Measuring the Impact of Industry-Linked Independent Study on Professional Identity Development in Undergraduate Biomedical Engineering Students

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INTRODUCTION

Current Challenge

Exposure to real-world projects, problems, and experiences is crucial for engineering trainees. While classroom interventions have been developed to expose engineering students to authentic engineering problems, often students need to go beyond traditional coursework and pursue work-integrated learning opportunities such as internships and co-ops. Students engaging in these work-integrated learning programs have expressed positive impacts on the development of their engineering identity [1]. Though these work-integrated learning experiences provide excellent benefits, they are not available to all students, and there are barriers to participating in these experiences. Summer classes, external responsibilities, program restrictions, and not being accepted to positions have been cited by students as reasons they did not participate in these activities [1]. In particular, BME students find difficulty in securing work-integrated learning opportunities [2]. Compared with other engineering majors, BME students have fewer internship and co-op offers, limiting their ability to gain experience prior to graduation.

Measure of Affinity Toward Engineering Professional Practice

Engineering identity is how an individual sees themselves as an engineer, which is influenced by their interest in the field, their sense of competence and performance in engineering tasks, and the recognition they receive from others. Engineering identity development has been linked to persistence in engineering academics and engineering careers and requires exposure to engineering-related experiences [3]. Key factors that relate to the development of engineering identity include interest, sense of belonging, performance/competence, and recognition [4], [5]. For BME students, recognition, being seen as an engineer by family and peers, resulted in a stronger sense of engineering professional identity [6].

Engineering identity encompasses both engineering as a discipline and engineering as a profession. The discipline aspect of engineering identity relates to broader identities tied to the specific field (i.e., science identity, physics identity, biology identity). The professional aspects of engineering identity relate to engineering practice itself, such as design, working with others, and responsibility [5]. Engineering students' affinity toward key aspects of engineering practice has been measured using an instrument developed by Patrick et al (2017). This instrument was created and validated using six key factors: analysis, collaboration, design, framing and solving problems, project management, and tinkering [7]. This instrument has been further used to correlate the affinity toward aspects of engineering practice with engineering identity and persistence [8]. Engineering identity development is supported by positive experiences in tinkering, designing, and analyzing. For Latinx students, analysis, framing and solving problems, and tinkering were linked to engineering identity [9].

Biomedical engineering graduates have a variety of career paths available which may impact professional identity development. Common career paths for BME graduates can include industry placement, medical/professional school, or graduate school. Recent data shows the distribution of graduates in each path is approximately 50-60% industry, and 20-30% graduate school, and 10-20% medical/dental school [2], [10], [11]. This makes engineering identity development unique for BME students, who are simultaneously developing identities as clinicians [12] or as scientists [6]. While studies have examined these aspects of conflicting identity development, the impact of career aspirations on affinity toward elements of engineering practice has not been largely investigated.

Course Intervention for Engineering Professional Practice

To address the need for BME work-integrated learning experiences, an industry-linked course was created as a three-credit independent study. This industry-embedded course was designed to support students with limited prior exposure to engineering practice. Students worked with Ohio at Home, a provider of direct and remote support for individuals with developmental disabilities. The course had two components: a six-hour weekly on-site and four-five hours of weekly project work supervised by the instructor. The six-hour shifts involved students working as Remote Support Associates (RSA), monitoring multiple clients' wellness and medical tracking based on individual needs. The project work was defined by Ohio at Home in advance based on priorities, and the instructor translated these into scaffolded, student-appropriate deliverables. Students provided weekly updates to both the instructor and the company and concluded the term with a final presentation. Projects varied widely by semester, ranging from RSA monitoring UI development, mapping client-intake processes, and improving RSA workstation layouts and systems, resulting in similarly varied deliverables such as prototypes, process diagrams, and interface mockups. The course effectively functioned as a “pre-capstone,” giving students authentic exposure to scoping open-ended problems and producing actionable outputs. Students were recruited through advertising via academic advisors. Students only needed instructor approval to add the course, and a cap of 10 students was set to support sustainability. An overview of the course can be seen in Appendix 1: Course Structure Overview.

