.

Transition probabilities for each timepoint to the next are provided in Table 4. Overall, students tended to stay within the same class over time, though some movement was detected. Of importance, it is noteworthy that students in Class 1 (MH) at Time 2, representing 10% of the total sample, have a 79% chance of transitioning to Class 3 (HH) at Time 3. The significant odds ratio related to this finding suggests that the students in Class 1 are 7.59 (2.26, 25.48) times more likely to transition to Class 3 during this time-period compared to remaining within their own class. In noting differences between these classes, this result indicates that students with moderate Valuing Diversity factor scores and high Inclusive Behavior factor scores, MH, are likely to demonstrate gains on both Valuing Diversity factors within this time-period. Indeed, young engineering student's IPEIs can change early within their collegiate/professional tenure.

Table 4

Transition Probabilities for the 4-Class Model with IB2 Noninvariant

		C1 (MH)	C2 (HM)	C3 (HH)	C4 (MM)
		Time 2			
Time 1	C1	.63	.14	.17	.06
	C2	.07	.29	.49	.15
	C3	.03	.12	.81	.04

	C4	.03	.13	.31	.53
			Time 3		
Time 2	C1	.10	.07	.79*	.04
	C2	.07	.63	0.00	.30
	C3	.07	.03	.88	.03
	C4	.40	.01	.21	.38
			Time 4		
Time 3	C1	.54	.04	.22	.20
	C2	0.00	.89	.07	.05
	C3	.03	.01	.94	.02
	C4	0.00	.12	.25	.64

Note. * Value is related to a statistically significant ($\alpha = .05$) transition probability odds ratio of movement to a different class. MH = Medium-High, HM = High-Medium, HH = High-High, MM = Medium-Medium.

3.2 Grouping Effects

To address *RQ3: Is there a statistically significant difference in engineering students' initial IPEI classification due to gender or the level of internalization of their engineering identity?* students' posterior probabilistic IPEI classifications provided by the 4-class, IB2 noninvariant baseline model were analyzed in relation to students' gender, engineering identity class/status and intervention status. The entropy of the baseline model, .88, afforded the opportunity to use these probabilistic classifications for examination with other variables as is recommended only for mixture models with entropy values greater than .80 (Clark, 2010).

Pearson's Chi-Squared Test revealed that initial IPEI classifications differed significantly across genders ($X^2(3) = 16.20$, $p = .001$). Interestingly, 84% of women were classified in Class 3 (HH) initially reflecting high values of diversity and willingness to enact inclusive behaviors in engineering, compared to 70% of men. Furthermore, only 4% of women were classified into Class 1 (MH) initially demonstrating moderate levels of valuing diversity but high levels of willingness to act inclusively within engineering contexts, while 11% of men received this same classification.

Results indicated initial IPEI classifications also differed significantly across engineering identity classifications ($X^2(6) = 12.84$, $p = .046$). Table 5 provides exact counts of students in each classification. For example, 77% (250 out of 325) of the "highest" engineering identity students were classified in IPEI Class 3 (HH) compared to 67% (34 out of 51) of the "lowest" engineering identity students. In contrast, 20% (10 out of 51) of the "lowest" engineering identity students, compared to only 6% (21 out of 325) of the "highest" engineering identity students were classified in IPEI Class 1 (MH), with high values on the Enacting Inclusive Behaviors factors but medium values on the Valuing Diversity factors.

Table 5

Distribution of Students' Initial IPEI Classifications and their Engineering Identity Classifications

Engineering Identity Classification	Initial Inclusive Professional Engineering Identity (IPEI) Classification				
	IPEI C1 (MH)	IPEI C2 (HM)	IPEI C3 (HH)	IPEI C4 (MM)	*Total*
EIC C1 (Lowest)	10	4	34	3	*51*
EIC C2 (Moderate)	34	43	218	12	*307*
EIC C3 (Highest)	21	44	250	10	*325*

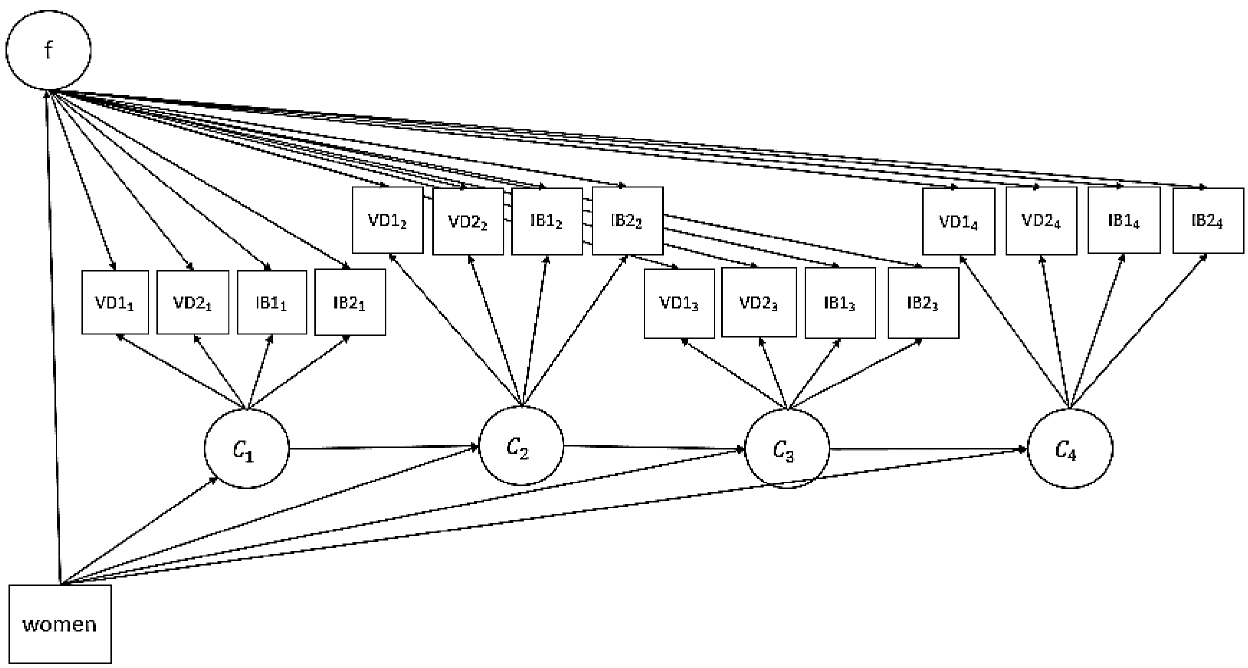
Total	*65*	*91*	*502*	*25*	*683*

Note. MH = Medium-High, HM = High-Medium, HH = High-High, MM = Medium-Medium.

Next, to address *RQ4: Does gender or engineering identity status influence students' IPEI classification stability over time, or their standing on the underlying IPEI construct?* independent main effects RI-LTA models utilizing gender and engineering identity classification were analyzed (see Figure 3 for an example model).

