Assessing Methods for Developing an Engineering Identity in the Classroom

Abstract

Engineering identity is an attractive lens being used by engineering education researchers to help understand the factors contributing to student retention and persistence in engineering. However, few studies have linked pedagogical approaches for developing an identity to their impact on engineering identity development. This research paper investigates the difference in students' engineering identity, engineering performance/competence, engineering interest, recognition in engineering, and affect towards six professional engineering practices in two difference engineering departments: a traditional program that *implicitly* supports engineering identity formation and a non-traditional program that *explicitly* supports engineering identity formation. Survey data was collected from a total of 184 students (153 from the traditional department and 31 from the non-traditional department). Using independent samples t-tests, results show that *engineering identity* was higher for students in the traditional department than for students in the non-traditional department. However, students in the non-traditional department showed statistically significantly higher levels of *collaboration* compared to the traditional department. This work contributes to the ongoing conversation about engineering identity development by beginning to explore the pedagogical approaches that impact students' engineering attitudes. Implications of results are discussed.

Motivation

The purpose of this research paper is to ascertain the impact course activities that are intentionally designed to develop engineering identity in students has on engineering identity development. The overarching goal of this project is to help students persist in engineering, particularly those underrepresented in engineering fields. According to the National Academy of Engineering's (NAE) [1] renewed call for change, "Only 40 to 60 percent of entering engineering students persist to an engineering degree, and women and minorities are at the low end of that range. These retention rates represent an unacceptable systems failure to support student learning in the field [...] Without refocusing and reshaping the undergraduate engineering learning experience, America's engineering preeminence could be lost [by 2020]." Prior research studies had discovered this trend and tried to interpret it in their own way [2], [3]. Some, e.g., [2], [4], sought to substantiate further the narrative of why retention of engineering students is low, but few consider identity to be an important factor in the equation, if at all.

Engineering identity has become an intriguing lens for exploring the factors that predict engineering identity development and thereby engineering identity formation [5], [6], [7]. In short, engineering identity describes the extent to which an individual sees themselves as an engineer. In an academic setting, this identity takes on academic factors related to learning about engineering. These factors were first introduced and applied to science education by Carlone and Jonson [8] and expanded on by Hazari [9] et al. to include concepts of Performance/Competence, Interest, and Recognition (Table 1). However, as engineering is not strictly an academic pursuit but also a profession with explicit expectations, skills, and practices (e.g., those espoused by the ABET criteria), professional affect factors also contribute to identity development of engineers

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(Table 1). The combination of these three academic factors and the six professional affect factors have been shown to improve engineering identity development of students [5], [6], [7], [10]. While other identity theories exist [11], [12], this framing of identity (Table 1), is the theoretical framework used in this study. This framework has been demonstrated to better predict engineering identity [13] and provide concrete areas where pedagogical innovation is possible, such as the professional factors.

Table 1. Engineering Identity Theoretical Framework [13], [14]

Factor	Description
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.
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 that are 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.

While this framework linking academic and professional identity has been used to predict factors contributing to student's engineering identity development [5], [15], [16], few studies have investigated the connection between pedagogical approaches and their impact on engineering identity retention [17]. One study looks at the impact of engineering design-based learning activities on preadolescent student's identification with engineering [18]. The study concluded that "students participating in the engineering learning activities had a significantly greater understanding of engineering as a profession compared to their comparison group counterparts." Within the field of teacher education, researchers perceive education as identity formation and used a research-based activity to build an identity in pre-service teachers [19]. As teaching is also a profession, the same principles, of realizing that the educational process is akin to identity formation, holds true in engineering.

Approach to Engineering Identity Development

This study compares two undergraduate engineering departments, both from the same college of engineering at a large, commuter-based, Hispanic serving, research institution in the southern United States. One of the degree plans is housed in a traditional engineering department where identity formation is implicit (i.e., our control group), and one is a non-traditional engineering degree plan where identity development is explicit. Therefore, before describing the research methods used to assess engineering identity development of students in both departments, what follows is a summary of how the departments implicitly and explicitly attempt to develop engineering identity, particularly in the non-traditional department.

