Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #46196

Investigating Perceptions of Engineering in First- and Third-Year Students

Maryann R. Hebda, Baylor University

Maryann R. Hebda, M.S., is a doctoral candidate in the Educational Psychology Department at Baylor University. Prior to relocating to Texas, Hebda taught elementary and middle school special education, gifted education, and STEM for 13 years. Her current research explores integrated STEM talent development and achievement motivation in twice-exceptional and advanced learners.

Morgan R Castillo, Baylor University

Morgan Castillo is a PhD student in Educational Psychology at Baylor University. Her research interests include talent development in STEM fields.

Mr. Joseph Anthony Donndelinger, Baylor University

Mr. Donndelinger joined Baylor Universityâ€™s School of Engineering and Computer Science as a Clinical Associate Professor after 23 years of experience in the automotive and cutting tool industries. During his 16 years as a Senior Researcher at General Mo

Prof. Adam Weaver, Baylor University

Mr. Adam Weaver joined the Baylor Department of Electrical and Computer Engineering with over 15 years of experience in industry and government service. He served in the Active Duty Air Force as an engineer for over eight years, specializing in test and evaluation of avionics, guidance/navigation, and space systems. After his time in the military, he worked as a Propulsion Test and Integration Engineer with Space Exploration Technologies as well as multiple positions with L3Harris Technologies. At L3Harris, Mr. Weaver served in Test and Integration roles supporting DoD special aircraft systems, as well as serving as a System Security Engineer where he developed and implemented cyber security solutions for a variety of Air Force aircraft, ground support, and training/simulation systems. Mr. Weaver earned his Bachelor of Science in Electrical and Computer Engineering from Baylor University in 2004, and his Master of Science in Electrical Engineering from the Air Force Institute of Technology in 2009. He also holds the Certified Information System Security Professional (CISSP®) certification with security architecture focus (ISSAP®) from ISC2®.

Tracey Sulak, Baylor University
Dr. Anne Marie Spence, Baylor University

Clinical Professor Mechanical Engineering

Investigating Perceptions of Engineering in First- and Third-Year Students

This empirical research brief investigates undergraduate students' perceptions of engineering as a career. Guided by theory on developing engineering perceptions [1], [2] and the 2024 Inclusive Mindset Report's challenge to create pathways "toward professional practice, graduate school, and challenges not yet known" [3, p. 39], we compare first-year and third-year student perceptions of engineering skills and work activities. Then we broaden to their perceptions of engineering as a field, which reflects their developing conceptualizations as informed by their educational journeys. As Lakin and colleagues describe, these developing perceptions reflect the "culture of the university, students' understanding of engineering, and students' perceptions of their knowledge and skills" [1, p. 215]. One essential component of retaining students in engineering programs and careers is to facilitate students' accurate understanding of engineering pathways and how they as individuals fit into those pathways. This benefits both the individuals and the field as a whole [4].

Engineering Education and Practice

Engineering education must prepare students to enter an ever-evolving profession. Sheppard and colleagues [5] distinguish between engineering practice and education, emphasizing the need to integrate fundamentals, specialized knowledge, and problem-solving with social considerations. However, classrooms often focus on well-defined problems and theoretical principles, with individual efforts prioritized for grading. In contrast, engineering careers require contextual application of diverse skills and collaboration among experts in various fields. Trevelyan [6] underscored this wide gap, suggesting that students may develop an educational perspective that is misaligned with a professional perspective. This gap is illustrated in Figure 1.

Decades of research support educational practices that show promise toward bridging this gap. For example, perceptions of the relative importance of technical and professional skills from first year to senior year can be influenced by experiences in co-ops, internships, project-based learning activities and participation in engineering extracurricular activities [7]. Guidance for instructors and program leaders also spring from program outcomes (e.g., ABET) such as Patrick and colleagues' [8] set of specific elements of engineering practice. Thus, the responsibility for developing accurate perceptions of the engineering profession begins with engineering education programs, then transfers to students as they pursue opportunities for authentic professional experiences such as projects and internships [7]. In this study, including undergraduates at multiple points in their program aims to capture elements of their changing perceptions.

