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WIP: Mapping Faculty Opinions of Student Skills Development in a Large-scale First-Year Design Program

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Introduction

This work-in-progress examines the differing perspectives of faculty teaching in the first-year design program at a mid-sized private R1 university. Findings here provide the groundwork of a larger study aiming to address a critical gap identified by the National Science Foundation's Division of Engineering Education and Centers [1]: that while significant strides have been made in both first-year engineering education and senior capstone experiences, many essential professional competencies introduced in first-year courses lack coordinated, program-level development through the middle years of engineering programs. As an initial phase of a larger research agenda, this study establishes baseline understanding of first-year design course instruction practices and perspectives, which will inform subsequent investigations into how these professional competencies are maintained and developed throughout the middle years of the engineering curriculum.

First-year design programs have gained popularity and offer opportunities to introduce students to the iterative engineering design process at the beginning of their degree [2]. Such courses are often transdisciplinary, allowing students to learn from peers with varying interests and perspectives [3]. Often programs integrate design and communication in first-year coursework, helping students develop various professional and technical skills [4]. Some programs have designated communication instructors as part of the teaching team to effectively teach these professional skills [5]. To provide meaningful first-year experiences, many design courses are taught with low student-instructor ratios [6]. This, and the large enrollment of first-year students, means whole-school design courses frequently require many faculty, often with diverse professional and academic backgrounds [7].

At the host institution, all first-year engineering students must complete two quarters of a course introducing the design process and embedded with learning objectives related to professional skill development. In this course, paired instructors—one specializing in design and the other in communication—teach teams of four students in sections of sixteen students. Many communication faculty (CF) and design faculty (DF) will teach multiple sections over an academic year or in a single quarter. With a first-year class size exceeding 500 students and a commitment to maintaining small class sizes, more than 65 faculty members have taught in this two-course sequence over the past two years.

Faculty are afforded significant instructional autonomy while students work towards major deliverables common to all sections. This autonomy allows faculty to implement and emphasize curricular elements that align with their expertise and teaching priorities. These pedagogical choices manifest primarily through the instructional emphases placed on specific assignments and the development of section-specific supplementary instructional materials. In this study, CF and DF reported their approach(es) to teaching students core technical and professional skills. They are then asked to assess student proficiency with these skills after the design course.

The diversity of faculty backgrounds and their varying approaches to instruction drive the research questions:

RQ1) Which teaching approaches are used by faculty to develop professional and technical skills, perspectives, and behaviors in their own sections?

RQ2) What are faculty perspectives on the professional and technical skills, and behaviors students acquire by the end of each quarter of the course?

Methods

This mixed-methods study employed a faculty survey to understand teaching approaches used in a first-year design program. Survey development began with a review of ABET criteria and engineering design literature to identify key professional and technical skills relevant to first-year engineering education. This initial skills framework was refined through consultation with experienced design and communication faculty including some familiar with the course but not currently instructors of this course. The resultant list of skills ranged from technical competencies including fabrication and engineering graphics to professional abilities such as written communication and teamwork.

The survey instrument contained four main components:

1) professional information capturing teaching experience and role (design or communication affiliation of respondents),
2) multiple-choice questions exploring approaches to teaching specific skills,
3) ordinal Likert-type questions regarding faculty assessment on student skill development upon completion of the course, and
4) open-ended questions about course strengths and opportunities for improvement.

To report teaching methods employed, faculty selected from five pedagogical approaches for each skill: direct instruction, individual or team coaching, specific assignment feedback, using Learning Management System (LMS) materials, relying primarily on their teaching partner, or not addressing the skill. Faculty could select multiple approaches for each skill, so that the data would describe both the breadth and depth of instructional strategies used.

Quantitative data analysis focused on identifying patterns in teaching approaches between faculty groups. Given the categorical nature of the measurement scales, Mann-Whitney U tests [8]—often considered the non-parametric equivalent of Student's *t*-test—were used to compare number of different teaching approaches used in total, and for skills associated as being within, or outside of, their domain of expertise (design or communication). For qualitative data, an inductive approach was taken by examining faculty responses at the statement-by-statement level before identifying emergent themes.