Engineering identity development in the non-traditional department is scaffolded across a range of activities, from project-based learning and reflection to the deliberate study of other identities, such as entrepreneur and leader. By doing so, students can reinforce their emerging identities through engineering practice. However, as undergraduate students, their engineering identities are forming alongside other personal and social identities (i.e., Multiple Identities Theory [20]). Therefore, projects in the department are not limited to helping develop engineering identity, some require a focus on other identities that are meant to build the foundation upon which their multiple identities can coexist, be it predominantly engineering or not. Based on the framework, however, engineering identity is likely to develop in the traditional department as well, as there is a recurrence of some factors in both departments. How the academic and professional factors of the theoretical framework are incorporated into the two departments, and the extent to which they impact students' attitudes regarding engineering is, therefore, the focus of this study.

Academic Factors

Performance/Competence – Both the traditional and non-traditional departments seek to support students' belief that they are or can become competent in engineering concepts. To do so, both introduce key concepts repeatedly throughout the degree plans, with increasing difficulty, to reinforce student learning at a developmentally appropriate pace. In the non-traditional department, feedback is not focused on summative assessment and grades [21]; rather, it relies on formative feedback via alternative assessment methods. This includes the use of presentations, prototype demonstrations, project-based learning (PBLs) [22], and other assessment activities intended to allow students to articulate and demonstrate their learning in a medium that is conducive to their own interests and ways of learning. Regular reflection assignments and having students maintain an e-portfolios are other staples of the department for reinforcing learning and helping students to perceive their growing competence and ability to perform engineering tasks.

In addition, intentional time is spent in the non-traditional department to describe and explore identity from a theoretical and applied basis. For example, the first project of the department, the Inside Out Project, asks students to develop a physical sculpture that communicates their identity. In this project, students build off of their knowledge of themselves, something that only they are the experts of, to develop skills in prototyping and communication. Projects like these help the students reflect on their overall successes, and what they must do to continue developing their competence.

Although not explicitly taught in relation to identity, both departments emphasize their student's performance and competence development through a variety of extracurricular activities. These include student services available to all engineering students, such as tutoring sessions, targeted workshops, and hands-on engineering projects led by student organizations.

Interest – The structure of the non-traditional department is intentionally designed to be student-centric and to adapt to diverse student interests. This student-centered design is apparent in both the degree plan and the course designs. The degree plan is intentionally flexible, allowing students to design a concentration or sequence of their choosing, from mechanics to music. In the non-traditional department, up to 24 semester credit hours are available as electives. Anecdotally, this flexibility has proved instrumental in attracting students' that may not have been interested in engineering otherwise. In class, students in the non-traditional program are regularly allowed to decide what project topics appeal to them and how to tackle the challenges and obstacles they encounter in completing the project. This project-based learning is used in all core course in the non-traditional degree plan.

Some flexibility is also provided in the traditional program to allow students to customize their degree based on their interests. In doing so, nine semester credit hours are available as electives. However, these electives must come from a predetermined list. Project-based learning is also implemented later in the upper-level course of the degree plan in capstone style courses.

Recognition – To build a sense of relatedness and recognition as an engineer for students, the non-traditional department intentionally seeks to create a sense of community within the department and help students see a connection between their engineering education and the world around them. Projects and course work are designed with the intent to simulate real-world problems and scenarios. By providing dedicated space for the commuters to work on campus, the department seeks to be a "home away from home" where students can feel like they are in an inclusive environment that promotes comradery and collaboration. With faculty and staff, there is a culture of approachability and expectations that all faculty serve as mentors. In addition to formal advising and mentoring of students, the department has an open-door policy, where faculty keep their office doors open so that students feel welcome to meet with faculty members as needed. Further, the cohort-based program heavily emphasizes team and project-based learning to encourage students to build a community of support with their peers. In the classroom, student instructors and teaching assistants are widely used to help bridge the gap between students and faculty.

