# Factors Influencing Engineering Identity Development of Latinx Students

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***Abstract*—*Contribution:*** **This study explores the factors contributing to the development of engineering identity in Latinx students at two institutions. A better understanding of these factors will support the development of more inclusive engineering education environments and experiences.**

***Background:*** **Persistence of Latinx engineering students is of particular interest due to their underrepresentation in the field. Identity is a lens for understanding student persistence, but Latinx students are underrepresented in prior engineering identity studies. This study seeks to identify the unique factors, academic and professional, that contribute to engineering identity development, and potential means for supporting the persistence of Latinx engineers.**

***Research Questions:*** **(1) What academic and professional affect factors predict engineering identity development of Latinx students? and (2) What role does the institution play in Latinx students' engineering identity development?**

***Methodology:*** **A mixed-methods approach was used to measure engineering identity based on a framework incorporating both academic and professional affect elements. Regression analyses were conducted on 892 responses to an online survey from Latinx engineering students, with additional insight from interviews with ten Latinx engineering students.**

***Findings:*** **Six of the nine factors analyzed (performance/competence, interest, recognition, analysis, framing and solving problems, and tinkering) were significant predictors of Latinx students' engineering identity, as were institution, gender, and having a parent with an engineering degree. Engineering identity was higher for Latinx students at the Hispanic Serving Institution, but none of the interaction terms were significant, so the relationship between these factors and engineering identity is similar at each institution.**

***Index Terms*—Engineering identity, Hispanic-serving institutions (HSIs), Latinx, mixed methods research, race/ethnicity, professional skills, undergraduate, underrepresentation**

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## I. Introduction

THE Latinx and Hispanic population in the U.S., inclusive of a variety of Spanish-speaking and Latin-American cultures, is substantial and growing. Latinx students were the largest minority group enrolled in the nation's four-year institutions in 2012 [1]. Within engineering, Latinx students make up nearly 10% of Bachelor's degree recipients, up from 6.8% in 2000, making it the largest minority group in U.S. engineering schools [2]. With this growing population, continued work is needed to ensure that these students are supported and persist in engineering.

One lens used to explain, and subsequently seek to improve, the persistence of students in a particular field is how a student identifies with that field [3]. However, few prior identity studies have focused on the engineering identity of Latinx students. Though prior studies have reported a variety of different factors that contribute to identity, described below, one factor of interest in this study is the role of the academic institution in Latinx students' engineering identity development.

Overwhelmingly, Latinx students enroll in Hispanic-Serving Institutions (HSIs) to pursue an academic degree [4]. Of Latinx students pursuing engineering degrees, 59% obtain their degrees from HSIs [5]. Due to gaps in the STEM workforce [6], HSIs play an important role in encouraging the recruitment and retention of Latinx students in the STEM disciplines. Therefore, understanding how these institutions impact students' engineering identity is valuable in identifying methods for supporting Latinx students' persistence in the field.

As described by Lent *et al.* [7] and expanded on by Estrada *et al.* [8], social influence—the feedback students receive from individuals in their environment—is a powerful factor in Latinx students' persistence. Further, students have expressed the value of establishing a *familia* within their engineering community [9]. Given the importance of community to Latinx students and the role that institutions can play in forming that community, this study explores factors that predict Latinx students' engineering identity development, including institution type. Knowledge of these factors would benefit educators at HSIs and other institutions invested in seeing their Latinx students develop and persist as engineers.

## II. Background and Theoretical Framework

### *A. The Role of Hispanic-Serving Institutions in Educating Latinx Engineers*

The Hispanic Association of Colleges and Universities defines Hispanic-Serving Institutions (HSIs) as not-for-profit public or private institutions whose student body consists of at least 25% Hispanic-identifying students [10]; slightly over half of these are two-year institutions [11]. For many institutions, the achievement of this HSI designation is largely due to

changes in the demographic makeup of the population in the surrounding geographic area; most were previously Predominantly White Institutions (PWIs) [10].