Figure 3

Women Main Effects RI-LTA Model for the Present Study



Note. RI-LTA = Random Intercept Latent Transition Analysis; f = Random intercept factor; women = Grouping Variable Acting as a Covariate; C_t = Latent Class Variable at time t; $VD1_1$ to $IB2_4$ = Continuous Latent Class Indicators Measured as Four Scale Scores of the VDEIE Scale in Appendix A across Four Timepoints.

The transition odds ratios for the gender covariate (men=0, women=1) RI-LTA model were observed. No significant odds ratios were detected (see Appendix E). However, the effect of gender on the underlying latent factor, *f*, in the RI-LTA main effects model was indeed positive (.37) and significant ($p < .001$). This suggested that women, in general, demonstrated significantly higher values on the underlying IPEI latent construct than men. Summarizing, gender did not significantly increase or decrease a student's likelihood of transitioning into a different IPEI class over time—suggesting no difference in IPEI developmental patterns between the genders. However, women demonstrated higher IPEIs in general than men and, as noted previously, differences in initial IPEI classifications based upon gender also existed.

Another main effects model utilizing engineering identity, EID, classifications as dummy-coded covariates (EID 1: EID1 = 1, otherwise = 0; EID 2: EID 2 = 1, otherwise = 0) was analyzed. The highest engineering identity class, EID 3, was utilized as the reference group since it was the largest class. The effect of engineering identity class 1 (lowest) on the underlying latent factor in the RI-LTA main effects model, the *f* estimate, was negative (-.151) but not statistically significant (p =.421). This suggested that students classified in the highest engineering identity statuses and who more deeply internalized their engineering identity, in general, demonstrated somewhat higher values on the underlying latent construct (IPEI) than students classified in the lowest engineering identity statuses, but these results were not statistically significant. The effect of engineering identity class 2 (moderate) on the underlying latent factor in the RI-LTA main effects model, the *f* estimate, was also negative (-.195) and not statistically significant (p =.053). This also suggested that students classified in the highest engineering identity statuses and who more deeply internalized their engineering identity, in general, demonstrated somewhat higher values on the underlying latent construct (IPEI) than students classified in the moderate engineering identity status, but these results were not statistically significant. The effect of engineering identity classification on transition probability odds ratios was observed over each time period. No significant odds ratios were detected. This indicated that different levels of students' internalization of their engineering identity did not influence their IPEI developmental patterns over time (see Appendix F and Appendix G for odds ratios).

Lastly, *RQ5: Do intervention experiences influence students' IPEI classification stability over time, or their standing on the underlying IPEI construct?* was addressed. To investigate if systematic differences existed in initial IPEI classifications between intervention and control groups, a Pearson Chi-Squared Test of Independence was utilized at the standard $\alpha = .05$ significance level. Results showed no statistically significant differences regarding initial IPEI classifications between intervention and control groups ($\chi^2(3) = 6.74$, $p = .08$) existed.

Next, a main effects RI-LTA model utilizing intervention status (control=0, intervention=1) as a covariate was analyzed. The effect of intervention status on transition probability odds ratios was observed over each time period. The significant influence of intervention status upon transition probabilities occurred solely between Time 1 and Time 2 where eight significant transition probabilities were detected. These ratios are provided in Table 6. See Appendix H for the full table of odds ratios. To highlight a few of these results, Table 5 shows that students in the intervention group who were initially in Class 1 (MH) were 15.12 times more likely to transition to Class 2 (HM) than control students, demonstrating increases on both Valuing Diversity factors (VD1 and VD2) and a slight decrease on the IB2 factor (see class intercept values for reference in Appendix D). Students in the intervention group and initially classified in Class 1 (MH) were 4.42 times more likely than students in the control group to transition to Class 3 (HH), demonstrating an increase on both Valuing Diversity factors (VD1 and VD2). In contrast, students in the intervention group were also 9.00 times more likely to transition downward from Class 1 (MH) to Class 4 (MM) than students in the control group. All in all, lots of differences in IPEI developmental patterns between intervention and control students were detected though not consistently towards higher or lower IPEI classifications. This is further evidenced by the *f* estimate being small (-.01) and statistically non-significant (*p* =.946). Taken together, intervention status significantly influenced IPEI classification stability (e.g., developmental patterns) between Time 1 and Time 2, though not always in an upward trajectory.

Table 6

Effect of Intervention Status on Transition Probability Odds Ratios

Time 1	Time 2			
	C1 (MH)	C2 (HM)	C3 (HH)	C4 (MM)
C1	1.00 (1.00, 1.00)	15.12 (2.79, 82.04)*	4.42 (1.26, 15.55)*	9.00 (1.71, 47.32)*
C2	.07 (.01, .36)*	1.00 (1.00, 1.00)	.29 (.10, .88)*	.60 (.13, 2.83)
C3	.23 (.06, .80)*	3.42 (1.14, 10.27)*	1.00 (1.00, 1.00)	2.04 (.62, 6.72)
C4	.11 (.02, .58)*	1.68 (.35, 7.98)	.49 (.15, 1.62)	1.00 (1.00, 1.00)

Note. *Statistically significant result at the standard $\alpha = .05$ significance level. Odds ratio (non-symmetric 95% confidence interval centered at 1.00). MH = Medium-High, HM = High-Medium, HH = High-High, MM = Medium-Medium.

4 Discussion

This study is the first to apply person-centered analytical techniques such as RI-LTA to investigating students' Inclusive Professional Engineering Identities. Applying this person-centered methodology allowed us to detect different groups of engineering majors demonstrating similarities in their IPEIs and then monitor these groups over time to detect changes and/or sources of changes to their IPEI developmental patterns. Noting the heightened attention and importance of inclusivity and diversity within engineering, we sought to investigate the stability of first-year engineering students' Inclusive Professional Engineering Identities and the potential impact that gender, engineering identity, and intervention experiences have on their IPEIs.

First, four IPEI classes of students emerged with varying represented levels on the four primary IPEI factors. The majority of these first-year engineering students demonstrated a HH IPEI (68%-72%) over the course of the semester, reflecting very high levels of personal identification with the duties, responsibilities and knowledge regarding the value of diversity, inclusion and equity within their developing roles as engineering professionals. More importantly, it was found that the developmental patterns of students' IPEIs across time was not always stable. Without considering interventions, students' IPEI classifications were capable of transitioning and changing throughout the course of the semester. These changes were all the more common when students experienced interventions. This provides further evidence to the IPEI correctly being situated within the professional identity framework where identities are believed to be most malleable early in one's profession (Ibarra, 1999). In particular, without considering interventions, students were most prone to demonstrate positive changes on their Valuing Diversity factor scores in the middle of the semester. This is suggestive that as these young engineers enter college and are exposed to a diverse range of peers and faculty within engineering and encounter basic collegiate engineering curricula, their perceived value for diversity is enhanced. These findings reiterate those of Rodriguez-Simmonds and colleagues (2017) who found that one semester or first-year experience in engineering could begin to shift students' embraced values of diversity, but students struggled with integrating values on diversity into teaming experiences. Similarly, students demonstrated changes in diversity values but not changes in a willingness to enact diversity valuing (inclusive) behaviors (Rodriguez-Simmonds et al., 2017).