This work was determined to be exempt from continuing oversight by the host institution's IRB.

Results and Discussion

Respondents' characteristics

Nineteen faculty completed the survey sufficiently for inclusion in the analysis. The distributions amongst different professional characteristics are shown in Table 1. The respondent pool included faculty across experience levels, from first-time instructors, to those with almost three decades of experience with the course. Whilst broadly representative of the course faculty as a whole, the total sample size (19) limits conclusions that can be drawn.

Table 1: Professional characteristics of faculty survey respondents. It is likely that many of the "Professor of Instruction" line faculty are dually employed as first-year academic advisors (in a full-time 50–50 effort teaching/advising role).

Professional Characteristics	Response	Count
Instructional domain / role	Design (DF)	11
	Communication (CF)	8
Years of experience teaching course	0–3	7
	4–10	5
	>10	7
Average number of sections taught per year	1	3
	2–3	3
	4+	12
	N.R.	1
Employment position	Tenured faculty	1
	Professor of Instruction line	9
	Lecturer/Clinical	4
	Other (e.g. adjunct)	5

Faculty approaches to teaching skills: domain-based patterns

Analysis of instructional approaches showed both commonalities and distinctions between DF and CF. Both groups actively engaged in skill development, with very few skills reported as "not addressed" by either group. *Individual and team-based coaching* emerged as a frequently used approach across both faculty types, suggesting a shared commitment to hands-on student development.

The data revealed different emphases in teaching approaches between the two faculty groups. As Figure 1 shows, CF consistently reported providing *specific assignment feedback* across nearly all skills, whereas DF showed more varied application of this instruction approach. This distinction may reflect domain-dependent pedagogical traditions or comfort levels of individuals with different groups of assignments.

Domain expertise significantly influenced teaching approaches. Unsurprising findings included that CF showed limited engagement with technical skills such as *fabrication* and *engineering graphics*. However, when teaching *communication skills* and *research methods* CF reported using 3, 4, or all 5 categories of teaching approaches. Design faculty, interestingly, showed broader involvement in instruction across all skill types, including those traditionally associated with communication instruction.

Statistical analysis (Mann-Whitney U tests [8]) revealed small-to-medium effect sizes in these teaching patterns. Communication faculty employed a greater number of teaching approaches within their domain expertise ($r = 0.221$) compared to DF. Conversely, DF showed greater likelihood of engaging with communication-focused skills ($r = 0.225$) compared to CF's engagement with technical skills. These patterns present open questions about the role of faculty confidence, course structure, and assignment design in shaping instructional approaches.

