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Experiences of Self-Evaluation for Capstone Engineering Students Professional Development

Prof. Emily Houston Monroe, Dartmouth College

Emily Monroe, PE is a lecturer at the Thayer School of Engineering at Dartmouth College. She serves as the director of the Cook Engineering Design Center at Dartmouth, which connects industry, government and nonprofit sponsors with Dartmouth Engineering students to collaborate on engineering design projects. Prior to joining Dartmouth, Emily was the lead engineer at Shark Tank-funded baby diaper startup Kudos, and she previously held roles in manufacturing and product development. Emily is a licensed professional engineer (PE) and holds a BSME from MIT and Master of Engineering Management from Duke University.

Jentry Elizabeth Campbell, Dartmouth College

Librarian for Research & Learning, STEM. Liaison to Thayer School of Engineering at Dartmouth College.

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Abstract

The capstone design engineering course at the Thayer School of Engineering at Dartmouth College is a two-term, project-based course sequence that involves industry and non-profit projects and professionals. The course addresses all seven ABET learning outcomes through lectures, workshops, team work, and individual assignments and culminates in a group-based final presentation and written paper. In addition to the project experiences, students complete several professional development activities intended to increase their understanding of various topics integral to the engineering profession, including economics, ethics, safety, social context, and technical communication.

As part of their professional development, students were asked to develop their own performance assessments. At the beginning of the course, students were asked to design a series of activities they could complete in one month's time in the categories of social/emotional, technical/instructional, and experiential/hands-on. Students were then asked to develop a plan to accomplish these goals and then evaluate their performance based on their identified goals. To measure change in confidence, students were asked to complete a pre- and post- assignment survey based on the validated SICKS instrument. Additionally in the post-assignment survey, students were asked to rate their improvement toward ABET outcomes 5 and 7.

Results indicate that aggregate evaluation showed a trend towards the mean. Results evaluated by gender showed that male students tended to lose confidence and non-male students tended to gain confidence. Only one question of the 15 question SICKS confidence instrument, during aggregate evaluation, showed statistical significance. Overall the majority of students rated their abilities, as defined in ABET 5 and ABET 7, as somewhat or much better following the assignment. Improvements to the method are discussed. Future research should include data analysis by race as well as gender.

Introduction

There are certain criteria every accredited engineering program must meet in order to maintain their accreditation with ABET. Among the criteria is that students complete a culminating major engineering design experience [1]. At the Thayer School of Engineering at Dartmouth, the culminating experience, also referred to as the capstone course, counts toward the accreditation process. As such the capstone's learning outcomes are directly linked to the ABET learning outcomes for a program at a Bachelor of Engineering (BE) level. These seven learning outcomes are shared with students in the capstone syllabus and introductory lectures, and those learning outcomes drive the design of assignments in the course [1]. For convenience, the seven learning outcomes of the capstone course are:

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. An ability to communicate effectively with a range of audiences
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

At Dartmouth's Thayer School of Engineering, the interdisciplinary capstone course lasts for two 10-week terms and welcomes students at the BE level as well as students in the Master of Engineering program. The capstone student experience is centered on a project in partnership with an industry or nonprofit organization. Like in other capstone programs, Dartmouth students are building on their foundational engineering knowledge and developing new knowledge. Additionally, industry-based projects in the capstone ground the students' learning in professional settings and give them early access to the professional communities they will join after graduation [2]. To set students up for success in this pre-professional experience, the capstone curriculum has grown to include direct instruction on topics like project management, technical risk management, and licensure, as well as a series of professional development (PD) assignments.

The PD assignment sequence consists of seven assignments designed to increase students' skill acquisition from a level of basic awareness toward mastery of the skill. Starting in the first week of the first term of the capstone course, one PD assignment was completed each week until the final three weeks, at which point the first term capstone project final presentations and reports were due and PD assignments ceased to allow students to focus on the final course deliverables. The learning outcomes of the course are the seven ABET outcomes, and each PD assignment was linked to an ABET criteria / learning outcome. The PD assignment titles, submission requirements, goals, and linked ABET criteria are outlined in Table 1. All PD assignments were submitted through the learning management system Canvas. For the purposes of this paper, we will be exploring a pair of PD assignments, PD2 and PD6, focused on goal setting and self-evaluation of performance.

Table 1. An overview of the professional development (PD) assignment series in the first term of the capstone course in engineering design at Dartmouth's Thayer School of Engineering. This paper relates to the highlighted assignments, PD2 and PD6.