Next, as women in engineering are known to often encounter obstacles and hurdles to overcome as they attempt to navigate their way into belonging in the primarily male-dominated engineering field (Godwin & Potvin, 2017b; Seymour, 1997; Sheppard et al., 2015) we sought to investigate the relationship between gender and IPEI. Being of marginalized status in the engineering field, it is not surprising that women demonstrated higher IPEIs than men—more personally identifying with the duties, responsibilities and knowledge of the value of diversity, inclusion and equity within the field than the dominant culture of men. Women were not only initially classified in the highest IPEI status (Class 3) at greater percentages than men (84% and 70%, respectively), but they also demonstrated significantly higher values on the underlying IPEI construct than men. Given the marginalized nature of women within engineering degree programs and professions, it is not surprising that they would more strongly endorse a professional identity that values diversity.

Of related importance, only 4% of women were initially classified into Class 1 (MH) demonstrating high values on the Enacting Inclusive Behavior factors compared to 11% of men. Together, this suggests that women are more likely than men to rate high on all four IPEI factors. On the contrary, for those not rating high on all IPEI factors, women are more hesitant than men to enact behaviors of inclusiveness. An alternative conclusion to this finding is that for those not rating high on all IPEI factors, men had a higher view of their willingness to act inclusively than the women did. It is difficult to distinguish which conclusion is accurate. It would be a noteworthy endeavor for future projects to also include an external measure of inclusive behaviors that would allow comparison with individuals' perceptions of themselves. Though specific reasons for women being potentially less likely to act inclusively were not the aim of this study, it is reasonable to conjecture that perhaps this finding signifies a lack of comfort of these women within the engineering field. Women who are continuing to work for acceptance and overcome norms in a male-dominated environment may be hesitant to point out problems in the culture or to single themselves out. In a study by Murphy and colleagues (2007), women STEM majors who viewed a video of a scientific conference with considerably more men than women reported a lesser sense of belonging and desire to participate in the conference compared to a gender-balanced group. Thus, the willingness of the women to act lessened as they were more marginalized.

Next, our investigation into the relationship between students' engineering identity and their IPEI yielded interesting results. The majority of students with the HH IPEI classification (Class 3) also had the "highest" engineering identity classification. Moreover, a much greater proportion of students initially in IPEI Class 1 (MH) also resided in the "lowest" engineering identity class rather than the "highest" engineering identity class. That is, for students not initially residing in the HH IPEI class, a greater proportion of students with the "lowest" engineering identity rated higher on the two Enacting Inclusive Behavior factors than students with the "highest" engineering identity. This in turn suggests less willingness of a portion of students with the "highest," most internalized, engineering identity to act inclusively on teams and challenge discriminatory behaviors when compared to students with the lowest level of internalization of their engineering identity. This is a critical finding. These students with the "highest" engineering identities are likely to persist within engineering. It is, therefore, imperative that intervention experiences continue to be geared directly towards helping these specific students cultivate a willingness to enact inclusive behaviors within engineering contexts.

Lastly, as this study resides within a larger research project focused on cultivating IPEIs within engineering majors, it was important to evaluate the effectiveness of the project's intervention practices on IPEI developmental patterns. Though no statistically significant differences were found initially between intervention and control groups on IPEI classifications, students involved in intervention experiences were significantly more likely to transition to different IPEI classifications over the first four weeks of the semester than students in control groups. Indeed, this signifies that early intervention experiences are capable of impacting students' IPEI development patterns and cultivation—instigating both positive and negative developmental patterns.

Perhaps students in intervention experiences during these first few weeks are simply gaining a better understanding and definition of what inclusivity and diversity are within the engineering context. This, in turn, could challenge students' prior beliefs about themselves in regards to inclusivity and diversity—yielding more accurate reflections of their true standings on the constructs at the second testing period. No matter the reasoning, intervention students presented an unstable, malleable, IPEI during the first few weeks of the semester in comparison to control students. This is good. To instigate change within the engineering culture regarding inclusivity and diversity, it is important to know that students' IPEIs are impressionable. Given that these students have the propensity to alter the trajectory of the engineering culture, documenting that their IPEIs are malleable provides a springboard into future investigations regarding how to positively cultivate their IPEIs towards higher classifications of valuing diversity and willingness to enact inclusive behaviors within engineering.

This finding also notes that students' encounters with inclusivity and diversity intervention experiences at the beginning of their undergraduate training are important. The intervention experience encountered during these early weeks included the Dean's welcome presentation. The Dean's welcome was given by the Deans of Engineering at each campus who were both White men. They addressed the students and encouraged attitudes valuing diversity and inclusion within the engineering program and field. Furthermore, this was the only intervention that was directed by someone at such a high level of authority. Other intervention experiences were led by faculty members, professionals, or students. Effects on students' IPEI developmental patterns following this intervention were documented. These effects are synonymous with the findings of Bennett and Sekaquaptewa (2014) who documented significantly greater changes in engineering students' attitudes towards diversity and intentions to confront racism after listening to a social norms message of egalitarianism than students' who did not listen to the message. They posited that individuals can be influenced by social norms messages, similar to the Dean's welcome address utilized during the first few weeks of this study (Bennett & Sekaquaptewa, 2014).

Furthermore, these findings are also similar to those of Godwin and colleagues (2017a) who studied first-year engineering students' attitudes about working in diverse teams and their perceptions of diversity using the CATME. Through the incorporation of diversity conversations at the beginning of students' first semester and revisiting diversity issues throughout students' first-year through teaming assignments, roles, and engineering design scenarios they found an increase in student development in their diversity awareness and their sensitivity over their first-year (Godwin et al., 2017a). At the same time, Godwin and colleagues (2017a) also noted increases in students' unwillingness to take action to support diverse teams. Thus, the results for their variable-centered study were mixed—suggesting positive and negative gains in students' value of diversity and willingness to act inclusively—perhaps suggesting the existence of instability (Godwin et al., 2017a).

4.1 Implications for Future Research

This study sets the groundwork for future investigations into Inclusive Professional Engineering Identity development and cultivation for engineering majors. Person-centered longitudinal, quantitative approaches are needed to continue investigating the development and successful cultivation of strong IPEIs throughout college. Though some instability in students' IPEI development patterns were observed over the first semester, this does not imply that further instability will be found with a more extensive longitudinal investigation. More study is needed to determine the stable and unstable nature of the IPEI throughout the college-tenure. This will enable scholars and researchers to detect periods of potential change in IPEIs and allow for more directed and effective intervention approaches.

Furthermore, prior research on professional identities believes that such identities are most malleable and formidable early within one's career—as this study also highlighted. Though the purpose of this manuscript was not to determine when the Inclusive Professional Engineering Identity begins forming within individuals, it is reasonable to assume that first-year engineering students are towards the beginning of this formation period. Future research studies would benefit from investigating IPEI formation within younger student populations to help determine when this professional identity begins forming.