This study focuses on the impact of this intervention on engineering professional development toward answering the following research questions:

RQ1 – In what ways do students’ experiences in a semester-long industry internship course shape their sense and alignment with elements of professional engineering practice?

RQ2 – To what extent do gender and career aspirations influence affinity for aspects of professional engineering practice?

METHODS

Student Population

A total of 23 students completed the independent study course, consisting of 12 males and 11 females. Among these students, 13 indicated interest in industry positions, 5 in graduate school, and 5 in medical school. Although the survey also collected information on students' academic year, these responses showed inconsistencies—likely due to the course occasionally being offered during summer terms—making it impossible to reliably match class standing across participants. For this reason, only post-survey reports of academic year are presented descriptively and were not included in the statistical analysis. Based on these post-survey responses, 14 students identified as seniors and 9 as juniors. Table 1 summarizes the cross-tabulation of gender, year, and career aspiration. (Table 1).

Table 1: Separation of student population by gender, year, and career outcome

Gender	Current Year	Graduate School	Industry	Medical School	*Totals*
Female	**Junior**	1	3	1	*5*
	Senior	1	5		*6*
Male	**Junior**	1		3	*4*
	Senior	2	5	1	*8*
	Totals	*5*	*13*	*5*	*23*

Instrument

Positive experiences in aspects of engineering practice are linked with engineering identity development. This study aims to evaluate if and how affinity of biomedical engineering students toward aspects of engineering practice are impacted through participating in an industry-integrated course. This study also explores how gender, career aspirations, and year in school may impact affinity toward aspects of engineering practice. The Patrick et al. (2017) instrument was used to measure students' perceived alignment with aspects of engineering practice. This instrument was designed to measure six constructs: Analysis, Collaboration, Design, Framing and Problem Solving, Project Management, and Tinkering. Patrick et al. removed Tinkering from the final validated instrument to improve model fit [7]. A modified version of the instrument was used, not including Tinkering.

The five constructs were measured on a five-point Likert scale from strongly agree to strongly disagree. Elaborating on the constructs, the Analysis (3 questions) construct evaluates students' ability to apply mathematical reasoning and quantitative methods. The Collaboration (6 questions) construct measures interpersonal and teamwork competencies. Design (7 questions) focuses on creativity and engineering practice, including simplifying technical solutions, creating prototypes, and designing within constraints. Framing and Problem Solving (6 questions) assesses curiosity, adaptability, and initiative in exploring solutions. Lastly, Project Management (4 questions) evaluates organizational skills, including planning, tracking progress, and completing long-term goals. The complete list of questions and their corresponding construct can be found in Appendix 2.

Industry Partner and Course

The industry partner for this internship course was Ohio at Home, a provider of remote healthcare and wellness monitoring services for individuals with developmental disabilities (IDD). This industry partner has been a strong capstone collaborator for +5 years and was excited to work with biomedical engineering students in an internship setting. Students were set as remote support associates (RSAs) in the company while they worked on their projects. RSAs are the company representatives who remotely monitor and interact with the company's IDD clients. This monitoring can include wellness checks, medication intake, engaging with client calls, and checking for other safety factors (such as responding to emergencies). The internship had students covering 6 hrs. of RSA monitoring and +5 hrs. for project development. As part of the RSA role, students were required to complete trainings including HIPPA, trauma-informed care, among other company required trainings. Students were paid $15 an hour for their RSA monitoring shifts. The projects ranged from identifying and implementing improvements in user interfaces, optimizing intake process flows, and understanding technological needs for each individual client (e.g. does a client need a camera, smart home application, etc) - projects varied by semester and business need identified by the CEO. The final deliverables were evaluated by both the instructor and the company's engineering team.