Term Week	Title	Required Submissions	Goal of Assignment	Related to Project	ABET Criteria
1	PD1 - Values	Bulleted list of values the student brings to their work	Bring values to top of students' minds as they select their capstone projects and lay out their PD2	Yes	2, 4
2	PD2 - Self-Assessment Proposal	Six goals to complete in 1 month's time, as described in Appendix C	Allow students an opportunity to pursue professional and personal development in a structured way (social, technical, experimental), without constraints of traditional academic grading	Yes	5, 7
3	PD3 - Ethics	Reflect and respond to three prompting questions related to an adapted National Society of Professional Engineers (NSPE) ethical scenario	Introduce NSPE Code of Ethics and encourage students to see complex ethical decision-making in their technical decisions	No	2
4	PD4 - Safety	Identify components of a safety data sheet (SDS), determine safety requirements for their project, reflect on what an effective Culture of Safety looks like and how they might implement one for their project and team	Familiarity with the elements of safe conduct of engineering design work, including SDS, PPE and training	Yes	4
5	PD5 - Engineering Economics	A problem set with 10 questions in various engineering economics prompts	Familiarity with and practice with engineering economics calculations, similar to what is included on the Fundamentals of Engineering (FE) exam	No	2, 4
6	PD6 - Self-Assessment	Brief assessment of completion of their six proposed goals from PD2, following the template as described in Appendix C	Spur self-assessment of student's personal and professional goal-setting ability related to scope and timing of the goals	Yes	5, 7
7	PD7 - FE	Nine question practice FE exam with	Prompt students to review their	No	4

	Prep	three questions each from ethics, safety, and engineering economics	learnings in ethics, safety, and engineering economics; lower barrier to licensure by familiarizing the FE		

Students enrolled in the design engineering capstone course are in a pivotal moment as they transition between their academic and professional careers. In the workplace, engineers are expected to be well versed in setting measurable goals then working to achieve them, both in their technical work and for their own professional development. Yet most academic experiences in a typical engineering curriculum do not prepare students to exercise this professional skill [3]. As this assignment was designed to encourage the exercise of goal-setting skills toward mastery, the PD2 (set goals) and PD6 (evaluate performance) assignments were assessed on a complete/not-complete basis, with no evaluative elements related to actual completion of the goals by the students. Extensions were issued to ensure 100% completion of both assignments by the 140 students within the 10-week course.

At the conclusion of the PD2 and PD6 assignments, we hoped that students would:

1. Identify areas of self-improvement and how to get that knowledge (ABET 7, ABET 5)
2. Experience a method related to how engineers in the profession are reviewed and rewarded
3. Self-assess their performance to improve areas they identify as strong and areas they identify as needing improvement

Implementing the PD2 and PD6 assignments for the first time in Fall 2024 allowed us the opportunity to plan a pre-assignment survey and post-assignment survey that looked at student confidence [4]. In doing so we planned to answer the following research questions:

1. Does student confidence increase as a result of the planning and completion of a professional development self-assessment?
2. As a result of completing this professional development activity, is there a change in self-reported student ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives (ABET 5)?
3. As a result of completing this professional development activity, is there a change in self-reported student ability to acquire and apply new knowledge as needed (ABET 7)?

Research questions 2 and 3 above were asked directly of the student research participants following the conclusion of the PD6 assignment. Research question 1 was assessed using a pre- and post-assignment survey instrument to determine student confidence before the course began and after the PD6 assignment concluded to allow us to evaluate if confidence changed. We chose the “Short Instrument for Measuring Confidence in Key Skills” (SICKS) validated instrument for measuring post-primary students’ confidence in six areas of “key skills”: critical thinking,

collaboration, communication, creativity and innovation, self-direction, and using technology for learning [5].

While the SICKS instrument was validated with a slightly younger population (ages 12 - 19 years) than the capstone course typically includes (ages 20 - 24 years), the key skills it includes in its confidence measures are relevant to ABET criteria 5 and 7, and therefore aligned with the goals of this research.

Literature Review/Background

ABET outcomes 5 and 7 are central to an interdisciplinary project-centered course, where teams of students who are not necessarily experienced in the project's technical areas work together for an extended period of time. In previous iterations of this capstone course, students received grades from instructors for their work and participation, but there was not a component that required introspection of skills, contributions, and future opportunities for professional development [6]. A growing body of research suggests that skills in self-evaluation drive self-efficacy, or confidence, and help retain students in the engineering profession [7], [8], [9]. Common in industry, performance evaluations include the identification of areas of improvement and self-directed learning; this assignment was designed to mimic these experiences [10].

Preparation for a career in engineering through professional development assignments in the capstone has been done at Dartmouth for at least the last 20 years. This is in keeping with other engineering education programs in the United States, with the most commonly included professional development topics including licensure, economics, and safety [11]. In addition to traditional engineering professional development assignments, other programs have made use of self-assessment assignments in a capstone or design course to develop professional skills in engineering students [4], [12]. Self-assessments in other engineering courses have been linked to exam preparation rather than professional development, with self-assessed confidence measured as an evaluation of preparation for the exam [13].

The act of setting measurable goals then self-assessing completion of the goal is similar to the performance review process in industry [14]. However, most capstone courses do not give students an opportunity to directly practice then self-assess their own goal-setting performance [11]. The professional development assignments PD2 (goal setting) and PD6 (performance evaluation) were designed to simulate the professional performance evaluation process while allowing students to gain skills in self-assessment of their performance. To determine the effectiveness of the self-assessment activity, we looked to what others have done related to confidence achievement from skill-building capstone assignments.

Professional development instruction related to student confidence, or self-efficacy, within engineering design courses ranges from grade-dependent and single-semester [15] to multi-year

efforts outside of a single course [7]. Validated instruments have been used to measure self-efficacy [16] while in some cases a customized assessment specific to a department or institution was implemented [10], [17], [18], [19].