More research is needed for the investigation into students' engineering identities, which are primarily stable, and students' IPEIs which show potential for change. In particular, focusing intervention efforts effective at cultivating IPEIs within students is particularly important for those with high internalizations of their engineering identities—noting that a proportion of these were found to be low in their willingness to enact inclusive behaviors within engineering. These students are likely to persist in engineering. In short, cultivating strong IPEIs within these students is critical to promoting diversity and inclusiveness within the engineering field.

Given the differences noted in this study between men and women's IPEIs, future research endeavors would benefit from exploring the reasons as to why these differences were found. Such theoretical investigations could include inquiries regarding stereotype threat, the Dunning-Kruger effect, or a communal goals perspective amongst many others. Understanding reasons as to why differences between men and women's IPEIs develop could be important to creating a more diverse and equitable engineering workforce.

This study also highlights the importance of intervention practices at instigating changes in students' IPEI development patterns. Though ultimately the desire is to cultivate strong IPEIs within engineering students as these are some of the primary individuals who will have the ability to alter the trajectory of the future engineering culture, this starts by documenting that IPEIs are indeed impressionable and capable of changing as the professional identity framework suggests. This study accomplished that. Future research should amplify the development and modification of intervention practices early in a student's collegiate tenure that are geared directly towards students' willingness to enact inclusive behaviors. Furthermore, future intervention practices should further investigate the effectiveness of top-down approaches.

4.2 Limitations

There are limitations to the present study that require attention. The sample size for this study, though adequate, was not optimal. A larger study with a more diverse sample obtained from a larger pool of higher education institutions across the US is needed to validate the results of this study.

The lack of a clear best fitting model is a limitation to this study. Though the 4-class solution was chosen, non-invariance was detected. Freeing the IB2 variable within each model, though not detrimental to the analysis, introduces some instability into the modeling framework and the comparison capabilities between models. Revisiting this issue with a larger sample is important to validating the results from this study.

Furthermore, though this study provided some insight into the underrepresented group of women engineers, other underrepresented groups were not considered as they accounted for too small of a percentage of the participants to be adequately modeled in the analytic approach. Not accounting for students' ethnicity potentially introduced some bias into this study and findings related to IPEIs. Additionally, this study did not account for students who selected a gender other than that of "man" or "woman." Though important, again, this group was too small to account for and was removed from the analytic sample during data cleaning. Unfortunately, many of these groups are too small to accurately model using several quantitative methods. Therefore, further qualitative work is needed with these populations and other smaller populations within engineering (e.g., LBGQT) to continue to gather and disseminate information about these marginalized groups so that their voices are heard.

Lastly, though the classification of students into one of three engineering identity classes and use of these classifications for investigations into relationships with IPEI classifications was based on previous findings, this methodology does introduce some inaccuracy into the modeling framework. The entropy of the 3-class engineering identity RI-LTA model was .86. It was good, but not perfect. However, prior research has shown these classifications to be stable across time. A student's average engineering identity score might change over time, but their engineering identity classification is stable. Thus, it was believed that this was the best way to describe and integrate student's engineering identities into the modeling framework for the present study.

5 Conclusion

This study sought to provide critical insights into the development patterns of undergraduate engineering students' IPEIs and several of the variables influencing IPEI development patterns and cultivation over time by utilizing the new person-centered analytical approach of Random Intercept Latent Transition Analysis. The use of this new approach produced several important findings. Students' IPEIs demonstrated some probabilistic likelihood to change over time with intervention experiences enhancing the likelihoods for changes to occur. Continuing to investigate factors influencing the successful cultivation of students' IPEIs—including the formation and implementation of interventions that produce positive IPEI developmental patterns—is fundamental to broadening participation in engineering and making the engineering culture more inclusive.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant #1725880. Any options, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

Atadero, R. A., Paguyo, C., Rambo-Hernandez, K. E., & Henderson, H. L. (2016, June), *Promoting Inclusive Engineering Identities in First-Year Engineering Courses.* Paper presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana. 10.18260/p.25994

Atadero, R. A., Paguyo, C. H., Rambo-Hernandez, K. E., & Henderson, H. L. (2017). Building inclusive engineering identities: Implications for changing engineering culture. *European Journal of Engineering Education, 43(3),* 378–398.

Baldwin, R. G. (2009). The climate for undergraduate teaching and learning in STEM fields. *New Directions for Teaching and Learning*, 9–17. https://doi.org/10.1002/tl.340

Barker, L. J., O'Neill, M., & Kazim, N. (2014, March). Framing classroom climate for student learning and retention in computer science. In *Proceedings of the 45th ACM technical symposium on Computer science education* (pp. 319-324).

Bennett, J. E., & Sekaquaptewa, D. (2014). Setting an egalitarian social norm in the classroom: Improving attitudes towards diversity among male engineering students. *Social Psychology of Education*, *17*(2), 343-355.

Bensimon, E. M., & Dowd, A. C. (2012). *Developing the capacity of faculty to become institutional agents for Latinos in STEM.* University of Southern California.

Burleson, S. D., Major, D. A., Hu, X., & Shryock, K. J. (2021). Linking undergraduate professional identity development in engineering to major embeddedness and persistence. *Journal of Vocational Behavior, 128.*

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching, 44*(8), 1187–1218.

Casper, A.M., Atadero, R.A., Hedayati-Mehdiabadi, A., & Baker, D.W. (2021). Linking Engineering Students' Professional Identity Development to Diversity and Working Inclusively in Technical Courses. *Journal of Civil Engineering Education, 147.*

Chemers, M. M., Zurbriggen, E. L., Syed, M., Goza, B. K., & Bearman, S. (2011). The role of efficacy and identity in science career commitment among underrepresented minority students. *Journal of Sociological Issues, 67,* 469–491.

Clark, S. L. (2010). *Mixture modeling with behavioral data.* [Unpublished doctoral dissertation] University of California, Los Angeles.

Eliot, M., & Turns, J. (2011). Constructing professional portfolios: Sense-making and professional identity development for engineering undergraduates. *Journal of Engineering Education, 100(4),* 630–654. https://doi.org/10.1002/j.2168-9830.2011.tb00030.x.

Erikson, E. H. (1959). *Identity and the life cycle*. New York, NY: Norton.

Finelli, C., & Kendall-Brown, M. (2009). Using an interactive theater sketch to improve students' perceptions about and ability to function on diverse teams. American Society for Engineering Education. Austin, TX.

Fonseca, J. R., & Cardoso, M. G. (2007). Mixture-model cluster analysis using information theoretical criteria. *Intelligent Data Analysis, 11,* 155-173. doi:10.3233/ida-2007-11204

Foor, C. E., Walden, S. E., & Trytten, D. A. (2013). “I wish that I belonged more in this whole engineering group”: Achieving individual diversity. *Journal of Engineering Education,* 96(2), 103–115. https://doi.org/10 .1002/j.2168-9830.2007.tb00921.x

Fry, R., Kennedy, B., & Funk, C. (2021). STEM jobs see uneven progress in increasing gender, racial and ethnic diversity. *Pew Research Center.* Retrieved from https://www.pewresearch.org/science/wp-content/uploads/sites/16/2021/03/PS_2021.04.01_diversity-in-STEM_REPORT.pdf

Gee, J. P. (2000). Identity as an analytic lens for research in education. *Review of Research in Education, 25,* 99–125.