Data Acquisition

Students in the first week of the semester would be introduced to the internship course, explained the course and work expectations, and asked to answer the pre-survey for the course. They would then meet with the company contact, begin their projects/internships throughout the semester, and the last week of the semester fill out the post-survey. This research was deemed IRB-exempt by Ohio State University's IRB (#20251727).

The survey collected the response to the instrument questions (Appendix #2), and asked students to indicate their gender, current academic year, and career aspiration.

Statistical Analysis

A chi-square test of independence was conducted to examine the association between students' gender and their career aspirations. Gender was categorized as male or female, and career aspiration was classified into three mutually exclusive categories: industry, graduate school, and medical school.

Prior to analysis, data were screened for completeness and consistency. A subset of responses related to students' current academic year (e.g., "sophomore," "junior", "senior") was excluded from the present analysis. Several respondents provided conflicting year designations across repeated survey administrations, and no reliable method was available to reconcile or match these entries. Because the academic year was not central to the research question and could not be validated, it was not incorporated into the chi-square analysis.

A secondary analysis was performed using a series of multiple linear regression models. These models intended to examine whether student characteristics predicted scores on the five constructs of the professional identity instrument (project management, problem solving, design, collaboration, and analysis). For each construct, a separate regression model was created with the construct average score serving as the dependent variable. Three student-level predictors were included: pre/post (pre- and post- semester survey responses), gender (female vs. male), and career aspiration (graduate school vs. medical school vs. industry). Categorical predictors were dummy-coded using reference coding. The statistical significance of each predictor was evaluated using t-tests, and overall model significance was tested using an F-test from the analysis of variance (ANOVA) table. All statistical testing was performed using Minitab software [13].

RESULTS

Chi-Square: Evaluating Gender and Career Aspiration

The chi-square test of independence was conducted to examine the relationship between gender and career aspiration. The association was not statistically significant, Pearson $\chi^2(2, N = 23) = 2.65$, $p = 0.265$, indicating that career aspirations did not differ meaningfully between male and female students in this sample. The likelihood ratio test yielded a similar conclusion, $\chi^2(2) = 2.78$, $p = 0.249$. The summary table can be seen below (Table 2). Four cells had expected frequencies below 5, suggesting that the test may have limited power and that results should be interpreted with caution. A box plot of gender and career aspiration can be seen in Figure 1.

Table 2: Chi-square table for Gender vs. Career Aspiration. This test did not yield significance. Expected value from Chi-Square is italicized and underlined (example: 2.391)

Gender vs. Career Aspiration				
	Graduate School	**Industry**	**Medical School**	**All**
Female	2	8	1	11
	2.391	*6.217*	*2.391*	
Male	3	5	4	12
	2.609	*6.783*	*2.609*	
All	5	13	5	23