While almost 50% of Latinx students attend an HSI, HSIs constitute only 6% of higher education institutions in the U.S. [10]. Therefore, HSIs heavily influence the type of education received by Latinx students and their resulting college experiences. While HSIs play an important role in outcomes of Latinx students, such as retention, they are also uniquely equipped to culturally serve Latinx students through relevant support programs and inclusive curricula [12], [13]. Cost of attendance and proximity to home are influential in student selection to enroll in an HSI [14], with Latinx students often unaware of the HSI designation until after enrollment [15]. HSIs offer a unique setting for Latinx students to explore and develop their identities that may not be available at a non-HSI, with additional opportunities to join organizations and complete coursework relevant to their cultural identity [16]. Latinx students attending an HSI are at least as likely to graduate as those attending PWIs [17]. With a reported larger impact on first-year students and seniors, attending an HSI also has a positive influence on Latinx student engagement [18].

When considering the impact that attending an HSI has on students pursuing a STEM degree, Latinas were found to be intrinsically motivated by their interest in pursuing a challenge, and rely heavily on familial support during their studies [19]. Latinx STEM students who participated in undergraduate research experiences at an HSI were found to have less communication with faculty advisors about future career paths than white students, and had the impression that research was only for scientists [20]. Latinx students were found to declare a STEM major more often than white students at an HSI, and were as likely to complete their STEM degree [21]. Interventions, such as peer mentoring programs and math and science resource centers, can increase the retention and graduation rates of Latinx STEM students [22].

### *B. Engineering Identity*

Identity has emerged as a potential lens for improving recruitment, retention, and persistence of students in the engineering profession [23], [24], [25]. The hypothesis is that students with stronger engineering identities are more likely to persist in engineering. This study utilizes several identity theories from psychology and science education, and the engineering identity framework presented in the authors' prior publications [24], [26], [27].

In engineering education, researchers have converged on the use of the Multiple Identities framework [28], [29], [30], [31]. Based on Gee's [3] use of a multiple identity framework as a lens for understanding the educational process, Carlone and Johnson [32] used qualitative research to break students' physics identity into factors related to competence, performance, and recognition. Later, Hazari *et al.* [33] used quantitative approaches to expand this science identity framework to include interest and found that competence and performance loaded on the same factor. Two research groups [23], [25] have demonstrated that this model of identity adapts well to engineering undergraduates with three factors similar to Hazari's: an individual's sense of engineering competence/performance, engineering interest, and recognition as an engineer by others, Table I.

The framework used in this study also considers an important aspect of engineering that distinguishes it from math and science: engineering is a profession. As such, it is characterized by a common set of practices and career paths [34] for which engineering students are trained. To capture these professional elements, Patrick *et al.* [24], [35] developed a scale of affect (i.e., liking or affinity) towards elements of engineering professional practice based on ABET EC2000 criteria and student outcomes. The development of this scale resulted in six factors related to professional practice [24]; it has since been used in conjunction with the original three academic factors of engineering identity to improve models for predicting engineering identity development from both an academic and professional perspective [27], [36]. These factors are described in Table I as well as [24], [35].

TABLE I
ENGINEERING IDENTITY THEORETICAL FRAMEWORK

| Factor | Description |
|---|---|
| | *Academic Factors* |
| Performance/ competence | A student's belief in their ability to perform academically or when conducting engineering-related tasks. |
| Interest | A student's desire or curiosity that drives them to think about, understand, and practice engineering. |
| Recognition | How others, such as parents, relatives, friends, colleagues, and faculty, see the student in the context of engineering. |
| | *Professional Affect Factors* |
| Framing and Solving Problems | An individual's interest in the application of math and science in solving engineering problems and finding ways to improve processes and methods. |
| Design | The interest that an individual has in creative and generative processes. It describes an individual's push to search for ways to be innovative and design and test out new ideas for all or a component of a system based on a set of constraints. |
| Project Management | The skill set an individual needs to help them bring projects to life, including organization, planning, and decision-making skills. |
| Analysis | An individual's ability to apply math and science and solve the relevant governing equations during design and evaluation. |
| Collaboration | Those skills necessary for working with other people, including the ability to communication, delegation, and teamworking. |
| Tinkering | The propensity an individual has to understand how something works by taking apart and fixing things. |

This framework describes how a student's identity as an engineer is constructed alongside their social and personal identities [35], [36]. Social identity relates to an individual's identity constructed with respect to a social group, such as their ethnicity. Personal identity relates to characteristics such as gender. As a student of engineering, an individual's identity as an engineer is developed based on both academic and professional aspects of engineering as they relate to an individual's social and personal identity [36].