Godwin, A. (2016). *The development of a measure of engineering identity.* Paper presented at the American Society for Engineering Education 123rd Conference & Exposition, New Orleans, June 26-29.

Godwin, A., Benedict, B., Rohde, J., Thielmeyer, A., Perkins, H., Major, J., … Chen, Z. (2021). New epistemological perspectives on quantitative methods: An example using topological data analysis. *Studies in Engineering*, *2*(1), 16–34.DOI: https://doi.org/10.21061/see.18

Godwin, A., Kirn, A., & Rohde, J. A. (2017a). Awareness without action: Student attitudes towards team diversity after engineering teaming experiences. *International Journal of Engineering Education, 33(6A),* 1878-1891.

Godwin, A., & Potvin, G. (2017b). Pushing and pulling Sara: A case study of the contrasting influences of high school and university experiences on engineering agency, identity, and participation. *Journal of Research in Science Teaching, 54(4),* 439-462.

Ibarra, H. (1999). Provisional selves: Experimenting with image and identity in professional adaptation. *Administrative Science Quarterly, 44(4),* 764–791. https://doi. org/10.2307/2667055

Ibarra, H. (2004). Becoming yourself: Identity, networks and the dynamics of role transition. In *Paper presented at the 2003 Academy of Management annual meeting, Seattle, WA*.

Jung, T., & Wickrama, K. A. S. (2008). An introduction to latent class growth analysis and growth mixture modeling. *Social and Personality Psychology Compass, 2(1),* 302-317.

Kline, P. (1999). *A handbook of psychological testing, 2nd edition*. London: Routledge.

Leydens, J. A., & Lucena, J. C. (2017). Engineering justice: Transforming engineering education and practice. *Wiley-IEEE Press.* https://doi.org/10 .1002/9781118757369

Lezotte, S. (2021). Making sense of diversity and inclusion in engineering. *Journal of Diversity in Higher Education.* http://dx.doi.org/10.1037/dhe0000371

Lichtenstein, G., Chen, H. L., Smith, K. A., & Maldonado, T. A. (2015). Retention and persistence of women and minorities along the engineering pathway in the United States. In *Cambridge Handbook of Engineering Education Research* (pp. 311-334). Cambridge University Press. https://doi.org/10.1017/CBO9781139013451.021

Little, R. J. A., & Rubin, D. B. (1987). *Statistical analysis with missing data*. New York: Wiley.

Lockhart, M. E., & Rambo-Hernandez, K. (2023). Investigating engineering identity development and stability amongst first-year engineering students: A person-centered approach. *European Journal of Engineering Education.* https://doi.org/10.1080/03043797.2023.2262412

Luyckx, K., Schwartz, S. J., Goossens, L., Soenens, B., & Beyers, W. (2008b). Developmental typologies of identity formation and adjustment in female emerging adults: A latent class growth analysis approach. *Journal of Research on Adolescence, 18*, 595–619.

McCave, E.J., Gilmore, J., & Burg, K. (2014). *Engineering and science student preparedness for research: Exploring the connections between student identity and readiness for research.* Paper presented at the American Society for Engineering Education Annual Conference, Indianapolis, IN.

Meeus, W., Van de Schoot, R., Keijsers, L., Schwartz, S. J., & Branje, S. (2012). Identity statuses as developmental trajectories: A five-wave longitudinal study in early-to-middle and middle-to-late adolescence. *Journal of Youth and Adolescence, 41,* 1008–1021.

Mohd-Yusof, K., Phang, F. A., Sadikin, A. N., Helmi, S. A., & Kamaruddin, M. J. (2014, June). *Determining the Effect of an Engineering Overview Assignment on First-Year Students.* Paper presented at the American Society for Engineering Education Annual Conference & Exposition.

Murphy, M. C., Steele, C. M., & Gross, J. J. (2007). Signaling threat: How situational cues affect women in math, science, and engineering settings. *Psychological Science, 18(10),* 879–85.

Muthén, B. (2021 February 28). *Using Mplus to do latent transition analysis and random intercept latent transition analysis* [Video file]. Retrieved from https://www.youtube.com/c/MplusVideos

Muthén, B., & Asparouhov, T. (2020, November 23). Latent Transition Analysis with Random Intercepts (RI-LTA). Psychological Methods. Advance online publication. http://dx.doi.org/10.1037/met0000370

Muthén, L. K., & Muthén, B. O. (1998-2021). *Mplus user's guide (eighth edition).* Muthén & Muthén.

National Science Foundation. (2021). *Women, minorities, and persons with disabilities in science and engineering.* National Science Foundation. Retrieved from https://ncses.nsf.gov/pubs/nsf21321/report/field-of-degree-minorities

Ong, M., Jaumot-Pascula, N., & Ko, L. T. (2020). Research literature on women of color in undergraduate engineering education: A systematic thematic synthesis. *Journal of Engineering Education, 109(3)*, 581–615.

Owen, C. & Rolfes, D. (2015). *Communication class size and professional identity.* Paper presented at the American Society for Engineering Education Annual Conference, Seattle, WA.

Paguyo, C. H., & Nosaka, T. (2018). Practitioner-experts and researchers in layers of learning: Researching and designing interventions in postsecondary education through the grammar of equity. In E. Mendoza, B. Kirshner, & K. D. Gutiérrez (eds), *Power, Equity, and (Re)Design* (pp. 149-166). Charlotte, NC: Information Age Publishing.

Ramaswamy, V., DeSarbo, W. S., Reibstein, D. J., & Robinson, W. T. (1993). An empirical pooling approach for estimating marketing mix elasticities with PIMS data. *Marketing Science, 12,* 103-124. doi:10.1287/mksc.12.1.103

Rambo-Hernandez, K. E., Atadero, R. A., Paguyo, C. H., Morris, M., Park, S., Casper, A. M., Pederson, B. A., Schwartz, J., & Hensel, R. A. (2021). Valuing diversity and enacting inclusion in engineering (VDEIE): Validity evidence for a new scale. *International Journal of Engineering Education*, *37*(5), 1382-1397. www.ijee.ie/1atestissues/Vol37-5/19_ijee4112.pdf

Revelo, R. A., Omitoyin, J., Cardona, M., Nazempour, R., & Darabi, H. (2019). *Engineering identity profiles of low-SES, high achieving incoming engineering students.* Paper presented at the IEEE Frontiers in Education Conference (FIE), Cincinnati, OH.