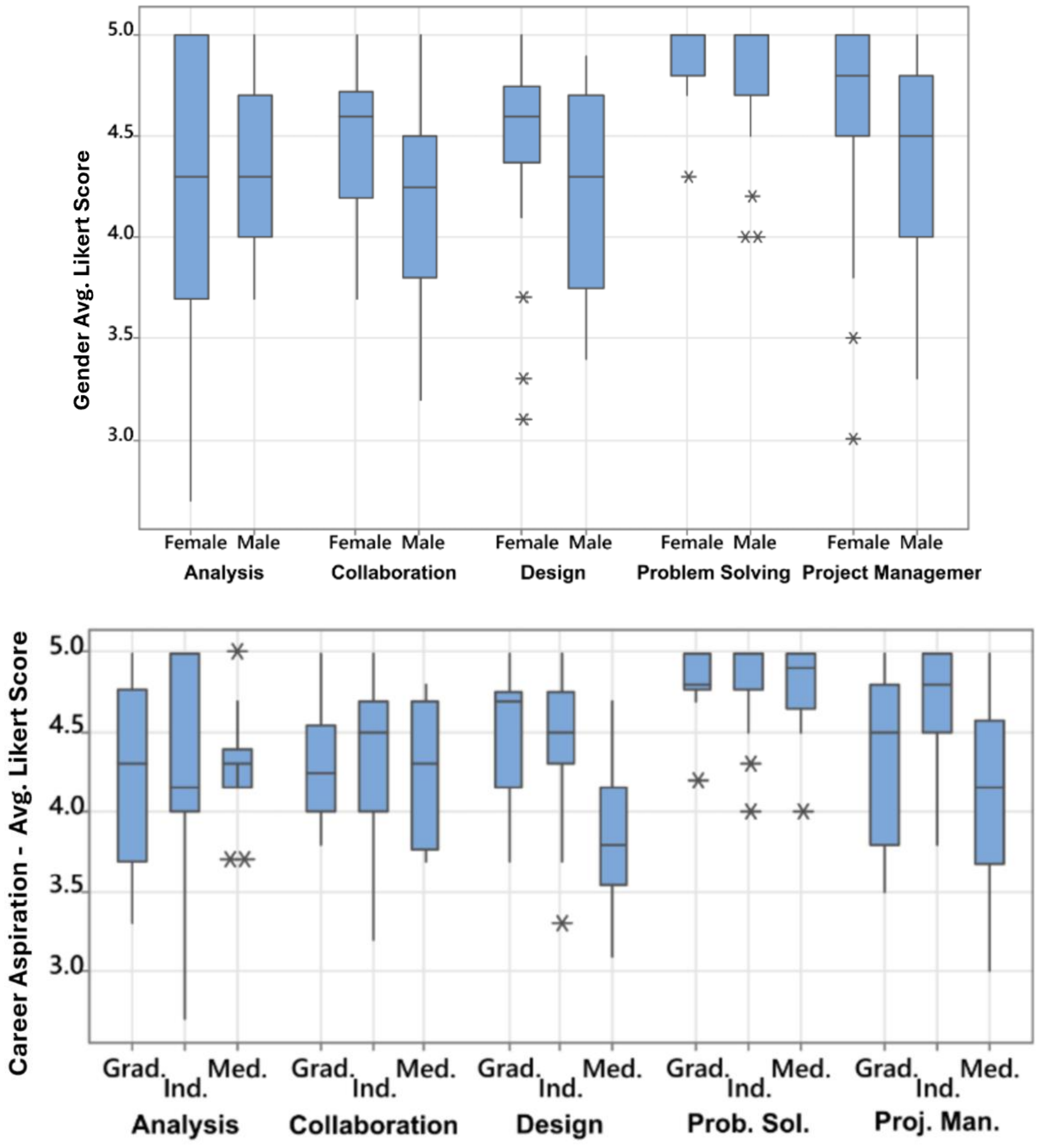

Figure 1: Box plot of each construct versus gender (above) and career aspiration (below). Asterisks denote data outliers.

Multilinear Regression Models: Evaluating the Five Constructs

Five regression models were used to evaluate if either gender, career aspiration, or the pre/post survey had an impact on a particular construct (e.g. Analysis, Design, Problem Solving, etc). Since each construct was found to be independent, no inter-factor analysis was performed. Below is a summary of the results (Table 3).

*Table 3: Summary of Regression Model Results by Construct. * Indicates significance ($p < 0.05$)*

	Project Management	Problem solving	Design	Collaboration	Analysis
Model Significance	**0.04***	0.59	**0.01***	0.08	0.98
Pre/Post Survey	0.76	0.74	0.43	0.16	0.94
Career Aspiration	**0.03***	0.88	**0.00***	0.98	0.97
Gender	0.43	0.19	0.65	**0.01***	0.53

Of the five constructs, only two models resulted in significant results: Project Management and Design. For Project Management, the overall model was statistically significant, $F(4, 41) = 2.82$, $p = .04$. Career aspiration significantly contributed to the model, $F(2, 41) = 3.88$, $p = .03$. Pre/post and gender were not significant predictors (both $p > .10$). The Design construct produced a significant model, $F(4, 41) = 3.91$, $p = .01$. Career aspiration was the only significant individual predictor, $F(2, 41) = 6.30$, $p < .001$. No other predictors reached significance.