### C. Engineering Identity Development of Latinx Students

Existing studies attempting to quantify Latinx students' engineering identity development tend to focus on science identity [32], [37] or use motivation as a surrogate for identity [38]. One mixed method study did explore engineering identity of Latinx engineering sophomores attending two Hispanic Serving Institutions (HSIs) [39]. Latinx students derived part of their engineering identity from the inherent challenge associated with studying engineering, and felt that the caring relationships they had with professors and peers strengthened their identity. The authors suggested that these caring relationships might be attributed to the minority-serving institution setting, yet Latinx students were not aware they were attending an HSI. Therefore, it is unclear what role attending an HSI has on Latinx student engineering identity development.

In the prior work [40] upon which this study builds, the authors compared the extracurricular experiences, familial influence, and engineering identity of Latinx students from an HSI and a predominantly white institution (PWI). It was found that Latinx students at the HSI had a statistically significant stronger engineering identity than Latinx students at the PWI. The HSI Latinx students also reported a higher engineering interest and greater intent to work in an engineering job after graduation, but lower participation in engineering-related student organizations than Latinx students at the PWI. When comparing Latinx and non-Latinx white students within each institution, no statistically significant difference was found in engineering identity. This suggests that institutional differences, rather than ethnicity, have more impact on overall engineering identity development, motivating a closer look at institutional and cultural differences.

Therefore, this study seeks to understand how institution type and the model in Table I predict engineering identity of Latinx students. The research questions the study addressed are: (1) What academic and professional affect factors predict engineering identity development of Latinx students? and (2) What role does the institution play in Latinx students' engineering identity development?

## III. Methods

This paper presents a mixed methods study following an embedded design with emphasis on quantitative survey data supplemented by qualitative interview data [41]. In expanding the authors' prior work, a further year's worth of survey data has been included in the analysis, more sophisticated regression analyses have been completed, and qualitative student interviews have been used to build potential explanations.

Participants were recruited from two institutions, an HSI and a PWI in the same state university system. The HSI is a nearly open-enrollment institution whose mission of access and excellence is reflected in its dual research and teaching orientations. A public institution located in the Southwestern United States, the HSI is an urban commuter school with approximately 84% of its students coming from the local community. The demographic make-up of the college of engineering consists of nearly 77% Hispanic students, 7.8% Mexican national, 7% other international, 5% non-Hispanic white students, and 1.4% black. In 2017, 3,900 undergraduate students were enrolled in the HSI's College of Engineering and 1,080 were pursuing degrees in mechanical engineering.

The PWI is a selective, research-oriented public institution. Situated in an urban setting, students attending the PWI are majority in-state students, with 90% of first-year students entering during fall 2017 classifying as in-state. The demographic make-up of the College of Engineering consists of 36% non-Hispanic white, 28% Asian students, 14% Hispanic students, and 1.8% black. In 2017, over 5,600 full-time undergraduate students were enrolled in the PWI's college of engineering, and over 1,100 undergraduate students enrolled in mechanical engineering majors. The PWI's engineering program is ranked in the top 15 undergraduate engineering programs in the U.S. [42].

As both institutions are located in the same southwestern state along the U.S.-Mexico border, the Latinx population in this study is largely made up of students whose culture and ethnicity are derived from a Mexican and Mexican-American heritage. While the authors acknowledge that the Latinx population globally is significantly more culturally and geographically diverse [43], due to the lack of local diversity in the Latinx population, all students identifying as Hispanic and/or Latinx are grouped for analysis. Results, therefore, may reflect the Mexican-American culture more than others.

### A. Quantitative Methodology

The survey, which took approximately fifteen minutes to complete, was administered electronically during select mechanical engineering courses during the 2016-17 and 2017-18 academic years. Twenty engineering courses were visited across both institutions. These courses were evenly distributed between first-, second-, third-, and fourth-year levels. The same courses were surveyed, when possible, each semester. Surveys were completed during the Fall and Spring semesters to ensure high completion rates. Duplicate responses were removed to analyze only one survey per participant.