Robinson, K. A., Perez, T., Carmel, J. H., & Linnenbrink-Garcia, L. (2019). Science identity development trajectories in a gateway college chemistry course: Predictors and relations to achievement and STEM pursuit. *Contemporary Educational Psychology*, *56*, 180–192. https://doi.org/10.1016/j.cedpsych.2019.01.004

Robinson, K. A., Perez, T., Nuttall, A. K., Roseth, C. J., & Linnenbrink-Garcia, L. (2018). From science student to scientist: Predictors and outcomes of heterogeneous science identity trajectories in college. *Developmental Psychology*, *54*(10), 1977–1992. https://doi.org/10.1037/dev0000567

Rodriguez, S. L., Lu, C., & Bartlett, M. (2018). Engineering identity development: A review of the higher education literature. *International Journal of Education in Mathematics, Science and Technology, 6(3),* 254–265.

Seymour, E., & Hewitt, N. M. (1997). *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview Press.

Seymour, E., & Hunter, A. B. (Eds.). (2019). Talking About Leaving Revisited: Persistence, Relocation, and Loss in Undergraduate STEM Education. Springer.

Shanahan, L., Copeland, W. E., Worthman, C. M., Erkanli, A., Angold, A., & Costello, E. J. (2013). Sex-differentiated changes in C-reactive protein from ages 9 to 21: The contributions of BMI and physical/sexual maturation. *Psychoneuroendocrinology, 38(10),* 2209-2217. https://doi.org/10.1016/j.psyneuen.2013.04.010

Sheppard, S., Antonio, A., Brunhaver, S. & Gilmartin, S. (2015). Studying the career pathways of engineers: An illustration with two data sets. In *Cambridge Handbook of Engineering Education Research* (pp. 283–310). Cambridge, UK: Cambridge University Press.

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology, 69(5*), 797–811. doi:10.1037/0022-3514.69.5.797.

Strauss, K., Griffin, M. A., & Parker, S. K. (2012). Future work selves: how salient hoped-for identities motivate proactive career behaviors. *The Journal of applied psychology*, *97*(3), 580–598. https://doi.org/10.1037/a0026423

Tierney, W. G. (1991). Academic work and institutional culture: Constructing knowledge. *The Review of Higher Education, 14(2),* 199–216. https:// doi.org/10.1353/rhe.1991.0024

Tonso, K. L. (2014). Engineering identity. In A. Johri & B. Olds (Eds.), *Cambridge handbook of engineering education research* (pp. 267-282). New York, NY: Cambridge University Press.

Trytten, D. A., Pan, R., Shehab, R. L., & Walden, S. E. (2015). *Inclusion or exclusion? The impact of the intersection of team culture and student identity and pathway on team diversity.* Paper presented at the American Society for Engineering Education Annual Conference, Seattle, WA.

Walton, G. M., Logel, C., Peach, J. M., Spencer, S. J., & Zanna, M. P. (2015). Two brief interventions to mitigate a 'chilly climate' transform women's experience, relationships, and achievement in engineering. *Journal of Educational Psychology, 107(2).* https://doi.org/10.1037/a0037461.

Appendix A

Valuing Diversity and Enacting Inclusion in Engineering (VDEIE) Scale

Valuing Diversity

Engineers should value diversity to:

Fulfill a Greater Purpose (VD1 Items)
1. Fulfill a social responsibility for making the world better.
2. Work for a greater cause.
3. Help improve the bottom line.
4. Do the right thing.

Serve Customers Better (VD2 Items)
1. Help them understand client and customer needs.
2. Improve products.
3. Increase public access to technology and engineered products.
4. Collaborate effectively with stakeholders in an engineering project.

Inclusive Behaviors

While working on a team, I:

Promote Healthy Behaviors (IB1 Items))
1. Include everyone in all team meetings.
2. Make sure to give credit to team members who make contributions to the project.
3. Make sure all team members have the opportunity to take part in decision-making.
4. Make sure every team member has the opportunity to contribute to the project.

Challenge Discriminatory Behaviors (IB2 Items)
1. Challenge homophobic behaviors.
2. Challenge racist behaviors.
3. Challenge any type of discriminatory behaviors.
4. Challenge sexist behaviors.
5. Challenge xenophobic behaviors, which are behaviors that discriminate against people from other countries.

Appendix B

Descriptive Statistics and Correlation Matrix of Study Variables

	M	SD	VD1_1	VD2_1	IB1_1	IB2_1	VD1_2	VD2_2	IB1_2	IB2_2	VD1_3	VD2_3	IB1_3	IB2_3	VD1_4	VD2_4	IB1_4	IB2_4
VD1_1	5.92	1.00	1.00															
VD2_1	6.12	.76	.68	1.00														
IB1_1	6.31	.66	.31	.44	1.00													
IB2_1	5.86	1.07	.35	.37	.45	1.00												
VD1_2	5.89	1.04	.63	.50	.25	.27	1.00											
VD2_2	6.08	.86	.47	.53	.27	.29	.75	1.00										
IB1_3	6.28	.76	.22	.30	.52	.28	.32	.41	1.00									
IB2_3	5.91	1.11	.03	.06	.14	.10	.06	.14	.29	1.00								
VD1_3	5.82	1.05	.23	.26	.32	.22	.23	.24	.50	.24	1.00							
VD2_3	6.01	.87	.20	.24	.36	.19	.20	.25	.58	.24	.76	1.00						
IB1_3	6.25	.77	.12	.17	.22	.10	.12	.14	.35	.26	.33	.43	1.00					
IB2_3	5.90	1.08	.10	.11	.13	.09	.09	.12	.25	.70	.34	.37	.51	1.00				
VD1_4	5.90	1.02	.15	.21	.35	.19	.20	.27	.52	.20	.68	.49	.32	.24	1.00			
VD2_4	6.05	.88	.12	.20	.36	.16	.16	.26	.57	.21	.48	.58	.36	.24	.73	1.00		
IB1_4	6.24	.81	.10	.13	.23	.11	.14	.18	.34	.25	.35	.38	.60	.37	.41	.48	1.00	
IB2_4	5.94	1.08	.05	.03	.14	.09	.08	.15	.28	.66	.32	.32	.40	.77	.33	.31	.55	1.00

Note. M = Mean, SD = Standard Deviation, VD1_1 = *Value Diversity in Engineering to Fulfill a Greater Purpose Factor at time 1,* VD2_1 = *Value Diversity to Serve Customers Better Factor at time 1,* IB1_1 = *Enact Inclusive Behaviors in Engineering by Promoting Healthy Behaviors Factor at time 1, and* IB2_1 = *Enact Inclusive Behaviors in Engineering by Challenging Discriminatory Behaviors Factor at time 1,* and so on.