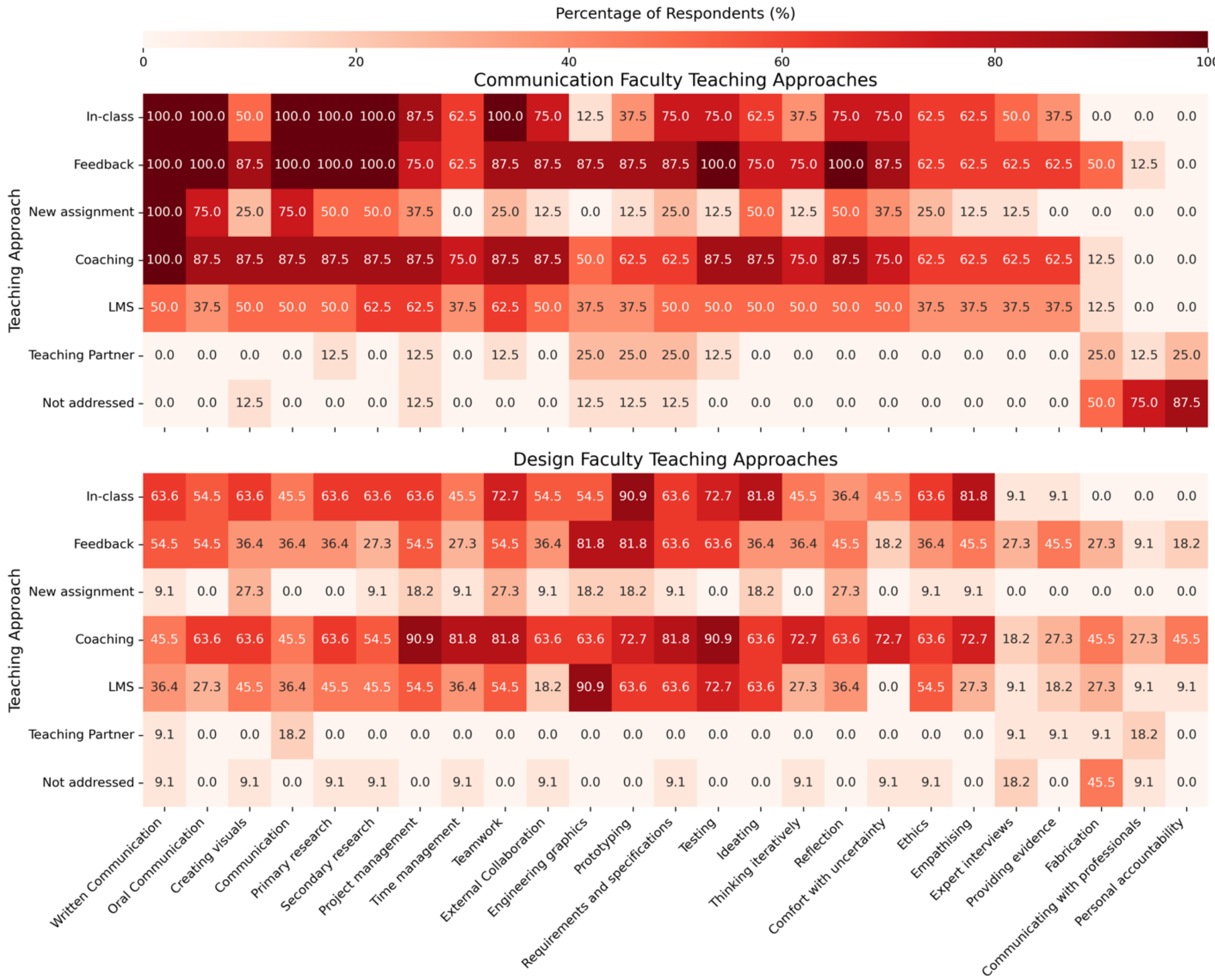

Figure 1: Percentage of faculty reporting usage of each teaching approach (columns) for each identified skill (rows). Questions allowed multiple response selections. Upper heatmap shows data from communication faculty (n=8); lower heatmap show data from design faculty (n=11).

Faculty approaches to teaching skills: experience-based patterns

Faculty with different levels of teaching experience also showed differences in instructional approaches as shown in Figure 2.

Whilst it is unsurprising that faculty less experienced with the course reported higher usage of Learning Management System (LMS)-based materials (course materials generated centrally and available to all instructors of all sections), it is notable that the most experienced faculty also reported relying on LMS-based materials for a greater number of skills. This may suggest that experienced instructors may strategically incorporate standard materials for topics they consider supplementary to their core teaching priorities.

A non-significant trend was observed toward increased diversity of teaching methods employed with increased experience. Faculty with 0–3 years of course experience used an average of 2.06 approaches per skill, those with 4–10 years used 2.41 approaches, and those with over 10 years used 2.91 approaches. This pattern suggests that experienced faculty may develop more varied pedagogical strategies over time.