One validated instrument called TRAILS was used by Hebda et. al. to measure confidence before, in-process, and after the course, as well as qualitative interviews with participants [16]. The TRAILS instrument was designed for high school students to assess the key skills of communication, collaboration, critical thinking, and creativity in a project-based context [20]. Like the SICKS instrument, the TRAILS instrument directly asks students to rate their confidence, but afterward the data is compiled then graded via rubrics to assess the factor loading of each of the skills considered [5]. The decision to proceed with the SICKS instrument was made to simplify the computational analysis of results.

Methods

We were granted an IRB Exempt Status from the Dartmouth College Committee on the Protection of Human Subjects and obtained consent from all participants. Any student that completed the initial survey but did not complete the final survey was removed from the analysis pool.

Using the validated SICKS instrument, we created a pre- and post-assignment survey to assess student confidence with a 5-point Likert style scale of “not at all confident” to “extremely confident” as seen in Appendices A and B. The surveys contained six sets of three questions (total of 18 questions) based on six themes: collaboration, communication, creation, self-management, critical thinking, and technology. The post-assignment survey had three additional questions on students' self-perception of how the PD6 assignment changed their abilities related to ABET 5 and ABET 7. Due to a construction error in the pre-assignment survey, question 5 asked the correct base question but had incorrect sub-questions and was therefore invalidated, leaving us with 15 questions to compare between pre-assignment and post-assignment surveys. This was corrected on the post-assignment survey but due to the lack of pre-assignment survey data, there is not a comparison available on question 5 and therefore SICKS question 5 was removed from this analysis.

The pre-survey was completed by students in mid-September and the post-survey was open to students from the conclusion of the PD assignment sequence until one week after the completion of the course, giving students approximately one month to complete the post-assignment survey following the due date of the PD6 assignment. From a total of 140 students enrolled in the course, 140 completed the PD2/PD6 assignment and 38 completed (27% response rate) the pre- and post-assignment survey.

Data was de-identified, linking a unique, random ID to the input data, including survey results as well as self-identified gender. The survey results were analyzed using Minitab Statistical Software using an analytical approach from biomedical industry experience to compare the pre- and post-assignment surveys and draw conclusions where possible. First, normality was assessed. Then, appropriate comparative statistical analyses were applied. The PD2/PD6 assignment submissions were analyzed using grounded theory [21]. The results should be considered a case study for this assignment in the context of this course and are not generalizable in any way to a different population.

Results: Survey Analysis

Summary statistics by gender of participants are shown in Table 2, with gender depicted as male and non-male, which includes female, non-binary, and prefer not to answer. This table shows that the participants in the study were representative of the overall makeup of the engineering program and the capstone course. All students in the capstone course have senior standing in the engineering sciences major or are candidates in the Master of Engineering degree program.

Table 2. Summary demographic statistics of the participants in this study by percent.

	Male	**Non-Male**
Enrolled in Study	55.2% (21)	44.7% (17)
Enrolled in Capstone	55.7% (78)	44.3% (62)
Graduated from BE program at Dartmouth's Thayer School of Engineering in the prior academic year	50.5% (51)	49.5% (50)

In nine questions of the SICKS instrument, we saw an overall increase in student confidence. Interestingly, in six questions, we saw a drop in the number of students responding "Extremely Confident." Taking the mean confidence value for each of the 15 SICKS questions included, each data set was non-normal (A-D $p<.05$). Despite non-normality, paired t-tests (null: $\mu_{difference} = 0$, alternative: $\mu_{difference} \neq 0$) showed a significant difference between pre- and post-assignment data ($\alpha = 0.05$) only on Question 4_1 ("How confident are you to track your own progress and change things if you are not working the way that you should be to complete a task?"). The results of the differences of means post-assignment minus pre-assignment are shown graphically in figure 1. Of note, there are five SICKS questions for which the difference in mean confidence was zero or negative. This indicates no change or a decrease in confidence after completion of the PD2/PD6 assignment.