Survey responses were matched with student records to include race/ethnicity and gender as reported to the university. A total of 892 survey responses were analyzed from undergraduate Latinx engineering students. The response rate was approximately 70%. Of the participants, 79% identified as male and 21% female, consistent with national averages; 28% were from the PWI and 72% were from the HSI. Based on their first semester of enrollment, 44% were lower division (first- and second-year students) and 56% were upper division (third-year and above). Twenty-eight percent of participants reported at least one parent obtained a Bachelor's degree in engineering. Based on participant responses, 38% percent of participants' mothers hold a high school degree, 9% hold an Associate's degree, 28% a Bachelor's degree, and 25% a Master's or Doctoral degree.

The survey, developed previously in [26], [36], had a total of 46 items, two items for the dependent variable and 41 items for the independent variables. Engineering identity, the dependent variable, was measured using a two-item scale that assesses

individual identification as an engineer. One item question was: "*to what extent does your own sense of who you are (i.e., your personal identity) overlap with your sense of what an engineer is (i.e., the identity of an engineer)*?" The other item is a visual version of the first item that represented the amount of overlap through the use of a Venn diagram. This factor was on a scale of "1: not at all/far apart" to "8: to a great extent/complete overlap." This two-item scale had an internal consistency of 0.82, measured by calculating Cronbach's alpha.

Two different scales were used for the independent variables. One scale measures academic factors of engineering identity, and the other scale measures affect factors toward elements of engineering professional practice, Table II. The academic factors of engineering identity scale [27] has three factors with a total of 11 items and uses a Likert response scale (5 = strongly agree and 1 = strongly disagree). The engineering professional practice affect scale has six factors with a total of 30 items [24]. The survey stem for the items was: "*As you think about your future after you finish your education, to what extent would you enjoy a profession or career that usually requires each of the following?*" All items used a 5-point Likert response scale (5 = very much; 1 = not at all). Table II lists the factors, the number of survey items in each, their internal consistency using Cronbach's alpha, and a sample item.

TABLE II
CRONBACH'S ALPHA, NUMBER OF ITEMS, AND SAMPLE ITEMS FOR SCALES MEASURING INDEPENDENT VARIABLES

| Variables | Alpha | # of items | Sample item |
|---|---|---|---|
| *Academic aspects of engineering identity* | | | |
| Engineering perf/comp | 0.86 | 6 | I can understand concepts I have studied in engineering |
| Engineering interest | 0.82 | 3 | I enjoy learning engineering |
| Engineering recognition | 0.83 | 2 | My friends see me as an engineer |
| *Affect toward elements of engineering professional practice* | | | |
| Collaboration | 0.80 | 6 | Working with people with different skills and interests |
| Analysis | 0.80 | 3 | Identifying what I need to know to solve a problem or complete a project |
| Framing and solving problems | 0.83 | 7 | Applying my science knowledge and skills |
| Design | 0.86 | 8 | Improving a design to make it more efficient (faster, better, cheaper) |
| Tinkering | 0.72 | 2 | Taking something apart to see how it works |
| Project management | 0.74 | 4 | Tracking various aspects of a project to ensure that it stays on track |

All assumption criteria, including normality, linearity, and equal variances, were tested on the data and satisfied prior to regression analysis. All variance inflation factor values were lower than 3.5 which suggests that the regression model does not have multicollinearity issues [44]. The bivariate correlation between the dependent variable and independent variables were all positively significant to each other. The correlation coefficient values were in the medium range [45].

These quantitative survey data could be considered multilevel, in that students were nested within different classrooms at different institutions during data collection. Due to the nested structure, the intraclass correlation coefficient was calculated to determine whether the classrooms explained the variance in the engineering identity variable. The intraclass correlation value accounted for by classrooms was 1.16%, which is under the threshold of 10% [46]. Thus, a nested model that accounts for classrooms difference was not used in this study, and multiple linear regression models were run.

Three of those models are described here. The first model established how much variance in engineering identity could be predicted using Latinx student characteristics: gender, institution, semester when the survey was completed (Fall 2016 through Spring 2018 semesters), division (upper vs. lower), parents' engineering degree, and mother's education. The second model incorporates the factors listed in Tables I and II. The third model incorporates interaction terms between the second model's factors and institution (HSI vs. PWI). STATA 15 software was used for all analyses. Among demographic variables, semester and mother's education were treated as numerical variables; other demographic variables were dummy-coded. The reference group for each is the one listed among characteristics (Table II) but not results (see the table in Section IV).