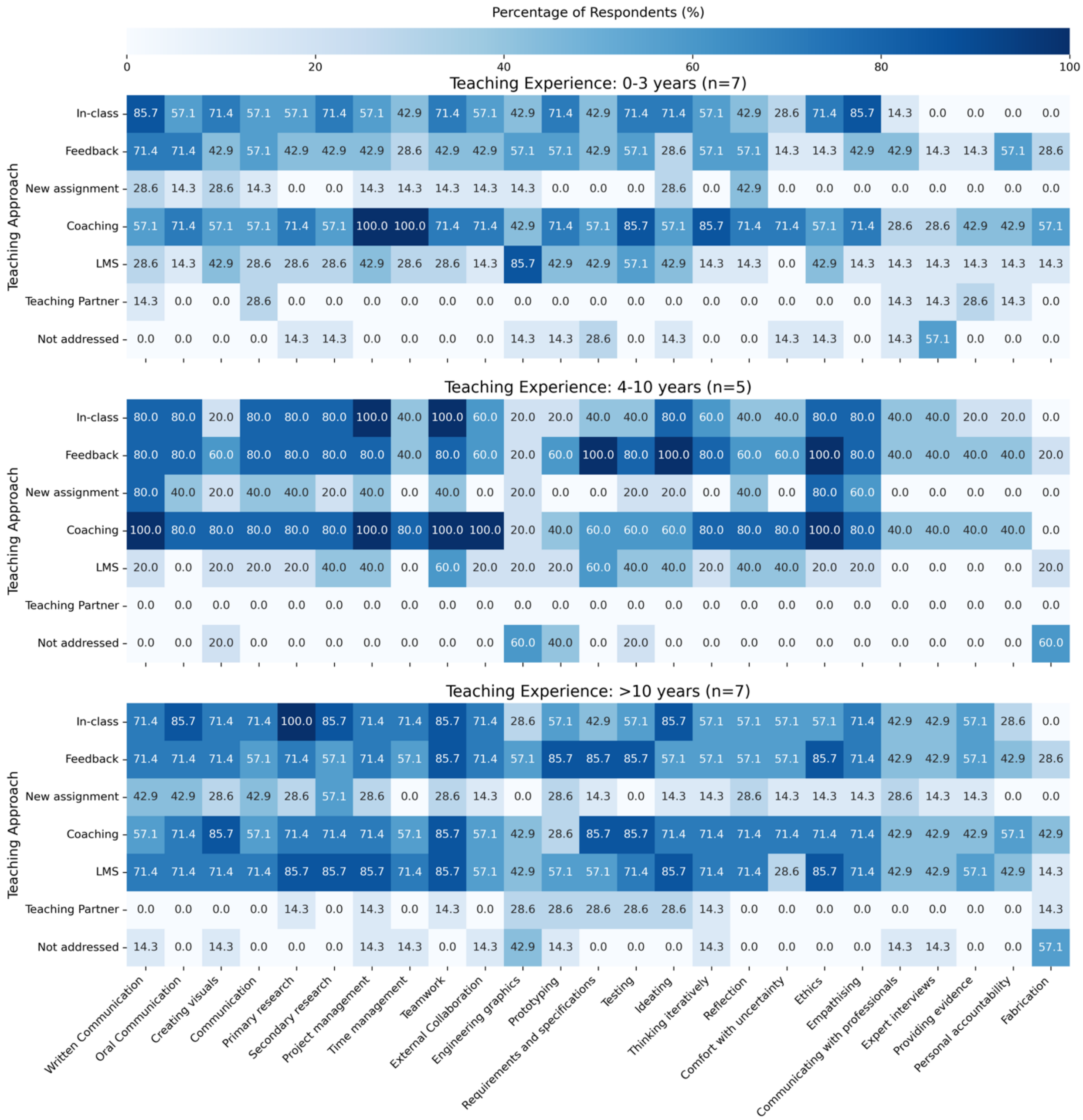

Figure 2: Percentage of faculty reporting usage of each teaching approach (columns) for each identified skill (rows). Questions were multiple choice. Upper heatmap shows data from faculty with 0–3 years experience teaching the course (n=7); center heatmap shows faculty with 4–10 years expeirence (n=5); lower heatmap show data from faculty with >10 years experience (n=7). CF and DF shown together.

Faculty perspectives on skills acquisition

Figure 3 shows survey data aggregated across all queried skills. Patterns were observed in faculty perceptions of the degree to which 'the average student' has acquired skills by the end of the course. Communication skills are viewed as well developed, with 40% of faculty reporting students need only minimal guidance in written and oral communication, while 35% indicate moderate guidance is needed.