Current Study

The research summarized above describes a gap between student and professional perceptions of engineering and suggestions for reducing it throughout an educational program [5-8], [10]). To better understand the progression of our students' perceptions, we begin by broadly asking them to describe engineering, then more specifically about the work that engineers do and the skills that are applied to their work. To illuminate any differences between student and professional perceptions, we incorporated professional engineers' perceptions of engineering.

To that end, this pre/post study begins by surveying first-year pre-engineering and third-year engineering students to determine how well they can identify important engineering skills and work activities from the O*NET 29.0 database (details in *Instrument* section). This purposive dual sample (first-year $n = 73$, third-year $n = 56$) allows between-group analyses as well as within-group mean differences from pre- to post-semester. Open-ended qualitative responses indicating students' perceptions of engineering will add perspective to the quantitative analyses. Through analyzing these data, we address four questions:

1. How accurate are first-year pre-engineering and third-year engineering students' identification of important engineering skills and work activities?
2. Are third-year students better at identifying important engineering skills and work activities than first year students?
3. Do these accuracies change from the beginning to the end of a semester-long engineering course?
4. How do first- and third-year students describe their perceptions of engineering as a field?

This current study is one small, descriptive part of a larger conversation about emphasizing authentic professional experiences in our university's program.

Methods

Program

Students at our institution enroll in multiple, required courses during the undergraduate curriculum that either focus entirely on the Engineering Design process, or contain a design project as a portion of the course content. A basic framework of engineering design is introduced in the very first Introduction to Engineering course that all engineering majors complete. The design process and attribute terminology from *Engineering Design: A Project Based Introduction* [9] is introduced in the first-semester introductory course and expounded upon in greater detail in the upper-level design courses. The upper-level design courses consist of a two-course sequence (Engineering Design I and Engineering Design II). Nominally, students take Engineering Design I during their third year of study and take Engineering Design II (Capstone Design) during their fourth year of study. Capstone Design builds upon the curriculum introduced in Engineering Design I, but these are two distinct courses with different student teams and unique design projects in each course. Design projects progress from solving well-defined to ill-defined problems throughout the program.

Participants and Procedures

First-year students in the Introduction to Engineering course are categorized as pre-engineering and have not yet declared an engineering discipline in which to major. These students work in small teams of 3-4 students on a design challenge that is integrated with the core technical curriculum. Third-year students in the Engineering Design I course are either Mechanical Engineering, Electrical and Computer Engineering, or General Engineering majors, placed into interdisciplinary teams of 6-7 students on each team. This course is focused entirely on a semester-long design challenge following a highly structured design process that mimics industry under the guidance of clinical faculty.

In this study, pre-engineering students (*n* = 73) are 93% first-year students, and will be referred to as first-year students throughout the manuscript. Students in the Engineering Design I course (*n* = 56) are third- and fourth-year students (*M* = 3.57, *SD* = .50), and will be called third-year students for simplicity. Their majors are 60.7% Mechanical Engineering, 26.8% Electrical and Computer Engineering, and 12.5% General Engineering. We did not collect demographic data in this study for the purpose of protecting identities in this relatively small sample.

Instrument

The instrument developed for this study has three main components: 1) an open-ended description of engineering, 2) important skills for engineers, and 3) important work activities for engineers. The open-ended description is based on Villanueva and Nadelson's work [10] reflecting professional identity in engineering, represented by one qualitative question on the survey: *how would you explain engineering to someone who is unfamiliar with the field?* The second and third sections are adapted from Fleming and colleagues' methodology [11], employing the Occupational Information Network (O*NET) database to denote most and least important skills and work as determined by industry professionals in electrical, mechanical, and computer engineering; the three available engineering majors at [university]. O*NET's skills and work items were initially generated from literature and experts, with documented continuous updates from job incumbents and occupational analysts. A 2-stage random sampling method (business, individual) selects participants within specific careers to rate skills and work activities by importance to their occupation [12]. Included skills/work activities were chosen by sorting each by importance rating (1-5) and choosing the most and least important O*NET categories (e.g., IWAs) based on mean scores with high importance represented by 3.6 – 4.9 and low importance at 1.6 – 2.3 (see Table 1). We then adapted the five-point scale to four for our survey to remove the neutral response choice and thus more accurately calculate agreement.