Average scores for Project Management and Design are provided on a Likert 5-point scale (Table 4). For Project Management, students interested in industry careers had the highest scores, followed by students interested in graduate school, and students interested in medical school had the lowest scores. For Design, students interested in industry and graduate school had similar average scores, while students interested in medical school scored lower.

Table 4: Average Likert scores for Project Management and Design by career aspiration

	Project Management		Design	
	Average	Standard Deviation	Average	Standard Deviation
Industry	4.63	0.39	4.47	0.40
Medical School	4.08	0.62	3.86	0.48
Graduate School	4.35	0.58	4.49	0.45

For Collaboration, the model approached significance, $F(4, 41) = 2.30$, $p = .08$. Though the model was not significant, it did show an interesting trend. This is the only model where Gender emerged as a notable predictor, $F(1, 41) = 6.59$, $p = .01$, with male students scoring lower on collaboration than female students. The magnitude of this effect ($\beta = -0.33$) suggests a meaningful group difference, though it should be interpreted cautiously given the nonsignificant of the model and the modest sample size. The last two models: Problem Solving $F(4, 41) = 0.72$, $p = .59$ and Analysis $F(4, 41) = 0.11$, $p = .98$ were found not significant.

DISCUSSION

This study examined the extent to which an industry-linked independent study course influenced biomedical engineering students' affinity for professional engineering practice, while also exploring how gender and career aspirations predicted differences across five constructs of engineering professional identity development.

Patrick et al. (2017) demonstrated that affinities toward analysis, collaboration, design, framing and solving problems, and project management meaningfully align with emerging engineering identity. The present study found limited statistically significant differences across constructs, with only Project Management and Design producing significant regression models with career aspiration as the only consistent predictor of these two constructs. For the Project Management construct, students interested in industry scored an average of 0.55 points higher than students interested in medical school (5-point Likert scale). This highlights the potential alignment of job function and project management skills for industry-bound students who are likely to engage in project-based work as an engineer in industry. Whereas a medical school-bound student may not have project-based work as part of their future career as a medical practitioner. Similarly, for the Design construct, students interested in medical school scored 0.61 and 0.63 points lower than students interested in industry and graduate school, respectively. This also highlights differences in future job function where skills related to design would be more useful in a job function such as in engineering industry roles and in graduate-level research projects compared with medical practice. Professional identity and affect toward aspects of engineering practice may differentiate according to intended career pathways, especially in interdisciplinary fields such as BME where students simultaneously form identities as engineers, clinicians, or scientists [6], [12].

Significant identity changes typically occur following substantial curricular or multi-semester interventions [3], [4]. The lack of observed change here suggests that a single semester, particularly for upper-division students, may be insufficient to shift affective measures of identity, even within an authentic industry experience. Additionally, students opting into an optional industry-linked independent study may already possess higher engagement with engineering practice, interest in industry-relevant skills, or recognition as engineers. Thus, the absence of statistically significant pre/post effects should not necessarily be interpreted as a failure of the intervention. Instead, it may reflect the developmental stage of the participants and the elective nature of the course.

Limitations

This study assessed affinity for professional engineering practice rather than full engineering identity. Instruments measuring recognition and belonging could provide complementary insights and capture additional dimensions of identity formation not reflected in the present analysis. Additionally, the inability to match pre- and post-surveys at the individual level reduced the sensitivity of detecting intra-student change over time, and the small sample size limited statistical power. Finally, because the study was conducted within a single institution and with one industry partner, the findings may not generalize to programs with different structures, demographics, or partnership models.