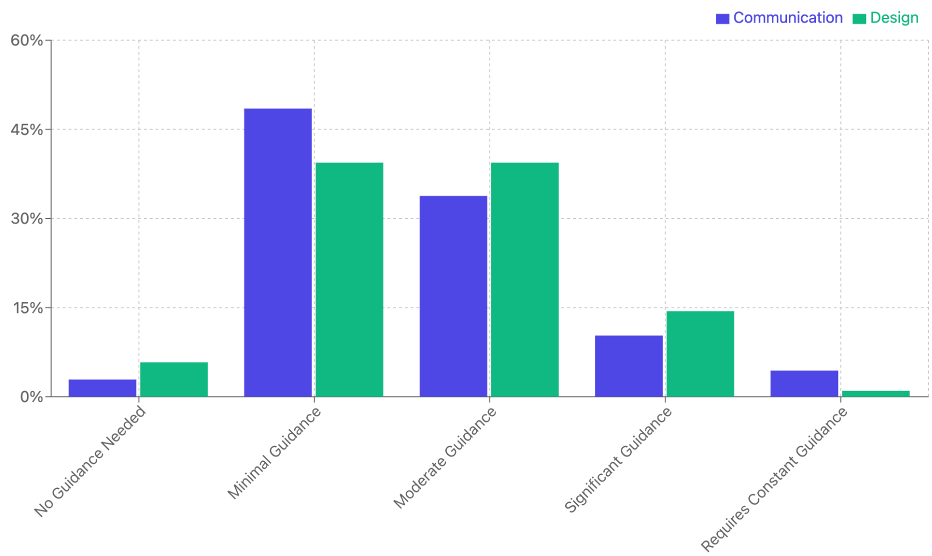

Figure 3: Percentages of responses across all queried skills for faculty perceptions of the capabilities of an 'average student' after successfully completing the course. Data disaggregated by instructional role: communication faculty (blue bars); design faculty (green bars).

Design-related skills demonstrate greater variation. For example, engineering graphics is viewed as requiring substantial support, with 50% of faculty indicating moderate guidance need and 29% reporting significant guidance required. While *prototyping*, which includes using prototypes to inform iterative design, shows more positive outcomes (43% minimal, 35% moderate guidance), fabrication appears more challenging to assess, with 47% of faculty responding "N/A". Among those who did evaluate fabrication, most indicated moderate (56%) or significant (22%) guidance needs. Often responsibility for fabrication instruction is shared or offloaded to workshop professionals which may explain these data. Conceptual design skills like ideating and iterative thinking show stronger development, with >55% of faculty reporting only minimal guidance is needed.

Project and time management consistently emerged as areas requiring additional support, with time management showing notably high proportions of "significant guidance needed" responses. Professional behaviors like teamwork and external collaboration demonstrate mixed results, with faculty split between reporting minimal and moderate guidance requirements.

The data reveal a clear distinction between CF and DF perspectives, particularly evident in technical skill assessments where communication faculty more frequently indicated "N/A". This suggests that while students develop strong foundational skills, ongoing support remains important in subsequent classes, clubs, or internships.

Open-ended response results

Inductive analysis of faculty responses to open-ended survey prompts revealed three interconnected themes, each with implications for first-year engineering education.

Conceptualizing the First-Year Experience

Faculty consistently described the course as an initial engagement with integrated engineering practice rather than a comprehensive skill-building experience. This framing aligns with established perspectives on first-year engineering courses as gateways that introduce students to engineering concepts, practices, and the profession while motivating them toward engineering [9], [10]. For example, one design faculty member characterized the course as where students first "apply HS physics, chemistry and math" to "problems they personally care to make happen." This characterization of "first exposure" appeared consistently across both design and communication faculty responses, suggesting a shared mental model of the course's role in students' development [11]. The emphasis on initial exposure rather than mastery reflects an understanding of first-year students' limited experience with design problems and their developing cognitive strategies [12]. This approach to early engineering education is particularly significant given research showing that student confidence in skill development can decline without structured project-based learning experiences [10]. The prevalence of this developmental framing was particularly evident in responses about student achievement, exemplified by one experienced instructor's observation that "students who satisfy all expectations are still early in their engineering learning." This approach balances the imperative to provide authentic design experiences [13] with the recognition that first-year students are still developing fundamental capabilities—a crucial consideration given that as few as 11% of students recognize the importance of fundamental design activities like problem formulation [14].