Analysis

Research questions required both quantitative and qualitative analyses of participants' responses. The free-response question was analyzed deductively using Villanueva and Nadelson's three categories: Mediator, Designer, and 21st Century conceptualizations of engineering.

1. Mediator: Engineers use science, math, and technology.
2. Designer: Engineers solve problems and invent, plan, and design industrial processes.
3. 21st Century: Engineers' work has real-world applications in service of society [10].

Responses were coded using framework analysis [13] and the categories were expanded to include overlapping conceptualizations as shown in Figure 2. Participant responses were analyzed for categorical alignment and depicted with frequencies to examine pre- to post-semester changes.

Responses to the quantitative skills and work activity questions were analyzed for accuracy and change over the course of the semester. The accuracy of student responses is based on O*NET designations (see third column in Table 1). Data was recoded to zeros and ones, with ones indicating agreement with the O*NET designation. Due to this truncated range, normality tests were significant (Skills W = .825, p < .001; Work W = .819, p < .001) but due to the sample size, planned analyses continued [14]. Descriptive statistics (for RQ 1), independent samples t-tests (for RQ 2), and paired-samples t-tests (for RQ 3) were calculated using SPSS version 29.0 [15].

Results

RQ 1: How accurate are first-year pre-engineering and third-year engineering students' identification of important engineering skills and work activities?

Both the pre- and post-survey indicated that first- and third-year students were more accurate in identifying important engineering skills than work activities. In comparison to professionals' ratings, first-year students agreed with the importance of engineering skills 68% and work activities 56% of the time post-semester. Third-year students identified the important skills 68% and work activities 63% accurately. In simpler terms, both student groups accurately identified an average of 4 out of 6 important skills for engineering. For important work activities, students averaged between 3-4 out of 6. See Table 2 for descriptive statistics.

RQ 2: Are third-year students better at identifying important engineering skills and work activities than first year students?

When comparing groups on the pre-survey, there was no significant difference between first- and third-year students on the identification of important engineering skills ($t(126) = .59$, $p = .28$), but third-year students were significantly more accurate at identifying important engineering work activities ($t(125) = -3.18$, $p < .001$) with a medium effect, $d = .57$. Results were similar at post-survey. No significant difference was found between first- and third-year students on skills ($t(101) = -.29$, $p = .39$), however third-year students identified important work activities more accurately ($t(98) = -2.33$, $p = .011$) with a medium effect, $d = .47$. Third-year students were consistently more accurate when identifying important work activities, but first- and third-year students did not significantly differ when identifying important skills for engineering.

RQ 3: Do these accuracies change from the beginning to the end of a semester-long engineering course?

First- and third-year students did not significantly change their identification of important engineering skills and work activities after one semester. A paired-samples *t*-test revealed that first-year students had similar pre- and post-survey skills accuracies, $t(32) = .90$, $p = .19$, as well as for work activities, $t(33) = .73$, $p = .23$. Similarly, third-year students did not significantly change in skills, $t(39) = .50$, $p = .31$, or work activities, $t(38) = .28$, $p = .39$.

RQ 4: How do first- and third-year students describe their perceptions of engineering as a field?

Both pre- and post-semester, students' perceptions of engineering revealed that the three main conceptions of mediator (integrating math and science), designer/tinkerer (inventor, innovator, problem-solver), and 21st century engineering (global professional service) were present in participants' responses, similarly to [5]. First- and third-year students overwhelmingly held a designer conceptualization, with 88% of first-year students and 85% of third-year students focusing on designing solutions to problems in their engineering definition pre-semester.