### *B. Qualitative Methodology*

Following initial analysis of survey data collected during the 2016-2017 academic year, and in parallel with 2017-2018 academic year survey administration, an interview protocol was created. Interviews followed a semi-structured protocol, with follow-up questions asked as needed. Five Latinx participants from each institution were interviewed. Interviews lasted forty to sixty minutes. Initial interviews were conducted with two interviewers to cross-check interview technique and quality of participant responses. Subsequent interviews were conducted with one interviewer at each institution. All interviews took place in a quiet, secure location, and audio was recorded for further analysis.

Students were recruited to participate in the study through email and in-class visits. The recruitment email was sent to students who identified as Hispanic or Latinx and were enrolled in Mechanical Engineering degree programs. While the majority of participants had previously completed the engineering identity survey, the recruitment email was sent to all qualifying students at the PWI to ensure higher response rates. A $10 Amazon gift card was offered as compensation for participating in the qualitative portion of the study. Participant demographic information and year of study are included in Table III.

TABLE III
QUALITATIVE ANALYSIS PARTICIPANT DEMOGRAPHICS

| PWI | HSI |
|---|---|
| Male, 3rd Year | Female, 4th Year |
| Male, 2nd Year | Female, 2nd Year |
| Female, 2nd Year | Male, 2nd Year |
| Female, 2nd Year | Male, 3rd Year |
| Male, 1st Year | Female, 3rd Year |

Between the two institutions, five males and five females participated in interviews. While this does not reflect the typical demographic make-up of either department, it provides an equal representation between the experiences of students of each gender while still including a range of academic classifications. This number of interviews was deemed satisfactory as the interview responses reached saturation and no substantially new information was gained from the later interviews.

Key themes were extracted from the interview transcripts to complete a thematic content analysis [47]. Researchers, one from each institution, completed their analysis separately before agreeing on a final version of the content analysis. During analysis, each researcher examined themes across each question. The interview protocol was designed to address prior significant findings in quantitative engineering identity studies, with each question addressing a different topic. Specific codes were created as needed during the content analysis. The transcripts were also reviewed holistically to capture any remaining overall themes. All five authors reviewed the initial content analysis findings to confirm validity and triangulate the data. Themes were developed collaboratively following the content analysis of the interviews. Three key themes were identified.

## IV. Results

### A. Sequential Multiple Linear Regression Models

Table IV presents two regression models for engineering identity. Based on the $R^2$ value of model 1, Latinx student characteristics explain 5.9% of the variance in engineering identity. Three of the student characteristics variables significantly predicted engineering identity. These variables are attending an HSI ($\beta$ = 0.178, p < .01), a parent holding an engineering degree ($\beta$ = 0.134, p < .01), and gender ($\beta$ = -0.118, p < .01).

TABLE IV
REGRESSION MODELS PREDICTING ACADEMIC AND PROFESSIONAL FACTORS INFLUENCING ENGINEERING IDENTITY DEVELOPMENT OF LATINX STUDENTS

| Variables | Model 1 | Model 2 |
|---|---|---|
| *Control Variables* | β | β |
| Female | -.118** | -.088** |
| HSI | .178** | .095** |
| Semester | -.046 | -.006 |
| Lower division | .028 | -.013 |
| Parents' engineering degree | .134** | .091** |
| Mother education | -.014 | .024 |
| *Academic aspects of engineering identity and affect toward elements of engineering practices variables* | | |
| Engineering perf/comp | | .150** |
| Engineering interest | | .203** |
| Engineering recognition | | .155** |
| Collaboration | | .020 |
| Analysis | | .112** |
| Framing and solving problems | | .108* |
| Design | | .000 |
| Tinkering | | .088* |
| Project management | | -.015 |
| $R^2$ | 0.059 | 0.340 |
| Delta $R^2$ | - | 0.281 |

Note: *p< .05 and **p< .01 (two-tailed tests)
[a]Engineering performance and competence

Model 2 introduces the three academic aspects of engineering identity factors and six affect towards engineering professional practice factors. These factors explain an additional 28.1% of the variance in engineering identity. Among the nine factors, six were significant: engineering interest ($\beta$ = 0.203, p < .01), engineering recognition ($\beta$ = 0.155, p < .01), engineering performance/competence ($\beta$ = 0.150, p < .01), analysis ($\beta$ = 0.112, p < .01), framing and solving problems ($\beta$ = 0.108, p < .05), and tinkering ($\beta$ = 0.088, p < .05). The three significant student characteristics in model 1 remained significant in model 2. Since the institution was significant in the models and is a primary focus, interaction terms between the model 2 factors and institution were included in a third model (not shown). None of these interactions were statistically significant.