Student Metacognitive Development

A second theme centered on faculty concerns about students' metacognitive awareness of skill development processes. This theme manifested primarily through faculty observations of student attitudes toward learning iteratively. Multiple respondents described student resistance to revisiting skills introduced in the first-year sequence, captured in one CF's characterization of the student perspective: "I've already done this—why do I have to do it again?". This resistance aligns with documented challenges in education where students struggle to recognize the iterative nature of learning and skill development [15].

The resistance or reluctance observed (perceived or actual) from students suggests a misalignment between faculty and student understanding of skill development trajectories, reflecting broader challenges in helping students develop metacognitive strategies for learning control and self-evaluation [16]. In these data, this was particularly evident in one DF's reflection: "They will do these specific activities (writing, ideating, researching, testing, making) repeatedly at [institution] and beyond. But do we help students see that?" This question cuts to the heart of the pedagogical challenge, highlighting how faculty recognize their role not just in teaching skills, but in helping students understand the developmental nature of engineering education. This observation parallels findings from Bailey [17], who emphasized the importance of helping students recognize not just how to execute design activities, but why these activities hold value throughout their educational journey.

In describing this gap between faculty and student perspectives, faculty emphasized the need to help students understand their own learning process. Rather than viewing it as simply a matter of student motivation, faculty recognized this as fundamental to how students develop expertise. This framing aligns with research showing that effective design education requires guiding students in acquiring metacognitive knowledge through structured learning tasks that enhance goal-setting abilities [12][18]. The prevalence of this concern across different faculty subgroups suggests a systemic challenge in helping students develop more nuanced understanding of skill development, a challenge that recent research suggests might be addressed through design-focused pedagogical practices that provide iterative opportunities for mastery [19].

Systemic Challenges in Vertical Integration

The third theme emerged from faculty reflections on curricula structure, revealing tensions with how skill development is conceptualized through subsequent courses in the major—a challenge that echoes broader issues of disconnected knowledge in engineering education [20]. Two interrelated subthemes emerged: limited vision into subsequent student development, evidenced by one design faculty member's acknowledgment of having “no framework to provide feedback” on later skill applications, and perceived misalignment of expectations across course levels. The latter manifested in assumptions that students should work “with minimal guidance” in upper-level courses based solely on introductory exposure - an expectation one participant deemed “widespread among instructors of upper-level engineering classes, and completely”. These findings align with documented challenges in vertical integration and research showing skill confidence deterioration across years without proper curricular reinforcement [21].

Conclusions and future work

These findings indicate several opportunities for improvement. First, developing mechanisms to track student skill development through curricula could provide valuable feedback for optimizing introductory experiences. Second, explicit instruction to foster the development of metacognitive skills or knowledge could help students better understand and engage with ongoing professional and technical skill development [22]. This is particularly relevant with the current course structure whereby all first-year students take the course twice in their first year. Finally, improved communication between faculty at different levels could help align expectations and ensure appropriate scaffolding of skill development throughout the curriculum.

Building on this work, the research team will next examine how these professional and technical skills are addressed throughout the various engineering major curricula. This work will map skill development pathways across different engineering disciplines, identifying where and how these foundational competencies are reinforced between first-year design courses and capstone experiences. Understanding these developmental trajectories is crucial for addressing the systemic gap in engineering education identified by the NSF, ultimately helping to create more cohesive and effective engineering programs that maintain and build upon first-year competencies throughout students' academic careers.