Post-semester, we chose to analyze responses by breaking down the original categories to explore multiple components of students' perceptions and how they might combine beyond the initial three categories. In addition to mediator, designer/tinkerer, and 21st century conceptualizations of engineering [5], we identified three additional categories present in our data (see Figure 2). The first is Mediator-Designer. Students focused on designing solutions to problems while incorporating other STEM content, mainly math and science. For example, one third-year student explained, "Engineering is the process of analyzing complex problems and designing creative solutions. These problems generally involve mathematics, physics, chemistry, or a combination of all three." A second designation continues the exploration of problem-solving by combining it with purpose: Designer-21st Century. One first-year student exemplified this combination by defining engineering simply as, "Creative problem solving and innovation for a purpose to help people, the world, and the functions of day-to-day life." A final category expands on the previous by integrating applied math and science, thus Mediator-Designer-21st Century. The most complex definition, mainly third-year students integrated all of the elements discussed previously. For example, one third-year student shared: "Engineering is the application of science, math, and creativity to solve real-world problems and create things that make life better. Engineers take ideas and turn them into reality by designing, building, and improving tools, systems, and structures." Through extracting and exploring different combinations of elements in students' explanations of engineering, we can build a better understanding of their overall perceptions. Additional examples from our findings are available in Table 3.

Though our sample strongly skewed toward a Designer perspective on engineering, the first-year students also added Mediator and 21st Century elements post-semester, clustering them in the green-blue-purple areas of Figure 2. Third-year students incorporated Mediator and Mediator-Designer-21st Century conceptualizations, placing them in the green-blue-middle areas. These categories are more clearly visible through frequencies, available in Table 4. Overall, these depictions show that first- and third-year perceptions of engineering contained similar elements, but with different emphases.

Discussion

This study explored the accuracy of first-year and third-year students in identifying key engineering skills, work activities, and their perceptions of the engineering field. The findings provide valuable insights into the progression of students' perceptions, particularly their understanding of engineering roles.

Results indicate that students' accuracy in identifying important engineering skills remained consistent across first-year and third-year students, at approximately 70%, suggesting foundational knowledge of engineering skills is established early. In contrast, students demonstrated less accuracy in identifying important work activities, with first-year students at 59% accuracy and third-year students increasing to 65%. This disparity highlights a potential gap in how engineering education bridges theoretical knowledge with practical application. Skills often represent broad competencies emphasized in coursework, while work activities reflect specific, actionable tasks performed in professional settings. Difficulty in recognizing these activities may point to insufficient exposure to real-world engineering contexts, which reflects findings in previous research (e.g., [7]). Addressing this gap is critical for preparing students to transition seamlessly into the workforce, where an understanding of work activities is essential.

It was surprising to find no significant growth from pre- to post-semester on identifying important skills and work activities. However, this agrees with the known gap between educational contexts and professional practice [5], [6]. A single semester and small sample size may have limited detection of change. Further research on the timing and trajectory of engineering perception development is needed.

Students primarily conceptualized engineers as designers, a view that aligns with problem-solving and innovation, but lacked broader, 21st-century conceptualizations of the field. For instance, modern engineering increasingly emphasizes sustainability, interdisciplinary collaboration, and societal impact [3]. This underscores the "moving target" that is the modern engineering profession and calls for constant analysis of instructional practices reflecting the 21st Century conceptualization of engineering.

Limitations and Future Directions

As part of a larger conversation about engineering and professional practice, this is a small study, and the results are not intended to be widely generalizable. Limitations include a lack of demographic information for participants, a small paired sample, and the choice to use a researcher-created instrument based on O*NET, lacking psychometrics at this time. Future iterations will address these limitations.