Similarly, the traditional program seeks to introduce topics and problems in class that students can relate to issues in the world around them. They also provide mentoring and advising. However, the larger scale of the department makes coverage of students' needs more challenging.

Professional Affect Factors

Framing and Solving Problems and Analysis – Concerning Framing and Solving Problems and Analysis, much remains the same between the traditional and non-traditional departments. A majority of the core engineering theory courses the non-traditional students take are taught outside the department, several of which are taught by the traditional department. Both departments view these skills as valuable to all engineers and therefore have integrated them throughout all their core engineering courses.

Design – Throughout all core courses in the non-traditional department, a heavy emphasis is placed on human-centered design. This results in a focus on real projects having a lasting impact. By doing so, students develop their design skills in real-world contexts that matter to the students and the users they are designing for. The traditional department typically assigns projects that are focused on the technical aspects of the design process.

Project Management and Collaboration – In the non-traditional department, engineering leadership is taught as the foundation of the department. Throughout, students learn and discuss leadership theory and then apply it to their team projects. With these team-based, human-centered design projects, students have the opportunity to learn to work as a team and to lead. The department also incorporates fundamental business skills and knowledge throughout the degree plan to help students develop project management skills. In the traditional program, students typically glean project management and collaboration skills from their capstone experience.

Tinkering – In the non-traditional department, students are encouraged to tinker with things and create something. There is time allotted in class for students to use a prototyping lab and work on their projects. Considering the surplus number of team-based design projects, tinkering is a fundamental part of being able to succeed in the department.

Therefore, the primary focus of this study is on understanding how pedagogical approaches impact engineering identity in undergraduate students. The research question is as follows: Are there differences in engineering identity, engineering performance/competence, engineering interest, recognition in engineering, and affect towards professional engineering practices between a traditional and non-traditional engineering department?

To answer this, we compare these two departments from the same institution that are different by design. One intentionally scaffolds activities throughout the degree plan and encourages students to learn more about themselves and reflect on what it means to be an engineer (i.e., education as identity formation), while the other is more in line with a traditional engineering degree, with engineering identity development of students occurring implicitly.

Methods

This study was a cross-sectional quantitative analysis of the engineering identity in undergraduate students from two departments of engineering at the same university. This section summarizes the target population, survey instrument, data collection, cleaning, and analysis.

Participants

Participants for this study were recruited from the two departments during the fall semester of 2018. A total of 184 responses (31 non-traditional, 155 traditional) were included in the study after exclusion of 57 incomplete responses. The response rate of students from each department was 17% for the traditional department and 34% for the non-traditional department. Table 2 summarizes the self-reported demographic information of participants included in this study.

Table 2. Participant Demographics

Variable	Traditional (n=153)	Non-Traditional (n=31)	*Total*
Gender			
Male	120	19	75%
Female	26	12	21%
Preferred not to answer	7	0	4%
Hispanic/Latinx/Chicanx			
Yes	139	26	89%
No	8	5	8%
Preferred not to answer	6	0	3%
Race			
White	114	25	75%
Asian	3	1	2%
Black	2	1	2%
American Indian/Native Hawaiian	2	0	1%
Preferred not to answer	33	4	20%
First Generation College Student			
No	117	25	77%
Yes	22	6	15%
Preferred not to answer	14	0	8%
Total	***83%***	***17%***	***100.0%***

Variables

The scales used in this study were borrowed from previously validated studies. To directly measure **engineering identity**, participants were asked to respond to two questions. One was a Venn diagram-style scale, and the other was a Likert-style question asking participants to identify the level to which their identity overlapped with that of an engineer's identity [23]. The Cronbach's Alpha value for the scale, reported in a previous study, was 0.84 [23].