### B. Qualitative Interview Results

Three key themes emerged during the content analysis of the interviews: engineering interest and future career pathways; professional affect; and ethnic identity salience. While participants were asked directly about the culture and learning environment of their institutions, key themes about institution type and engineering identity arose in response to other interview questions.

#### 1) Engineering Interest and Future Career Pathways

Interview participants from each institution were asked about their interest in pursuing engineering as their major, what they enjoy about learning engineering, and their future career plans. PWI participants frequently mentioned a general interest in math and science, while HSI participants tended to have a specific interest in a given applied field, such as space exploration, robotics, or cars. As HSI2 explained, "*If I can't race a car, I might as well build one*," highlighting her specific interest in automobiles. In contrast, PWI1 described engineering as "*a safe degree to get job-wise*" after deciding to major in engineering despite viewing math as his dream major.

HSI participants heavily emphasized their interest in learning about engineering as a practical application of their knowledge, viewing their learning as more effective during hands-on activities. While PWI participants also spoke of engineering as involving practical application, they generally enjoyed learning about engineering concepts separately from application as well.

HSI and PWI participants also described their future career paths differently. Participants from HSI viewed their future along a very specific technical career path, while participants from PWI focused on broader, not necessarily technical career options, such as project management, patent law, or management. As PWI participants described it, "*If I get bored with anything with a career, I can just switch over to something new*" (PWI3) and *"[my] identity as an engineer feels like it's in so many different places*" (PWI4). In contrast, several HSI participants named specific companies they were interested in working for after graduation.

#### 2) Professional Affect Factors

Interview participants were asked about their enjoyment of

tinkering, analysis, and design and whether they thought each factor was related to being an engineer. Whether or not they enjoyed these factors, participants from both HSI and PWI viewed them as related to engineering. A few PWI participants noted importance would depend on future career type and specific role responsibilities, stating "*I think it depends on what type of engineer you are*" (PWI4). Enjoyment of the three factors differed between each institution. While HSI participants spoke enthusiastically about tinkering and frequently mentioned tinkering during free time, PWI participants gave mixed responses on tinkering and generally expressed a vague interest in it. Coursework tended to be PWI participants' only exposure to tinkering.

HSI participants had limited exposure to analysis in their coursework and personal experience but expressed an interest in it. All but one PWI participant expressed strong enjoyment of analysis, speaking in detail about the analyses done in their coursework. Participants from both institutions discussed design in an overwhelmingly positive manner; however, they talked about the concept of design in different ways. HSI participants had less interest in computer-aided design (CAD) and spoke of design similarly to tinkering: "*In other words, I like designing on the fly. If something needs to be done, just do it*" (HSI2). In contrast, PWI spoke positively about the use of CAD and similar tools and expressed interest in the detailed planning aspect of the design process.

#### *3) Ethnic Identity Salience*

Ethnicity did not play a significant role in defining the engineering identity of most students. Participants were intentionally not asked about their ethnicity until the end of the interview. The topic of ethnicity arose prior to being asked during three of the interviews with HSI participants. Due to the influence of attending an HSI, participants noted when they traveled elsewhere, the Latinx population became the minority. HSI participants expressed that they wanted their ethnicity to reflect positively and to elevate perceptions of their community, rather than using ethnicity to define themselves. When directly asked about ethnicity, HSI3 stated that he does not believe that "*race makes an impact in what you do in your life*." Two PWI participants mentioned their ethnicity prior to being asked in relation to their involvement in the Society of Hispanic Professional Engineers (SHPE). Overall, both PWI and HSI participants stated that ethnicity did not play a major role in defining their engineering identity.