Appendix C

Class Intercept Estimates and Standard Errors for the 2,3,4, and 5-Class RI-LTA Models

	2-Class Solution – Intercept (S.E.)		3-Class Solution – Intercept (S.E.)			4-Class Solution – Intercept (S.E.)				5-Class Solution – Intercept (S.E.)				
	Class 1	Class 2	Class 1	Class 2	Class 3	Class 1 - MH	Class 2 – HM	Class 3 - MM	Class 4 - HH	Class 1	Class 2	Class 3	Class 4	Class 5
VD1	4.35 (.09)	6.21 (.03)	6.22 (.03)	3.99 (.12)	5.20 (.14)	4.04 (.14)	5.95 (.09)	4.77 (.20)	6.22 (.03)	4.25 (.19)	4.74 (.16)	6.00 (.09)	3.72 (.20)	6.22 (.03)
VD2	4.97 (.08)	6.30 (.02)	6.31 (.03)	4.93 (.11)	5.33 (.14)	4.96 (.14)	6.13 (.06)	4.90 (.21)	6.32 (.03)	4.33 (.18)	4.85 (.17)	6.14 (.06)	5.97 (.13)	6.31 (.03)
IB1	5.90 (.07)	6.35 (.02)	6.44 (.03)	6.39 (.05)	4.93 (.16)	6.41 (.06)	6.07 (.09)	4.71 (.13)	6.44 (.03)	6.44 (.06)	4.79 (.13)	6.03 (.10)	6.38 (.10)	6.45 (.03)
IB2	5.62 (.08)	5.95 (.03)	6.07 (.06)	5.81 (.12)	4.72 (.13)	6.08 (.14)	4.22 (.17)	4.73 (.13)	6.32 (.04)	6.15 (.13)	4.74 (.12)	4.23 (.13)	5.90 (.24)	6.32 (.04)

Note. S.E. = *Standard Error,* VD1 = *Value Diversity in Engineering to Fulfill a Greater Purpose Factor,* VD2 = *Value Diversity to Serve Customers Better Factor,* IB1= *Enact Inclusive Behaviors in Engineering by Promoting Healthy Behaviors Factor, and* IB2 = *Enact Inclusive Behaviors in Engineering by Challenging Discriminatory Behaviors Factor,* MH = *Medium-High*, HM = *High-Medium*, MM = *Medium-Medium,* HH = *High-High,* Class intercepts and standard errors are held constant across timepoints by default.

Appendix D

Class Intercept Estimates, Standard Errors and Proportions for the 4-Class RI-LTA Model with IB2 Noninvariant

	Time 1 - Intercept (S.E.)				Time 2 – Intercept (S.E.)				Time 3 – Intercept (S.E.)				Time 4 – Intercept (S.E.)			
	Class 1 MH	Class 2 HM	Class 3 HH	Class 4 MM	Class 1 MH	Class 2 HM	Class 3 HH	Class 4 MM	Class 1 MH	Class 2 HM	Class 3 HH	Class 4 MM	Class 1 MH	Class 2 HM	Class 3 HH	Class 4 MM
Proportion of Participants	.10	.14	.72	.04	.10	.15	.68	.08	.10	.12	.69	.09	.07	.13	.70	.10
VD1	4.03(.16)	5.89 (.11)	6.22 (.04)	4.82 (.34)	4.03 (.16)	5.89 (.11)	6.22 (.04)	4.82 (.34)	4.03 (.16)	5.89 (.11)	6.22 (.04)	4.82 (.34)	4.03 (.16)	5.89 (.11)	6.22 (.04)	4.82 (.34)
VD2	4.88 (.15)	6.11 (.07)	6.32 (.03)	4.95 (.37)	4.88 (.15)	6.11 (.07)	6.32 (.03)	4.95 (.37)	4.88 (.15)	6.11 (.07)	6.32 (.03)	4.95 (.37)	4.88 (.15)	6.11 (.07)	6.32 (.03)	4.95 (.37)
IB1	6.38 (.05)	6.06 (.19)	6.45 (.03)	4.70 (.13)	6.38 (.05)	6.06 (.19)	6.45 (.03)	4.70 (.13)	6.38 (.05)	6.06 (.19)	6.45 (.03)	4.70 (.13)	6.38 (.05)	6.06 (.19)	6.45 (.03)	4.70 (.13)
IB2	5.63 (.19)	4.27 (.19)	6.27 (.05)	4.61 (.28)	6.07 (.11)	4.08 (.20)	6.28 (.06)	5.86 (.40)	6.30 (.15)	4.08 (.25)	6.31 (.05)	4.50 (.17)	6.51 (.12)	4.21 (.26)	6.37 (.05)	4.69 (.22)

Note. S.E. = *Standard Error,* VD1 = *Value Diversity in Engineering to Fulfill a Greater Purpose Factor,* VD2 = *Value Diversity to Serve Customers Better Factor,* IB1= *Enact Inclusive Behaviors in Engineering by Promoting Healthy Behaviors Factor, and* IB2 = *Enact Inclusive Behaviors in Engineering by Challenging Discriminatory Behaviors Factor,* MH = *Medium-High*, HM = *High-Medium*, HH = *High-High, and* MM = *Medium-Medium. IB2 allowed to vary across time due to invariance testing.*

Appendix E

Effect of Gender on Transition Probability Odds Ratios

		C1 (MH)	C2 (HM)	C3 (HH)	C4 (MM)
		Time 2			
Time 1	C1	1.00 (1.00, 1.00)	2.90 (.79, 10.69)	2.51 (.68, 9.30)	.76 (.09, 6.33)
	C2	.34 (.09, 1.27)	1.00 (1.00, 1.00)	.87 (.40, 1.89)	.26 (.04, 1.92)
	C3	.40 (.11, 1.47)	1.16 (.53, 2.53)	1.00 (1.00, 1.00)	.30 (.06, 1.51)
	C4	1.31 (.16, 10.85)	3.80 (.52, 27.78)	3.29 (.66, 16.29)	1.00 (1.00, 1.00)
		Time 3			
Time 2	C1	1.00 (1.00, 1.00)	.95 (.17, 5.28)	.79 (.24, 2.64)	.77 (.20, 3.01)
	C2	1.05 (.19, 5.06)	1.00 (1.00, 1.00)	.83 (.22, 3.11)	.81 (.24, 2.66)
	C3	1.27 (.38, 4.25)	1.21 (.32, 4.52)	1.00 (1.00, 1.00)	.97 (.30, 3.11)
	C4	1.31 (.33, 5.14)	1.24 (.38, 4.09)	1.03 (.32, 3.30)	1.00 (1.00, 1.00)
		Time 4			
Time 3	C1	1.00 (1.00, 1.00)	.29 (.04, 2.35)	.67 (.17, 2.71)	.25 (.02, 3.13)
	C2	3.45 (.43, 27.88)	1.00 (1.00, 1.00)	2.32 (.41, 13.08)	.86 (.11, 6.96)
	C3	1.48 (.37, 5.96)	.43 (.08, 2.42)	1.00 (1.00, 1.00)	.37 (.07, 1.95)
	C4	3.99 (.32, 49.82)	1.16 (.144, 9.33)	2.69 (.51, 14.09)	1.00 (1.00, 1.00)

Note. Odds ratio (non-symmetric 95% confidence interval centered at 1.00). MH = Medium-High, HM = High-Medium, HH = High-High, MM = Medium-Medium.