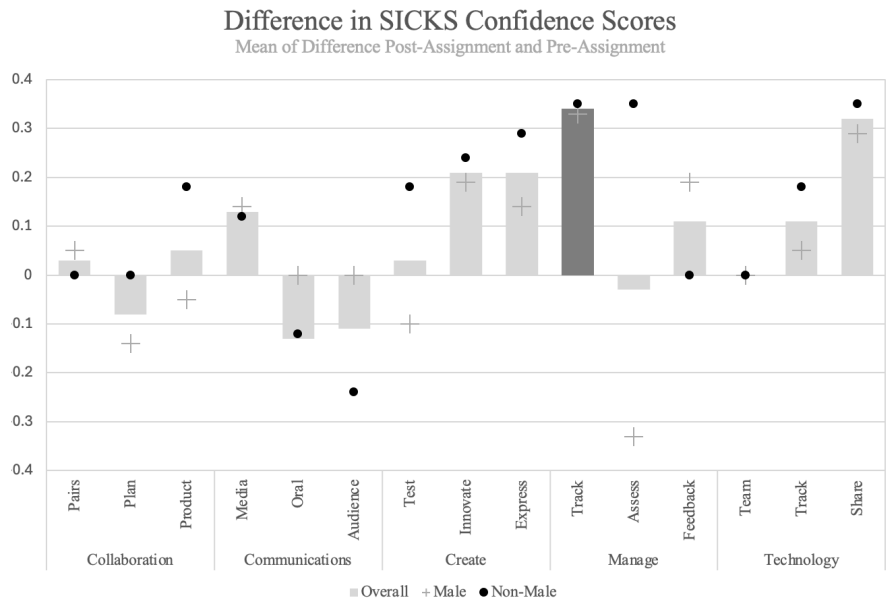

Fig. 1: Average difference in the means of student confidence between pre-assignment and post-assignment based on SICKS instrument survey responses overall (N=38, indicated by bars) as well as by male (plus sign) and non-male (circle) responses. Data points with no bar signify no change. The darkest bar signifies a p-value of $p < 0.05$ in a paired t-test.

An unexpected result of this research is that 30 of the 38 students reported feeling less confident in at least one of the five areas (each with three sub-areas) of the SICKS instrument we included in this analysis (Critical Thinking, Collaboration, Communication, Creativity and Innovation, Using Technology for Learning). When we group mean confidence by gender, a common analytical method in engineering education datasets, the results show differences in the mean by gender across almost every survey question. This is seen in figure 1 with the plus icon representing self-identified males and the circle icon representing self-identified women or other genders (seen in the key as 'non-male'). Overall, the differences in pre- and post-assignment confidence by gender aligns with the difference in means seen in figure 1 with more detailed SICKS Confidence measures shown in Table 3.

Table 3. Summary demographic statistics showing the means of confidence measured as a sum of the SICKS instrument (max possible value of 75) by grouping of self-identified male and non-male groups.

	Male	Non-Male
Mean of Pre-Assignment SICKS Confidence	61.19	59.06
Mean of Post-Assignment SICKS Confidence	61.95	60.94
Average Difference in SICKS Confidence	0.76	1.88
Average Occurrences of Decreased SICKS Confidence within Instrument (max possible value of 15)	3.71	3.35

In the post-assignment survey two additional questions were asked. Question 11 (“How has this assignment changed your ability to acquire and apply new knowledge as an engineer?”) directly addresses ABET outcome 7. Question 12 (“How has this assignment changed your ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives?”) directly addresses ABET outcome 5. All but one survey respondent who completed the rest of the survey completed these questions, resulting in N=37 for these ABET outcome questions. Results are shown in Table 4.

Table 4. Aggregate responses to Questions 11 (ABET 7) & 12 (ABET 5) from the post-assignment survey

	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better
ABET 7 (Q11)	0	0	16	14	7
ABET 5 (Q12)	0	1	12	20	4

Aggregate results show that for question 11, 55% (n=21) of students felt that their ability to acquire and apply information following the PD2/PD6 assignment was either somewhat or much better, while 45% (n=16) felt that their skills remained about the same following the assignment. For question 12, most (65%, n=24) believed that their ability to work in a team was improved following the PD2/PD6 assignment. As the entirety of the course is team-based work, it is likely the practice of structured group work and project management throughout the term influenced the response to question 12.

When we break out these responses by gender, non-male students reported better performance in both the ABET outcomes included in the survey. A higher percentage of non-male students (81%) reported a somewhat or much better ability to function in a team, seen in figure 2 as ABET 5 (Q12), following the assignments than male students (62%). This is also true for non-male students (69%) versus male students (48%) when rating their ability to acquire and apply new knowledge, seen as ABET 7 in figure 2.

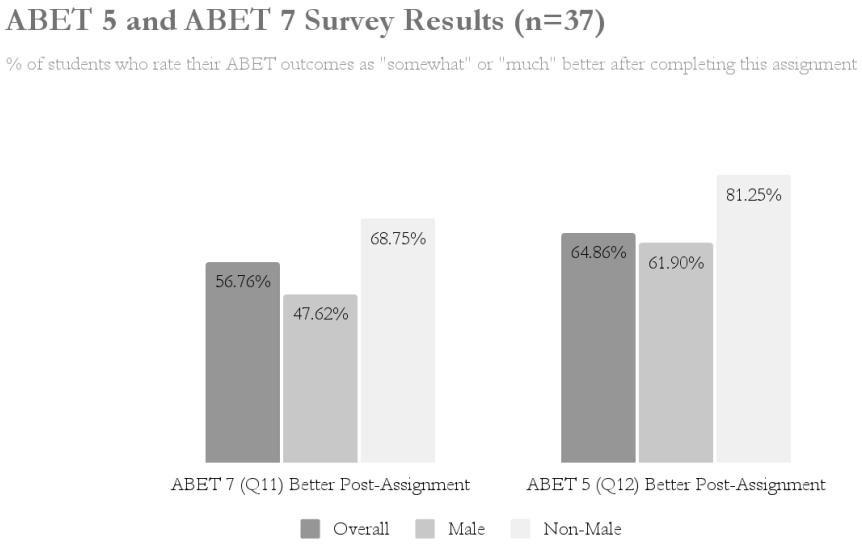

Fig. 2: Survey results from Questions 11 and 12 on our post-assignment survey, showing the percentage of students who felt "somewhat better" or "much better" about their ability to achieve ABET outcomes 5 and 7 following the PD2/PD6 assignment. Students who identified as "Male" were included as "Male" here, and any students who identified as female, non-binary, or "prefer not to say" were included as "Non-Male".