## V. Discussion

### *A. RQ #1: What academic and professional affect factors predict engineering identity development of Latinx students?*

Regression models demonstrate that the academic factors (performance/competence, interest, and recognition) and three of the six professional affect factors (tinkering, analysis, and framing/solving problems) predict engineering identity in Latinx students. Academic factors have consistently predicted engineering identity in previous studies, e.g., [27]. Interviews reflect how participants at HSI and PWI viewed tinkering and analysis as essential to engineering, regardless of their personal enjoyment. Participants revealed their interest in engineering through discussing problem-solving, why they chose to major in engineering and future career goals, and ways they engage in tinkering and analysis during class activities and free time. Many students mentioned projects they had worked on during class in their interview responses, particularly in answer to questions about tinkering, analysis, why they enjoy learning engineering, and what keeps them interested in engineering. This highlights the influence that course content and in-class projects have on developing engineering identity.

However, the results of this analysis may have limited generalizability outside of mechanical engineering. Activities like design and tinkering may traditionally be more heavily emphasized in mechanical engineering coursework than in electrical engineering. However, framing and solving problems and analysis, core practices of electrical engineering, as well as performance/competence, interest, and recognition could easily be seen as generalizable and not discipline-specific. Future work should expand to include other engineering disciplines.

Further, the development of this instrument was based on measuring the impact of both academic and professional factors as they contribute to engineering identity at large, not mechanical or electrical engineering specifically. The professional factors were derived based on both qualitative analysis from professional engineers from a variety of fields, including electrical engineering, and extraction of the elements of professional practice espoused in the ABET criteria [36]. Further, the authors' prior work has shown no significant difference between engineering identity across disciplines studied within the same institution [26], suggesting that there may not be an appreciable difference between mechanical engineering and electrical engineering students.

### *B. RQ #2: What role does the institution play in Latinx students' engineering identity development?*

Engineering identity differed significantly between HSI and PWI participants, and institution was a significant predictor of engineering identity. Yet, none of the interaction factors between institution and academic or professional affect factors were significant. This shows that the relationship between these factors and engineering identity is similar at each institution. It is also important to note that the coefficient of the institution variable, Table IV, is lower than any of the identity factors.

Interviews provide additional insight into engineering identity differences between HSI and PWI. Participants discussed their interest in engineering and future career pathways differently. HSI students conveyed greater interest in technical-focused engineering work, while PWI participants viewed their engineering degree as an opportunity leading to many different career paths. HSI participants discussed design in a manner similar to tinkering, with an emphasis on hands-on work. PWI participants' responses about tinkering were less detailed, as were those of HSI participants for analysis.

Translating these findings into practical implications is tricky. For example, both analysis and tinkering were significant predictors of identity in the model. Analysis seemed to be emphasized more in PWI's engineering curriculum, while

tinkering was more salient for HSI students. Given the variety of significant factors in the final model, institutions should consider how and when they emphasize various aspects of engineering in their curriculum and culture. It is just as interesting to note which professional aspects of engineering were not significant predictors of identity: collaboration, design, and project management. Team projects are suggested in the higher education literature for Latinx students to appeal to their sense of community [48], but the dynamics of engineering student projects teams may not address this effectively. Similarly, affinity for design is a significant predictor of identity in combined analyses dominated by non-Latinx white students [36], but there is no such relationship for Latinx students. This suggests an intriguing future direction in separating attitudes toward design, tinkering, analysis, and other factors for this student population. It also suggests that electrical engineering programs may not need to emphasize design as much as other aspects to retain Latinx students.

It is unclear whether the differences in institutional type are caused by the culture, coursework, and curriculum offered by the institutions, by the demographics of the students who choose to attend each institution, or a combination of both. Further attention should be paid to the content and design of engineering coursework at different institutional types to explore the impact of course structure on engineering identity.

### C. Limitations and Future Work

One major limitation of this study is that the participants are from the same state and university system, and the majority of Latinx students are of Mexican-American descent. Therefore, the authors' future work is expanding this engineering identity work to six other HSIs. Extending the study to other geographic regions will provide a more comprehensive investigation of engineering identity development of Latinx students. This is important as institutional characteristics, such as admissions selectivity, can be conflated with institution type in the current study. Further, this study focused on mechanical engineering students. Future studies should include other engineering disciplines.

## VI. Conclusion

Based on survey and interview responses of Latinx students at two institutions, this study explored engineering identity development in Latinx undergraduates. Given the variety of significant factors in the final model, faculty and administrators seeking to support Latinx students should consider how and when to emphasize academic and professional aspects of engineering in the curriculum. Enhancements could include encouraging hands-on tinkering, analysis activities, and integration of examples from a variety of engineering career trajectories.

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