Thirteen items asked questions related to **three academic factors**: *performance/competence, interest,* and *recognition*. These variables were taken from a previous study of engineering identity [6]. *Performance/competence* is composed of the following items: I can understand concepts I have studied in engineering, I am confident that I can understand engineering in class, I can overcome setbacks in engineering, I am confident that I can understand engineering outside of class, I can do well on exams in engineering, and others ask me for help in engineering. *Interest* is composed of two items: I enjoy learning engineering, and I am interested in learning more about engineering. Both performance/competence and interest were measured on a 5-point Likert scale from "1" strongly disagree "2" disagree "3" neutral "4" agree "5" strongly agree. *Recognition* was measured by asking students to respond to the extent to which others (parents, relatives, friends) saw them as an engineer. This was on a 5-point Likert scale from "1" not at all to "5" very much.

Thirty-four items asked questions related to the **six professional factors** [7]. Students were asked to respond to the following prompt: "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?" For each of the 34 items, students responded using a scale from "1" (not at all) to "5" (very much). These items loaded onto six factors: *1) framing and solving problems, 2) design, 3) tinker,* 4) *project management, 5) collaboration, and 6) analysis.* The internal consistency for both the professional and academic factors was based on Cronbach's Alpha values gathered from a dedicated research study involving these scales and range from 0.74 to 0.88 [13]. Demographic information was also collected on participants' self-reported gender, race/ethnicity, and first-generation status.

Research Design

Participants were asked to complete the survey in-class midway through the fall semester of 2018. The survey took approximately 15 minutes to complete and was administered electronically via Qualtrics. To increase response rates, a research team member visited the primary required course or courses in each year of the two departments' degree plans. This included nine courses in the traditional department and 5 in the non-traditional department. The analysis did not take into consideration students' academic classification or attempt to assess changes in a particular course. Following data collection, incomplete responses were removed, and data were analyzed using t-tests in Stata. Student responses were compared using an independent samples t-test to identify any significant differences between the mean responses for each group.

Results

The results reveal differences in the non-traditional and traditional engineering departments. Table 3 shows the means and standards deviations for each of these variables by department. Results reveal significant differences in *engineering identity* ($p= 0.043$). Students in the traditional courses had a statistically significantly higher mean than students in the non-traditional (T=5.74; NT=5.23). While students in the traditional courses express a stronger relative identity, the means for both groups indicate reporting a moderate to large degree of overlap between their personal identity and the identity of an engineer.

The only statistically significant difference between the groups in the academic factors was in *collaboration* (p=0.003). Students in the non-traditional department reported a statistically significantly higher mean than students in the non-traditional (T=4.09; NT=4.47). We also note similarities between the departments and the other 5 professional affect factors in which there was not a significant difference. Additionally, there were no statistically significant differences in any of the academic factors.

Table 3. Comparison of Survey Responses

Variable	Traditional Mean (S.D.)	Non-Traditional Mean (S.D.)	# items	p-value
Engineering Identity +	5.74 (1.31)	5.23 (1.06)	2	0.043*
Academic Factors				
Engineering Perf./Comp.	4.12 (0.68)	4.17 (0.71)	6	0.712
Interest	4.67 (0.53)	4.60 (0.65)	2	0.518
Recognition	4.19 (0.81)	3.98 (0.90)	3	0.199
Professional Affect Factors				
Framing & Solving	4.55 (0.43)	4.66 (0.38)	7	0.191
Design	4.52 (0.48)	4.48 (0.55)	8	0.652
Tinker	4.56 (0.67)	4.50 (0.67)	2	0.657
Project Management	4.45 (0.51)	4.56 (0.46)	4	0.282
Collaboration	4.09 (0.65)	4.47 (0.56)	6	0.003*
Analysis	4.33 (0.68)	4.38 (0.55)	3	0.672

+ Engineering Identity is on a scale of 1-8. All other variables are on a scale of scale 1-5.
*p<0.05

Discussion

Despite the concerted effort to incorporate activities in the degree that help build engineering identity in students, the non-traditional students reported a statistically significantly lower engineering identity than their traditional department counterparts. On the surface, this may appear discouraging. However, the non-traditional department takes an intentional approach that values holistic engineer formation that embraces developing multiple identities for students, including those of leaders, entrepreneurs, designers, or musicians. As a result, these identities may have moderated, or even conflicted with each other, and may very well have resulted in a lower level of engineering identity when compared to a department whose emphasis is more purely engineering.