Future Work

Further work is also needed to compare identity-affect profiles across different career aspiration groups to better understand the divergent identities of industry-, graduate school–, and medical school–bound students. These studies could include longitudinal tracking of identity development and affect toward professional practice to produce a more holistic picture of how BME students develop engineering professional identity. Implementing similar courses earlier in the curriculum may help determine whether lower-level students exhibit more pronounced identity shifts.

CONCLUSION

This paper aimed to uncover a direct linkage between students' gender, career aspirations, and professional practice identity, specifically in a new industry/independent study course. It was found that career aspirations significantly impacted two constructs from the implemented instrument: project management and design. Even though the Collaboration model resulted in a non-significant result, gender was found to be a significant predictor. Although the results contrast with other literature, the authors acknowledge that this course opportunity was populated mainly with seniors who would potentially have more settled identities and do not represent the often chaotic journey most students have in forming their field and professional identities.

APPENDIX 1:

Course Structure Overview

Week	Topic From ebiodesign.org
Week 1	1.1 Strategic Focus
	1.2 Needs Exploration
	1.3 Need Statement Development
Week 2	2.1 Disease State Fundamentals
	2.2 Existing Solutions
	2.3 Stakeholder Analysis
Week 3	2.4 Market Analysis
	2.5 Needs Selection
Week 4	3.1 Ideation
	3.2 Initial Concept Selection
Week 5	4.1 Intellectual Property Basics
	4.2 Regulatory Basics
	4.3 Reimbursement Basics
Week 6	4.4 Business Models
	4.5 Concept Exploration & Testing
	4.6 Final Concept Selection
Week 7	5.1 IP Strategy

Weekly Reading Reflection
1. What clicked or made sense for this week's reading?
2. What was confusing or unclear for this week's reading?
3. How is the work with [Company] going / Any needs from me?

First Four Week Content
1. Discussion of expectations, contacts, and overall responsibilities
2. Introductions to system thinking
3. Best practices for communication in industry
4. Diagrams, schematics, and process charts

Typical Lecture/Meeting Format
1. Present prepared content (first four weeks only)
2. Go over student reflections and match student experience with reading
3. Discuss any needs, resources, or overall help the students may need.

	5.2 R&D Strategy
	5.3 Clinical Strategy
Week 8	5.4 Regulatory Strategy
	5.5 Quality Management
	5.6 Reimbursement Strategy
Week 9	5.7 Marketing & Stakeholder Strategy
	5.8 Sales & Distribution Strategy
	5.9 Competitive Advantage & Business Strategy
Week 10	6.1 Operating Plan & Financial Model
	6.2 Strategy Integration & Communication
	6.3 Funding Approaches
	6.4 Alternate Pathways

APPENDIX 2:

Modified Instrument

Applying my math knowledge and skills	Analysis
Using calculations and equations to evaluate things	Analysis
Identifying what I need to know to solve a problem or complete a project	Analysis
Presenting my work to others	Collaboration
Working with people with different skills and interests	Collaboration
Communicating verbally, for example in discussion with others	Collaboration
Convincing others to accept my ideas	Collaboration
Breaking a complicated problem into smaller parts	Collaboration
Working collaboratively in teams	Collaboration
Identifying technical solutions that are as simple as possible	Design
Designing and conducting experiments to test an idea	Design
Improving a design to make it more efficient (faster, better, cheaper)	Design
Searching for innovative ways to do things	Design
Using technology to solve environmental problems	Design

Creating prototypes to test an idea	Design
Designing a system, a part/component of a system, or a process based on realistic constraints	Design
Solving problems that allow me to help a lot of people	Framing and problem solving
Learning new things from other people I'm working with	Framing and problem solving
Finding a better way of doing something	Framing and problem solving
Continually learning new things	Framing and problem solving
Applying my science knowledge and skills	Framing and problem solving
Being curious	Framing and problem solving
Planning a project and staying organized to complete it	Project management
Using facts and information, instead of opinions, to make decisions	Project management
Tracking various aspects of a project to ensure that it stays on track	Project management
Seeing a project through to its end	Project management

References:

[1] A. Castillo, B. McIntyre, and A. Godwin, “Understanding the Influence of Work-Integrated Learning Experiences on Students’ Identity Formation in Engineering,” presented at the 2022 ASEE Annual Conference & Exposition, Aug. 2022. Accessed: Nov. 20, 2025. [Online].