The gap between engineering education and practice is well-documented, but it is also contextual, making it crucial to understand in context to identify when and where to incorporate authentic professional elements. We are considering expanding this study to include Engineering Design II (fourth-year) students and faculty voices. Interviews and focus groups with a more inductive approach would add depth to the current qualitative aspects of this study. A longitudinal lens has also shown promise when studying engineering perception development, which we are considering in future iterations. These are time-intensive options that would focus in on our specific university context. Another option we are considering is to continue the search for an instrument with established evidence of validity and reliability, then implementing it with an expanded sample of engineering students from our university and others. This could provide broader and more generalizable insights about students' developing engineering career perceptions throughout their undergraduate studies.

In summary, this study underscores the importance of aligning engineering education with the evolving demands of the profession. By examining students' accuracy in identifying skills and work activities and their perceptions of the field, the research highlights the need for educational programs to balance foundational knowledge with practical applications and broader conceptualizations of engineering. Such alignment is essential for fostering well-rounded professional identities and equipping students to meet the challenges of modern engineering careers.

References

[1] J. M. Lakin, A. H. Wittig, E. W. Davis, and V. A. Davis, “Am I an engineer yet? Perceptions of engineering and identity among first year students,” *European Journal of Engineering Education*, vol. 45, no. 2, pp. 214–231, Mar. 2020, doi: 10.1080/03043797.2020.1714549.

[2] L. S. Nadelson *et al.*, “Am I a STEM professional? Documenting STEM student professional identity development,” *Studies in Higher Education*, pp. 1–20, Jul. 2015, doi: 10.1080/03075079.2015.1070819.

[3] American Society for Engineering Education and National Academy of Engineering, “The engineering mindset report: A vision for change in undergraduate engineering and engineering technology education,” Jun. 2024. [Online]. Available: https://mindset.asee.org/

[4] Systems Approach for Better Education Results (SABER), “What matters for workforce development: A framework and tool for analysis,” 6, Apr. 2013.

[5] S. Sheppard, A. Colby, K. Macatangay, and W. Sullivan, “What is engineering practice?,” *International Journal of Engineering Education*, vol. 22, no. 3, p. 429, 2006.

[6] J. Trevelyan, “A framework for understanding engineering practice,” in *2008 Annual Conference & Exposition Proceedings*, Pittsburgh, Pennsylvania: ASEE Conferences, Jun. 2008, p. 13.42.1-13.42.21. doi: 10.18260/1-2--3319.

[7] S. Sheppard *et al.*, “Exploring the engineering student experience: Findings from the academic pathways of people learning engineering survey (APPLES).,” *Center for the Advancement of Engineering Education (NJ1)*, 2010, Accessed: Jan. 14, 2025. [Online]. Available: https://eric.ed.gov/?id=ED540124

[8] 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,” presented at the ASEE Annual Conference & Exposition, Columbus, Ohio, Jun. 2017. [Online]. Available: https://peer.asee.org/27476

[9] C. L. Dym, P. Little, and E. J. Orwin, *Engineering Design: A Project-Based Introduction*, 4th ed. Harvey Mudd College: John Wiley & Sons, Inc., 2014.

[10] I. Villanueva and L. Nadelson, “Are we preparing our students to become engineers of the future or the past?,” *International Journal of Engineering Education*, vol. 33, no. 2, pp. 639–652, 2017.

[11] G. C. Fleming, M. Klopfer, A. Katz, and D. Knight, “What engineering employers want: An analysis of technical and professional skills in engineering job advertisements,” *J of Engineering Edu*, vol. 113, no. 2, pp. 251–279, Apr. 2024, doi: 10.1002/jee.20581.

[12] U.S. Department of Labor/Employment and Training Administration (USDOL/ETA), “O*NET 29.0 Database.” Accessed: Sep. 23, 2024. [Online]. Available: https://www.onetcenter.org/database.html

[13] A. Srivastava and S. B. Thomson, “Framework analysis: a qualitative methodology for applied policy research,” *Journal of Administration and Governance*, vol. 4, no. 2, 2009.

[14] T. Lumley, P. Diehr, S. Emerson, and L. Chen, “The Importance of the Normality Assumption in Large Public Health Data Sets,” *Annual Review of Public Health*, vol. 23, no. Volume 23, 2002, pp. 151–169, May 2002, doi: 10.1146/annurev.publhealth.23.100901.140546.