Appendix F

Effect of Engineering Identity Class 1 on Transition Probability Odds Ratios

		C1 (MH)	C2 (HM)	C3 (HH)	C4 (MM)
		Time 2			
Time 1	C1	1.00 (1.00, 1.00)	.62 (.09, 4.23)	.63 (.12, 3.18)	.63 (.08, 5.04)
	C2	1.62 (.24, 11.12)	1.00 (1.00, 1.00)	1.01 (.34, 3.02)	1.02 (.19, 5.63)
	C3	1.60 (.31, 8.12)	.99 (.33, 2.94)	1.00 (1.00, 1.00)	1.01 (.28, 3.62)
	C4	1.59 (.20, 12.68)	.98 (.18, 5.34)	.99 (.28, 3.57)	1.00 (1.00, 1.00)
		Time 3			
Time 2	C1	1.00 (1.00, 1.00)	.30 (.05, 1.90)	.86 (.22, 3.41)	.29 (.04, 2.04)
	C2	3.38 (.53, 21.70)	1.00 (1.00, 1.00)	2.89 (.35, 24.11)	.99 (.13, 7.26)
	C3	1.17 (.29, 4.65)	.35 (.04, 2.89)	1.00 (1.00, 1.00)	.34 (.04, 3.28)
	C4	3.42 (.49, 23.85)	1.01 (.14, 7.44)	2.92 (.31, 28.02)	1.00 (1.00, 1.00)
		Time 4			
Time 3	C1	1.00 (1.00, 1.00)	1.31 (.07, 25.37)	2.48 (.28, 21.64)	.65 (.03, 14.26)
	C2	.76 (.04, 14.82)	1.00 (1.00, 1.00)	1.89 (.13, 28.35)	.50 (.01, 31.22)
	C3	.40 (.05, 3.52)	.53 (.04, 7.90)	1.00 (1.00, 1.00)	.26 (.02, 3.39)
	C4	1.53 (.07, 33.51)	2.01 (.03, 125.60)	3.80 (.30, 48.94)	1.00 (1.00, 1.00)

Note. Odds ratio (non-symmetric 95% confidence interval centered at 1.00). MH = Medium-High, HM = High-Medium, HH = High-High, MM = Medium-Medium.

Appendix G

Effect of Engineering Identity Class 2 on Transition Probability Odds Ratios

		C1 (MH)	C2 (HM)	C3 (HH)	C4 (MM)
		Time 2			
Time 1	C1	1.00 (1.00, 1.00)	1.77 (.58, 5.40)	1.79 (.66, 4.90)	.81 (.21, 3.20)
	C2	.57 (.19, 1.72)	1.00 (1.00, 1.00)	1.01 (.53, 1.93)	.46 (.14, 1.47)
	C3	.56 (.20, 1.53)	.99 (.52, 1.89)	1.00 (1.00, 1.00)	.45 (.18, 1.17)
	C4	1.23 (.31, 4.85)	2.18 (.68, 7.00)	2.20 (.86, 5.68)	1.00 (1.00, 1.00)
		Time 3			
Time 2	C1	1.00 (1.00, 1.00)	.93 (.29, 2.93)	.95 (.36, 2.53)	.91 (.32, 2.60)
	C2	1.08 (.34, 3.40)	1.00 (1.00, 1.00)	1.03 (.32, 3.31)	.98 (.38, 2.58)
	C3	1.05 (.40, 2.79)	.98 (.30, 3.15)	1.00 (1.00, 1.00)	.96 (.37, 2.48)
	C4	1.09 (.39, 3.13)	1.02 (.39, 2.67)	1.04 (.40, 2.70)	1.00 (1.00, 1.00)
		Time 4			
Time 3	C1	1.00 (1.00, 1.00)	1.18 (.10, 14.43)	.82 (.28, 2.45)	.88 (.20, 3.88)
	C2	.85 (.07, 10.36)	1.00 (1.00, 1.00)	.70 (.08, 5.82)	.74 (.04, 15.26)
	C3	1.22 (.41, 3.62)	1.44 (.17, 11.99)	1.00 (1.00, 1.00)	1.07 (.25, 4.46)
	C4	1.14 (.26, 5.06)	1.35 (.07, 27.72)	.94 (.22, 4.09)	1.00 (1.00, 1.00)

Note. Odds ratio (non-symmetric 95% confidence interval centered at 1.00). MH = Medium-High, HM = High-Medium, HH = High-High, MM = Medium-Medium.

Appendix H

Effect of Intervention Status on Transition Probability Odds Ratios

		C1 (MH)	C2 (HM)	C3 (HH)	C4 (MM)
		Time 2			
Time 1	C1	1.00 (1.00, 1.00)	15.12 (2.79, 82.04)*	4.42 (1.26, 15.55)*	9.00 (1.71, 47.32)*
	C2	.07 (.01, .36)*	1.00 (1.00, 1.00)	.29 (.10, .88)*	.60 (.13, 2.83)
	C3	.23 (.06, .80)*	3.42 (1.14, 10.27)*	1.00 (1.00, 1.00)	2.04 (.62, 6.72)
	C4	.11 (.02, .58)*	1.68 (.35, 7.98)	.49 (.15, 1.62)	1.00 (1.00, 1.00)
		Time 3			
Time 2	C1	1.00 (1.00, 1.00)	.49 (.10, 2.52)	.46 (.15, 1.38)	.46 (.09, 2.36)
	C2	2.03 (.40, 10.43)	1.00 (1.00, 1.00)	.93 (.25, 3.40)	.94 (.19, 4.63)
	C3	2.19 (.72, 6.63)	1.08 (.29, 3.94)	1.00 (1.00, 1.00)	1.01 (.24, 4.28)
	C4	2.16 (.42, 11.06)	1.07 (.22, 5.24)	1.00 (.23, 4.24)	1.00 (1.00, 1.00)
		Time 4			
Time 3	C1	1.00 (1.00, 1.00)	3.10 (.16, 58.40)	1.83 (.43, 7.74)	1.76 (.27, 11.31)
	C2	.32 (.40, 6.09)	1.00 (1.00, 1.00)	.59 (.04, 8.90)	.57 (.04, 8.81)
	C3	.55 (.13, 3.65)	1.69 (.11, 25.40)	1.00 (1.00, 1.00)	.96 (.22, 4.20)
	C4	.57 (.09, 3.65)	1.76 (.11, 27.27)	1.04 (.24, 4.57)	1.00 (1.00, 1.00)

Note. Odds ratio (non-symmetric 95% confidence interval centered at 1.00). MH = Medium-High, HM = High-Medium, HH = High-High, MM = Medium-Medium.

Author Biographies

Mary Elizabeth Lockhart is a Postdoctoral Research Associate in the Department of Teaching, Learning and Culture at Texas A&M University, College Station, TX, 77843-4232, mlockhart@tamu.edu.

Karen E. Rambo-Hernandez is an Associate Professor in the Department of Educational Psychology and the Department of Teaching, Learning and Culture at Texas A&M University, College Station, TX, 77843-4232, rambohernandez@tamu.edu.

Rebecca A. Atadero is a Professor in the Department of Civil and Environmental Engineering at Colorado State University, Fort Collins, CO, 80523-1372, Rebecca.Atadero@colostate.edu.