For the open response answers on post-assignment survey question 13, "How will you apply what you learned in this assignment going forward?" 47% (n=18) of survey respondents provided responses. Example responses that showcase the overall tone and content of the open response feedback include:

"This is a great reflection of how I can improve myself for the team and me as an engineer. It's the progress I have been making with the help of my [project] teammates."

"I really enjoyed how this assignment encouraged accountability and an honest reflection on my ability to both produce individual work and collaborate with a team. I plan to apply my new understanding on the importance of accountability to my future group work by giving myself the time to perform an honest self reflection and also ensure that I am listening to others and taking feedback."

"I will continue to use what I learned in this assignment to set goals for myself and hold myself accountable to them."

Results: Assignment Analysis

The scope of our research included analysis of the content of students' PD2/PD6 goal-setting assignments. We believe this analysis will allow us to improve future versions of both the assignment and this assessment of student confidence following this assignment. The activities

students proposed to complete during their PD2/PD6 assignment for each area of practice (Appendix C) were analyzed for each of the 38 survey respondents. These were considered open text responses and were coded using a grounded theory approach. After several rounds of coding, eight categories emerged with several activities being coded to multiple categories. The eight categories as well as definitions or examples are listed in the codebook in Table 5 with the total number for each category listed in Table 6.

Table 5: Codebook for PD2/PD6 assignment [Appendix C] responses for "Activity to cultivate growth and improvement" goals for each area of practice

Category of Response	Definition or Example
Technical Skills	Making, building, repairing, learning CAD/Python, etc.
Leadership/Project Management	Decision making, project management or organization, ethical decision making
Campus Resources	Use of library resources, machine shop, technology transfer, etc.
Communication	Improving or practicing written, oral or visual communication, interpersonal communication, etc.
Relationships/Teamwork	Cultivating team culture, networking, emotional intelligence, group dinners
Productivity and Habits	Tracking time or work, organizing own time, accountability, mindfulness of work and self
Career or Certifications	Job preparation, interviews, certifications
Miscellaneous	Unrelated activities (going on adventures, participating in a hobby, etc.)

Table 6: Summary results from the PD2/PD6 assignment, showing the types of goals set by gender. Table is ordered by highest to lowest response category, and goals can be in more than one category.

	Female	Male	Non-binary	Prefer not to answer	Grand Total
Technical Skills	42	68	4	4	118
Leadership/Project Management	9	28	1	0	38
Campus Resources	9	22	1	1	33
Communication	10	16	1	0	27
Relationships/Teamwork	10	13	0	1	24
Productivity/Habits	12	7	0	1	20
Career/Certifications	5	9	0	1	15
Miscellaneous	10	5	0	0	15

As seen in Table 6, 118 of the activities listed on the PD2/PD6 assignment dealt with Technical Skills largely related to the skills needed to complete the course's overall project-based

objectives. This category was three times larger than the next highest categories being Leadership/Project Management (n=38), and campus resources (n=33) respectively, and has the majority of coded responses for any gender.

Discussion, Conclusions, Lessons Learned

These results are unfortunately limited in their ability to draw conclusions about confidence or assignment effectiveness overall. Future work is needed to create a more robust dataset, and we plan to continue this research for at least three future course offerings. We will ideally revise the assignment and survey design to more clearly link the students' SICKS assessment to the professional development assignment, as well as revise our IRB to allow us to include a disclosure of race. We feel that this additional datapoint will enrich our analysis and is in step with the granularity of data seen in reports such as ASEE's *Engineering by the Numbers* [22].

When considering the cause of those reported decreases in confidence, as well as differences in reported confidence by gender, we hypothesize that these are likely due to a variety of factors including a greater awareness of their own knowledge gaps in the skill areas following a self-assessment of an attempt to set and meet goals in one month's time. The decrease in confidence may also come from general experiences within the term increasing their overall perception of their own confidence in the key skills measured by SICKS. We cannot confirm these suspicions with the currently available data or the current study design. These noticeable differences in confidence by gender are worth further consideration at a later time, possibly alongside race.

Looking at the aggregate, there appear to be overall trends toward the mean, as some students who were less confident in pre-assignment survey results became more confident in the post-assignment survey, and other students who were initially confident responded with less confidence in their post-assignment surveys. When broken out by gender, results become slightly (though not significantly) more telling, as women (non-male) students tended to feel more confident in nine of the 15 SICKS questions measured. There is no obvious trend across all SICKS measures by gender or overall, however. This showcases the difference in the interpretation of educational experiences by students of different genders, as well as the importance of examining this data outside of the aggregate.