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Appendix: Survey

Part 1: Biographical Information

1. [Course] Affiliation
   □ Design
   □ Communication
   □ Both

2. Current Position
   □ Tenured Faculty
   □ Tenure-track Faculty
   □ Clinical Faculty
   □ Professor of Instruction Track
   □ Lecturer
   □ Other (e.g., adjunct) [Text entry]

3. How many years have you been teaching [Course]?
   [Text entry]

4. How many sections of [Course] ([Course] 1 and/or [Course] 2) have you taught per year (on average) since the Winter of 2022 (Return to in-person instruction)?
   [Text entry]

5. What other courses (Design, Communication, or otherwise) have you taught at [Institution] or another university? (An exhaustive response is not required. You may list general types of coursework)
   [Text entry]

6. Have you been a member of the [Course] core committee in the last five years? (Note: The [Course] Core Committee is a monthly commitment by invitation of the [Course] co-leads)
   □ No
   □ Yes

Part 2: Understanding the [course] Learning Context: How are Skills Addressed?

The research team has identified 25 skills related to the development of engineers that they believe are introduced in [Course]. For each skill, we'd like to know what emphasis you place on the development of the skill in your [Course] section.

Teaching Strategies Matrix

For each skill listed below, indicate which teaching strategies you employ (check all that apply):

□ Not Addressed: The skill is not addressed by me
□ Canvas: I rely on assignments in the Canvas shell (ex. [Course] textbook, videos)
□ Class Instruction: I provide specific instruction during class
□ Feedback: I provide specific feedback on assignments to support this skill
□ New Assignment: I generate additional and/or alternative assignments
□ Coaching: I provide coaching in or out of class for individuals/teams
□ Teaching Partner: My teaching partner primarily addresses this skill

Skills:

1. Written Communication (in a design context)
2. Oral Communication (in a design context)
3. Creating visuals (flowcharts, journey maps, charts, tables, etc.)
4. Communicating to a target audience
5. Conducting primary research
6. Conducting secondary research
7. Project management
8. Time management
9. Teamwork (ex., defining goals, team norms, and decision-making processes)
10. Collaboration (working well with others to bring together diverse perspectives within or outside of a team environment)
11. Creating engineering graphics (ex., Isometric sketches, dimensions, orthographic projection)
12. Creating mock-ups and prototypes (building to learn)
13. Fabrication skills (laser cutter, 3D printing, machining)
14. Generating requirements and specifications
15. Testing mock-ups and prototypes (User, Performance)
16. Ideating to develop potential solutions
17. Thinking iteratively
18. Reflecting on their work
19. Demonstrating comfort with uncertainty and ambiguity
20. Applying ethical principles to the design problem
21. Treating others with empathy
22. Communicating with professionals or users (written and oral communication)
23. Conducting expert interviews
24. Providing evidence to support decisions
25. Demonstrating personal accountability (for team actions or performance)

Part 3: Student Skill Development Assessment

For each skill, rate how successfully these skills are developed on average in a typical section you teach. Consider how well students in your section would demonstrate those skills in another course or internship. If you only teach [Course] 1, describe how the students would perform after [Course] 1. If you teach [Course] 2, describe how the students would perform after [Course] 2.

Assessment Scale
After [Course] coursework and instruction (lectures, coaching, Canvas, etc.), the average student can perform the skill in a subsequent internship or course with the following level of guidance:

1 = Requires Constant Guidance
2 = Significant Guidance Needed
3 = Moderate Guidance
4 = Minimal Guidance
5 = No Guidance Needed (Independent)
6 = N/A (I have no opinion or no frame of reference)

[Rate each skill 1-25 using the scale above]

Part 4: Additional Feedback

1. Please provide any additional context to your responses to the earlier questions.
   [Text entry]

2. What skills do students gain that are not reflected in the list of skills presented above?
   [Text entry]

3. What skills do students struggle with that are not reflected in the list of skills presented above?
   [Text entry]

4. How do you, or would you, support the development of any new skills you listed in the last two questions when teaching in your sections?
   [Text entry]

5. Please share any additional comments that might help the research team.
   [Text entry]