[15] IBM Corp., *IBM SPSS Statistics for Windows, Version 29.0*. (2024). IBM Corp.

Figure 1: Conceptual framework of engineering perceptions [5], [8], [10]

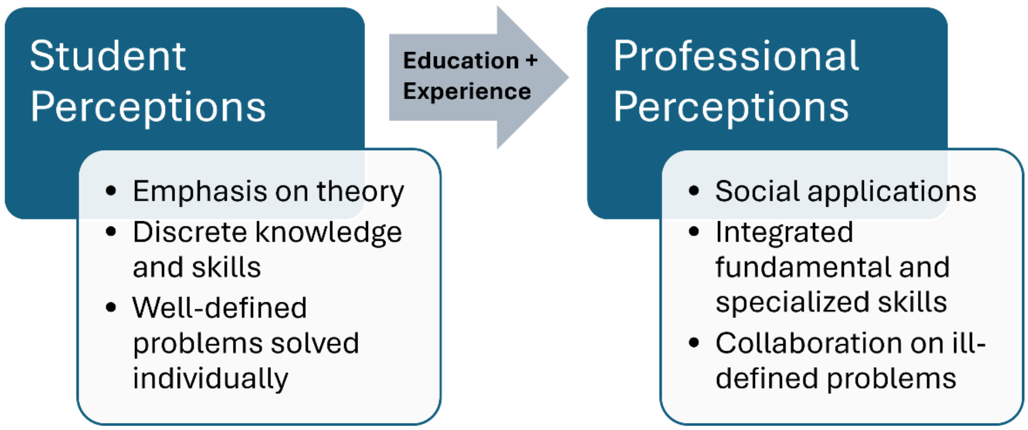


Table 1: O*NET importance ratings for survey questions

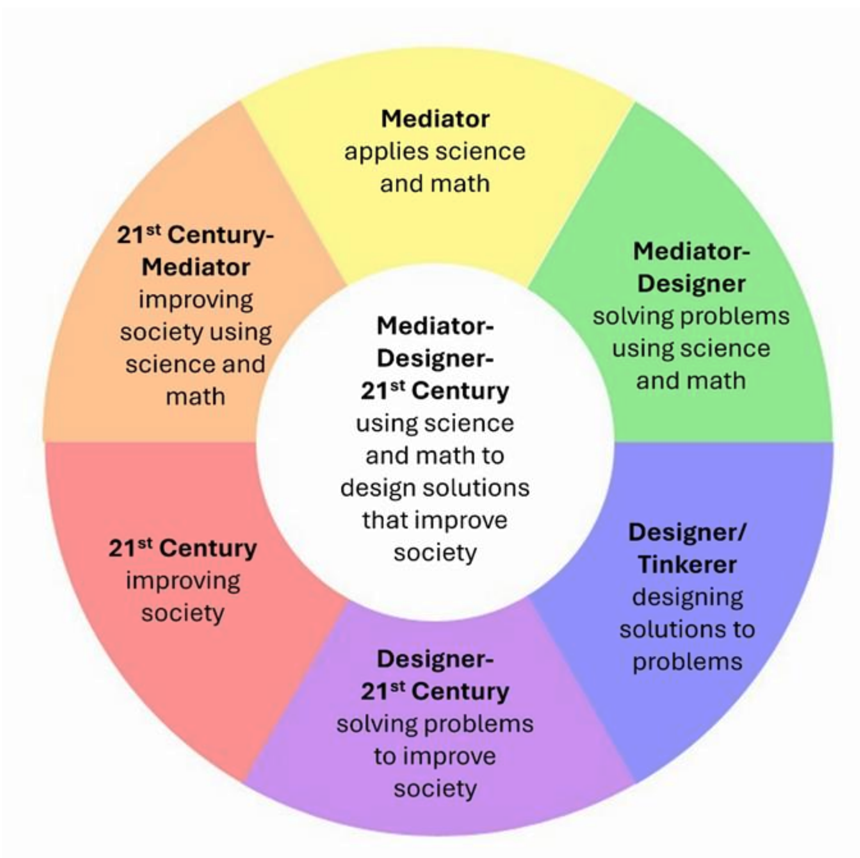
	Mean	Designation
Engineering Skills		
Content skills such as using science and mathematics to solve problems	4.1	Most Important
Process skills such as using logic, reasoning, self-monitoring, and actively incorporating new information	4.0	Most Important
Cross-domain skills such as developing and evaluating potential solutions for complex problems	4.1	Most Important
Systems skills such as evaluating system performance and considering costs and benefits	3.6	Most Important
Resource management skills such as ordering materials and accounting for the amount spent	2.3	Least Important
Technical skills such as choosing, controlling, and maintaining equipment	1.9	Least Important
Engineering Work Activities		
Communicate with others (e.g. technical personnel) about designs, specifications or project details.	4.8	Most Important
Read and interpret blueprints, technical drawings, schematics, or computer-generated reports to inform work processes.	4.7	Most Important
Design instruments, equipment, facilities, components, products, or systems.	4.9	Most Important
Assemble equipment or components to meet special needs.	1.6	Least Important
Supervise or train project team members on operational or work procedures.	2.0	Least Important
Establish or coordinate the maintenance or safety procedures, service schedule, or supply of materials required to maintain machines or equipment in the prescribed condition.	1.8	Least Important