Two goals of this research included assessing ABET 5 & ABET 7 through two questions. The results for question 11 (ABET 7) indicate most students did feel that their ability to acquire and apply information following PD2/PD6 was either somewhat or much better, while a non-trivial percent of participants felt their skills remained about the same following the assignment. The results for question 12 (ABET 5) indicated most students believed that their ability to work in a team was improved following the PD2/PD6 assignment. After reviewing the data, we feel that it is impossible to correlate a difference in confidence in team skills (ABET 5) after completing the

PD2/PD6 self-assessment assignments directly to the assignments as opposed to the course. This might be improved by more closely timing the final survey to the due date of PD6, but is likely to be obscured by the overall impact of the course itself. Regardless, students did indicate improvement towards mastery of ABET 5 & ABET 7, which at a minimum shows that the course, including the professional development assignment sequence, is meeting its outcomes in this regard.

In the process of conducting this study and performing the analysis, we noted that the study design did not effectively allow for isolation of variables to more effectively determine what interventions helped most. The SICKS instrument may not be the most effective way to gather data related to these questions, or it may need to be combined with additional data gathering activities such as student interviews. We also plan to amend our IRB and survey instrument to include participant disclosure of race to further parse the data.

Within the course, we feel that students were largely able to meet the learning outcomes attributed to PD2/PD6 as noted in the introduction. There are components of the PD2/PD6 assignment that need to be improved for future capstone years regardless of future data collection. The goal-setting elements of the PD2/PD6 assignment were not well understood by all students. In the process of coding the goals and activities, it was evident that some students did not understand how to construct a quality goal (time-bound, measurable, etc.) nor what might constitute evidence of a goal being met. Future versions of the PD2/PD6 assignment will need to be paired with classroom discussions or activities teaching the design of SMART goals to ensure that students can frame their goal to be measurable and timely, which represents a key skill for a practicing engineer. Additionally, with the initiation of this research, perhaps there are opportunities to begin the training of goal-setting and self-assessment for professional skill development earlier in the engineering curriculum, so that in the capstone students are honing skills rather than initiating skills.

Overall, we found that change to student confidence as a result of specific professional development assignments is difficult to measure. The use of the SICKS instrument provided some insights into the effectiveness of the assignment but the data retrieved from students was not sufficiently causal to draw conclusions about student confidence. Overall, the aggregate data is consistent with regression toward the mean, but this is not true when data is spliced by gender. The literature supports further stratifying respondents by race, which may result in more apparent changes in confidence in specific demographic groups. Loss of confidence may indicate that students who were perhaps overconfident in their pre-assignment surveys realized the scope and depth of the unknowns and reduced their confidence rating, whereas students who were less confident at the beginning of the course gained confidence over time.

Future research design questions may include:

1. Is more granularity, including race, required in our data to determine if confidence truly changes as a result of professional development assignments?
2. Are professional development activities effective in increasing a student's perceptions of confidence to achieve ABET outcomes 5 and 7?

Works Cited

[1] ABET, "Criteria for Accrediting Engineering Programs, 2024-2025." ABET, 2023. Accessed: Jan. 15, 2025. [Online]. Available: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2024-2025/

[2] D. M. Gilbuena, B. U. Sherrett, E. S. Gummer, A. B. Champagne, and M. D. Koretsky, "Feedback on Professional Skills as Enculturation into Communities of Practice," *J. Eng. Educ.*, vol. 104, no. 1, pp. 7–34, 2015, doi: 10.1002/jee.20061.

[3] K. Christopher, C. J. Witherell, and A. G. Sarhan, "Reflection and Goal Setting: Methods for Improved Performance and Engagement in Engineering Courses," presented at the 2023 ASEE Annual Conference & Exposition, Jun. 2023. Accessed: Feb. 19, 2025. [Online]. Available: https://peer.asee.org/reflection-and-goal-setting-methods-for-improved-performance-and-engagement-in-engineering-courses

[4] A. Pagano, T. T. Parks, and S. Shehab, "Developing a Human-Centered Engineering Design Self-Assessment Survey," presented at the 2024 ASEE Annual Conference & Exposition, Jun. 2024. Accessed: Dec. 04, 2024. [Online]. Available: https://peer.asee.org/developing-a-human-centered-engineering-design-self-assessment-survey

[5] A. Bray, P. Byrne, and M. O'Kelly, "A Short Instrument for Measuring Students' Confidence with 'Key Skills' (SICKS): Development, Validation and Initial Results," *Think. Ski. Creat.*, vol. 37, p. 100700, Sep. 2020, doi: 10.1016/j.tsc.2020.100700.

[6] J. W. Prados, "The Editor's Page. Engineering Criteria 2000," *J. Eng. Educ.*, vol. 86, no. 2, pp. 69–70, 1997, doi: 10.1002/j.2168-9830.1997.tb00268.x.

[7] J. R. Gurganus, S. M. Clancy, R. O. Blorstad, R. Reinhardt, C. D. Eggleton, and L. D. T. Topoleski, "Engineering State of Mind Instrument: A Tool for Self-assessment," presented at the 2020 ASEE Virtual Annual Conference Content Access, Jun. 2020. Accessed: Dec. 04, 2024. [Online]. Available: https://peer.asee.org/engineering-state-of-mind-instrument-a-tool-for-self-assessment

[8] M. A. Kanny, L. J. Sax, and T. A. Riggers-Piehl, "INVESTIGATING FORTY YEARS OF STEM RESEARCH: HOW EXPLANATIONS FOR THE GENDER GAP HAVE EVOLVED OVER TIME," *J. Women Minor. Sci. Eng.*, vol. 20, no. 2, pp. 127–148, 2014, doi: 10.1615/JWomenMinorScienEng.2014007246.