However, there was a statistically significant difference between the groups in one professional affect factor, *collaboration*. Of all six of the affect factors, the non-traditional department emphasizes leadership, communication, and collaboration the most. The focus on these practices are intentionally scaffolded in the non-traditional department in a way that is distinctly different from the traditional department. Students are exposed on many levels to collaboration with their fellow peers, faculty, and external project stakeholders. From class assignments to year-long projects, students are heavily encouraged to learn how to learn, not just what to learn, and adapt to working with others. This is a quality that traditional engineering departments seem to overlook; students are often left to themselves to acquire these traits. Therefore, based on these results, it is uncertain whether engineering identity can be influenced in the classroom setting, though some impact is seen in the area of *collaboration*.

These findings, however, are not generalizable. A major limitation of this study is the different and relatively small sample sizes in each department. However, the non-traditional department is approximately a tenth the size of the traditional department. Therefore, differences are unavoidable. Similar response rates in each department were sought to alleviate this issue. As the non-traditional department grows, future comparative studies would be beneficial.

Conclusion and Future Work

This study sought to support educators interested in incorporating engineering identity development in their classroom by offering examples of in-class activities that may be beneficial for students. To better understand the impact of targeted classroom interventions on engineering identity of students, this paper compared the engineering identity of students from two engineering departments at the same institution. The non-traditional department intentionally scaffolded engineering identity activities in the classroom while the other, more traditional department, does not. From the responses obtained from participants of both departments, the study discovered that the students in the non-traditional department had statistically significantly lower *engineering identity* than their more traditional department counterparts. However, students in the non-traditional department, where leadership is intentionally scaffolded, did show statistically significantly higher levels of *collaboration*, when compared to their traditional-department peers.

Considering the results and study limitations, qualitative research is warranted. The limitations of the current study design restrict the understanding to a comparison of numbers that do not tell the whole story. Qualitative work, particularly classroom observations, can provide a richer understanding of what is occurring in these two departments. For example, given that engineering identity development is a goal of the non-traditional department, follow-up interviews could be conducted to help explain why these students had a lower engineering identity. This type of follow-up analysis could also explore whether students' other identities are conflicting with their engineering identity development. Future work can also pursue predictive models to understand the extent to which the different factors contribute to engineering development of the students in each department and the impact of individual pedagogical approaches on each of the academic and professional identity factors.