Table 2: Descriptive statistics for results including percent accuracy for research question 1

	Skills Accuracy	Mean (SD)	Work Activities Accuracy	Mean (SD)
Pre-Survey				
First-Year Students	70%	4.18 (.74)	59%	3.56 (.82)
Third-Year Students	70%	4.18 (.69)	65%	3.93 (.97)
Post-Survey				
First-Year Students	68%	4.06 (.38)	56%	3.36 (.73)
Third-Year Students	68%	4.09 (.59)	63%	3.77 (.99)

Note. Means and standard deviations are based on 6 total items in Skills and 6 in Work Activities.

Figure 2: Expanded categories based on Villanueva and Nadelson's work [5]



Note. 21st Century-Mediator was not present in the current study.

Table 3: Expanded categories and participant examples

Category	First-Year Quote	Third-Year Quote
Mediator	"[Engineering is the] logical application of math and science."	n/a
Mediator-Designer	"Engineering is the science of innovative solutions for complex problems. It is the understanding of physics [and] using that understanding to solve problems."	"Engineering is the process of analyzing complex problems and designing creative solutions. These problems generally involve mathematics, physics, chemistry, or a combination of all three."
Designer	"It is the process of building things for specific reasons. Most importantly it is the process of finding problems and solving them."	"Engineering covers a wide variety of fields, most of which involve coming up with creative and technical solutions to solve problems."
Designer-21st Century	"Creative problem solving and innovation for a purpose to help people, the world, and the functions of day-to-day life."	"Engineering is a field that takes real world issues and fixes them for the ease and benefit of our society."
21st Century	"Engineering is a field in which one questions what the world needs in it rather than what the world it is."	"Understanding the way the world works and using our knowledge to improve quality of life."
Mediator-Designer-21st Century	"The application of science to the conversion of the resources of nature to the uses of humankind."	"Engineering is the application of science, math, and creativity to solve real-world problems and create things that make life better. Engineers take ideas and turn them into reality by designing, building, and improving tools, systems, and structures."

Note. Based on categories from Villanueva and Nadelson [5]. 21st Century-Mediator was not present in our data.

Table 4: Frequency table from analyzed post-survey responses

Category	First-Year Frequency (*n* = 44)	Third-Year Frequency (*n* = 55)
Mediator	2	0
Mediator-Designer	10	12
Designer	17	26

Designer-21st Century	10	4
21st Century	2	4
Mediator-Designer-21st Century	3	9

Note. Based on categories from Villanueva and Nadelson [5]. 21st Century-Mediator was not present in our data.