[9] L. J. Sax, M. A. Kanny, T. A. Riggers-Piehl, H. Whang, and L. N. Paulson, "'But I'm Not Good at Math'': The Changing Salience of Mathematical Self-Concept in Shaping Women's and Men's STEM Aspirations," *Res High Educ*, vol. 56, pp. 813–842, 2015, doi: https://doi.org/10.1007/s11162-015-9375-x.

[10] D. Woods and H. Sheardown, "An Approach To Developing Students' Skill In Self Assessment," presented at the 2004 Annual Conference, Jun. 2004, p. 9.163.1-9.163.11. Accessed: Dec. 04, 2024. [Online]. Available: https://peer.asee.org/an-approach-to-developing-students-skill-in-self-assessment

[11] S. Howe, L. Rosenbauer, and S. Poulos, "The 2015 Capstone Design Survey Results: Current Practices and Changes over Time," *Int. J. Eng. Educ.*, vol. 33, no. 5, pp. 1393–1421, 2017.

[12] S. Sarin and D. Headley, "Validity Of Student Self Assessments," presented at the 2002 Annual Conference, Jun. 2002, p. 7.1293.1-7.1293.7. Accessed: Dec. 04, 2024. [Online]. Available: https://peer.asee.org/validity-of-student-self-assessments

[13] J. Sloan and T. Frank, "Relationships Between Student Self-Assessment Ability and Performance,"

presented at the 2024 ASEE Annual Conference & Exposition, Jun. 2024. Accessed: Dec. 04, 2024. [Online]. Available: https://peer.asee.org/relationships-between-student-self-assessment-ability-and-performance

[14] J. L. Moseley and J. C. Dessinger, *Handbook of Improving Performance in the Workplace, Measurement and Evaluation*. John Wiley & Sons, 2009.

[15] K. B. Reed, "Assessment of Student's Confidence of Learned Knowledge," presented at the 2012 ASEE Annual Conference & Exposition, Jun. 2012, p. 25.232.1-25.232.12. Accessed: Dec. 02, 2024. [Online]. Available: https://peer.asee.org/assessment-of-student-s-confidence-of-learned-knowledge

[16] M. R. Hebda, M. R. Castillo, and T. Sulak, "Developing KSAs in Engineering Capstone Students (WIP)," presented at the 2024 ASEE Annual Conference & Exposition, Jun. 2024. Accessed: Dec. 02, 2024. [Online]. Available: https://peer.asee.org/developing-ksas-in-engineering-capstone-students-wip

[17] B. A. Sones, "A Capstone Design Experience that Makes Easy the Assessment of Some of the Trickier ABET Student Outcomes to Measure," presented at the 2015 ASEE Annual Conference & Exposition, Jun. 2015, p. 26.18.1-26.18.16. Accessed: Dec. 04, 2024. [Online]. Available: https://peer.asee.org/a-capstone-design-experience-that-makes-easy-the-assessment-of-some-of-the-trickier-abet-student-outcomes-to-measure

[18] J. Trevelyan, "Incremental Self-Assessment Rubrics for Capstone Design Courses," presented at the 2015 ASEE Annual Conference & Exposition, Jun. 2015, p. 26.951.1-26.951.17. Accessed: Dec. 04, 2024. [Online]. Available: https://peer.asee.org/incremental-self-assessment-rubrics-for-capstone-design-courses

[19] J. Wang, E. Patten, R. Shelby, F. Ansari, and L. A. Pruitt, "Leadership and Service Learning Improves Confidence of Engineering Skills in Women," presented at the 2012 ASEE Annual Conference & Exposition, Jun. 2012, p. 25.878.1-25.878.16. Accessed: Dec. 02, 2024. [Online]. Available: https://peer.asee.org/leadership-and-service-learning-improves-confidence-of-engineering-skills-in-women

[20] T. R. Kelley, J. G. Knowles, J. Han, and E. Sung, "Creating a 21st Century Skills Survey Instrument for High School Students," *Am. J. Educ. Res.*, vol. 7, no. 8, Art. no. 8, Sep. 2019, doi: 10.12691/education-7-8-7.

[21] A. Bryant and K. Charmaz, *The SAGE Handbook of Current Developments in Grounded Theory*. 1 Oliver's Yard, 55 City Road London EC1Y 1SP: SAGE Publications Ltd, 2019. doi: 10.4135/9781526436061.