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References

1. National Academy of Engineering (NAE), "Adapting Engineering Education to the New Century Educating the Engineer of 2020," Washington, D.C.: The National Academy Press, 2005.
2. L. E. Bernold, J. E. Spurlin, C. M. Anson, "Understanding Our Students: A Longitudinal Study of Success and Failure in Engineering With Implications for Increased Retention," in *Journal of Engineering Education*, 2013.
3. Seymour, E., and N.M. Hewitt, "Talking about Leaving-Factors Contributing to High Attrition Rates Among Science, Mathematics, and Engineering Undergraduate Majors," Final Report to the Alfred P. Sloan Foundation on an Ethnographic Inquiry at Seven Institutions, University of Colorado, Boulder, CO: Bureau of Sociological Research, 1994.
4. Lumsdaine, M., and E. Lumsdaine, "Thinking Preferences of Engineering Students: Implications for Curriculum Restructuring," *Journal of Engineering Education*, Vol. 84, no 2, pp. 193-204, 1995.
5. A. Godwin, G. Potvin, and Z. Hazari, "The Development of Critical Engineering Agency, Identity, and the Impact on Engineering Career Choices," in 2013 ASEE Annual Conference and Exposition, Atlanta, GA, 2013.
6. A. Prybutok, A. D. Patrick, M. J. Borrego, C. C. Seepersad, and M. J. Kirisits, "Cross-sectional Survey Study of Undergraduate Engineering Identity," in 2016 ASEE Annual Conference and Exposition, New Orleans, LA, 2016.
7. A.D. Patrick, M. Bourego, N. Choe, M.R. Kendall, L. Martins, C. Riegle-Crumb, C.C. Seepersad, "A Measure of Affect towards Key Elements of Engineering Professional Practice," Proceedings of the ASEE Annual Conference and Exposition, Columbus, OH, June 26-29, 2017.
8. H. B. Carlone and A. Johnson, "Understanding the science experiences of successful women of color: Science identity as an analytic lens," Journal of research in science teaching, vol. 44, pp. 1187-1218, 2007.
9. Z. Hazari, G. Sonnert, P. M. Sadler, and M. C. Shanahan," Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study," Journal of Research in Science Teaching, vol. 47, pp. 978-1003, 2010.
10. A. Patrick, M. Borrego, L. Martins, N. Choe, C. Seepersad, and M. Kendall, "Constructing a Measure of Affect Towards Professional Practice: What matters for Engineers?" in Research in Research in Engineering Education Symposium, Bogotá, Colombia., 2017.
11. E. D. Tate and M. C. Linn, "How does identity shape the experiences of women of color engineering students?" *Journal of Science Education and Technology*, vol. 14, no. 5, pp. 483-493, 2005.
12. K. L. Tonso, "Student engineers and engineer identity: Campus engineer identities as figured world," Cultural studies of science education, vol. 1, no. 2, pp. 273-307, 2006.

13. N. H. Choe, L. L. Martins, M. Borrego, M. R. Kendall, “Professional aspects of Engineering: Improving Prediction of Undergraduates’ Engineering Identity,” in *American Society of Civil Engineers*, 2019.
14. M. R. Kendall, M. Denton, N. H. Choe, L. M. Procter, M. Borrego, “Factors Influencing Engineering Identity Development of Latinx Students,” in *IEEE Transactions on Education*, 2019.
15. B. Rubineau, “Gendering Engineering: Professional Identity Formation and Peer Effects,” Academy of Management Best Paper Proceedings, 2007.
16. R. Anderson, T. Beam, O. Pierrakos, J. Constantz and A. Johri, "On the development of a professional identity: engineering persisters vs engineering switchers," 2009 39th IEEE Frontiers in Education Conference (FIE), San Antonio, TX USA, 2009, pp. 1-6. doi:10.1109/FIE.2009.5350571
17. E. Aguiar, N. V. Chawla, J. Brockman, G. A. Ambrose, and V. Goodrich. Engagement vs performance: using electronic portfolios to predict first semester engineering student retention. In Proceedings of the Fourth International Conference on Learning Analytics And Knowledge, pages 103–112. ACM, 2014.
18. B. M. Capobianco, J. H. Yu, B. F. French, “Effects of Engineering Design-Based Science on Elementary School Science Students’ Engineering Identity Development across Gender and Grade,” in *Research in Science Education*, vol. 45, no. 2, pp. 275-292, 2015.
19. J. Trent, “Teacher education as identity construction: insights from action research,” in *Journal of Education for Teaching*, vol. 36, no. 2, 2010.
20. P. J. Burke, J. E. Stets, “*Identity Theory*,” New York: Oxford Press, 2009.
21. P. T. Knight, “Summative Assessment in Higher Education: Practices in disarray,” in *Studies in Higher Education*, vol. 27, no. 3, pp. 275-286, 2002.
22. P. C. Blumenfeld, E. Soloway, R. W. Marx, J. S. Krajcik, M. Guzdial, A. Palincsar, “Motivating Project-Based Learning: Sustaining the Doing, Supporting the Learning,” in *Educational Psychologist*, vol. 26, no. 3-4, pp. 369-398, 1991.
23. M. Borrego, A. Patrick, L. Martins, M. Kendall, “A New Scale for Measuring Engineering Identity in Undergraduates,” Proceedings of the ASEE Gulf Southwest Annual Conference, Austin, TX, 2018.