[2] T. M. Nocera, A. Ortiz-Rosario, A. Shermadou, and D. A. Delaine, “How Do Biomedical Engineering Graduates Differ from Other Engineers? Bridging the Gap Between BME and Industry: a Case Study,” presented at the 2018 ASEE Annual Conference & Exposition, Jun. 2018. Accessed: Nov. 20, 2025. [Online].

[3] O. Pierrakos, T. K. Beam, J. Constantz, A. Johri, and R. Anderson, “On the development of a professional identity: engineering persisters vs engineering switchers,” in *2009 39th IEEE Frontiers in Education Conference*, Oct. 2009, pp. 1–6. doi: 10.1109/FIE.2009.5350571.

[4] A. Godwin, “The Development of a Measure of Engineering Identity,” *ASEE Annu. Conf. Expo.*, Jan. 2016, doi: 10.18260/p.26122.
[5] K. L. Meyers, M. W. Ohland, A. L. Pawley, S. E. Silliman, and K. A. Smith, “Factors relating to engineering identity,” *Glob. J. Eng. Educ.*, vol. 14, no. 1, pp. 119–131, 2012.
[6] E. J. Springer and A. Huang-Saad, “Understanding Identity among Biomedical Engineering Students and Professionals,” presented at the 2020 ASEE Virtual Annual Conference Content Access, Jun. 2020. Accessed: Nov. 20, 2025. [Online]. Available: https://peer.asee.org/understanding-identity-among-biomedical-engineering-students-and-professionals
[7] A. D. Patrick, N. H. Choe, L. L. Martins, M. J. Borrego, M. R. Kendall, and C. C. Seepersad, “A Measure of Affect toward Key Elements of Engineering Professional Practice.,” *ASEE Annu. Conf. Expo. Proc.*, Jun. 2017, Accessed: Oct. 21, 2025. [Online].
[8] N. H. Choe, L. L. Martins, M. Borrego, and M. R. Kendall, “Professional Aspects of Engineering: Improving Prediction of Undergraduates’ Engineering Identity,” *J. Prof. Issues Eng. Educ. Pract.*, vol. 145, no. 3, p. 04019006, Jul. 2019, doi: 10.1061/(ASCE)EI.1943-5541.0000413.
[9] M. R. Kendall, M. Denton, N. H. Choe, L. M. Procter, and M. Borrego, “Factors Influencing Engineering Identity Development of Latinx Students,” *IEEE Trans. Educ.*, vol. 62, no. 3, pp. 173–180, Aug. 2019, doi: 10.1109/TE.2019.2909857.
[10] R. A. Linsenmeier and A. Saterbak, “Fifty Years of Biomedical Engineering Undergraduate Education,” *Ann. Biomed. Eng.*, vol. 48, no. 6, pp. 1590–1615, Jun. 2020, doi: 10.1007/s10439-020-02494-0.
[11] “Council of Chairs of Bioengineering and Biomedical Engineering.,” Survey Results and Documents. [Online]. Available: https://www.bmes.org/biococ
[12] W. Guilford, “Clinician-Engineer Self-Concept in Biomedical Engineering students and Its Relationship to Race, First-Generation Status, and Mode of Delivery,” Jun. 2023. doi: 10.18260/1-2--43209.
[13] *Minitab*. (2024). Minitab, LLC, State College, PA, USA.