[22] American Society of Engineering Education, "Engineering and Engineering Technology: By the Number 2023 Report." American Society of Engineering Education, 2023. Accessed: Feb. 21, 2025. [Online]. Available: https://ira.asee.org/by-the-numbers/

Appendix A: Pre-Survey
Note: Corrected to include question 5
Assessing Professional Development Skills

Q0.2 Please enter your NetID _____

Q0.3 Please select the gender you most identify with:

- O Male (1)
- O Female (2)
- O Non-binary / third gender (3)
- O Another gender (enter here) (4) _____
- O Prefer not to say (5)

Q0.4 Consenting to participate in this study indicates that you are a current student in ENGS 89 or ENGS 190, and aged 18 years or older. Please select whether you agree to participate in this study:

- O Yes, I consent to participate in this study (1)
- O No, I do not consent to participate in this study (2)

Skip To: End of Survey If Consenting = No, I do not consent to participate in this study

Start of Block: Survey

Q1 When working with others or collaborating, how confident are you to:

	Not confident at all (1)	Slightly confident (2)	Moderately confident (3)	Very confident (4)	Extremely confident (5)
Work in pairs or small groups to complete a task together (1)	O	O	O	O	O
Work with other students to set goals and create a plan for your team (2)	O	O	O	O	O
Create joint products using contributions from each student (3)	O	O	O	O	O

Q2 When communicating your ideas, how confident are you to:

	Not confident at all (1)	Slightly confident (2)	Moderately confident (3)	Very confident (4)	Extremely confident (5)
Communicate your ideas using media other than a written paper (e.g., posters, video, blogs, etc.) (1)	O	O	O	O	O
Prepare and deliver an oral presentation to the teacher or others (2)	O	O	O	O	O
Answer questions in front of an audience (3)	O	O	O	O	O

Q3 When being creative or innovative, how confident are you to:

	Not confident at all (1)	Slightly confident (2)	Moderately confident (3)	Very confident (4)	Extremely confident (5)
Test out different ideas and work to improve them (1)	O	O	O	O	O
Invent a solution to difficult problems (2)	O	O	O	O	O
Create something new that can help you express your ideas (3)	O	O	O	O	O

Q4 Consider how you manage or direct yourself. How confident are you to:

	Not confident at all (1)	Slightly confident (2)	Moderately confident (3)	Very confident (4)	Extremely confident (5)
Track your own progress and change things if you are not working the way that you should be to complete a task (1)	O	O	O	O	O
Assess the quality of your work before it is completed (2)	O	O	O	O	O
Use peer, teacher or expert feedback to change your work (3)	O	O	O	O	O

Q5 When managing information and using critical thinking, how confident are you to:

	Not confident at all (1)	Slightly confident (2)	Moderately confident (3)	Very confident (4)	Extremely confident (5)
Try to solve problems or answer questions that have no single correct solution or answer (1)	O	O	O	O	O
Draw your own ideas based on analysis of numbers, facts, or relevant information (2)	O	O	O	O	O
Analyse different arguments, perspectives or solutions to a problem (3)	O	O	O	O	O

Q6 When using technology for educational purposes, how confident are you to:

	Not confident at all (1)	Slightly confident (2)	Moderately confident (3)	Very confident (4)	Extremely confident (5)
Use technology to work in a team (e.g., shared work spaces, email exchanges, giving and receiving feedback, etc.) (1)	O	O	O	O	O
Use technology to keep track of your work on assignments (2)	O	O	O	O	O
Use technology to help to share information (e.g., multi-media presentations using sound or video, presentation software, blogs, podcasts, etc.) (3)	O	O	O	O	O

End of Block: Survey

Appendix B: Post-Survey

The post-survey was identical to the pre-survey with the addition of the following questions to the end of the survey:

Assessing Professional Development Skills

Start of Block: Post-Assignment

Q The following questions are based on completing the class assignment PD6:

Q11 How has this assignment changed your ability to acquire and apply new knowledge as an engineer?

- O Much worse
- O Somewhat worse
- O About the same
- O Somewhat better
- O Much better

Q12 How has this assignment changed your ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives?

- O Much worse
- O Somewhat worse
- O About the same
- O Somewhat better
- O Much better

Q13 How will you apply what you learned in this assignment going forward?

End of Block: Post-Assignment

Appendix C: Template and PD2/PD6 Assignment

Professional Development Assignment 2 (PD2 - Proposal)
ENGS 89-90 | Fall 2024

Engineering professionalism arises from living our values with integrity. Our values help to guide us in determining right versus wrong in our thoughts, speech, and actions. Learning to practice engineering with integrity begins by becoming aware of how we think, speak and act in relation to our values. This awareness arises from self-reflection and gives us the opportunity to identify our strengths and where we have room for improvement.

None of us are perfect and our reactions to situations where we see particularly large gaps between our values and actions are often driven by what we **d**on't **k**now we **d**on't **k**now (DKDK), strong emotions that may arise, and a lack of prior experience. To help organize a constructive response around this multitude of conditions, we have organized this assignment into areas of (1) intellectual/technical, (2) social/emotional, and (3) physical/experiential.

Purpose
The purpose of this assignment is to develop the skills of self-reflection and continuous learning with the intent of increasingly living our values with integrity. Instilling this process of lifelong learning is part of the learning objectives for the capstone experience because of its importance to the practice of engineering and enduring value throughout your post-Dartmouth life and career.

Submission Instructions
For PD2 - Proposal: Using the Template for Professional Development Assignment 2 (PD2 - Proposal), create a performance evaluation rubric for yourself that reflects strengths and growth opportunities in the three specific areas of: intellectual/technical, social/emotional, and physical/experiential. For inspiration, you may select from a list of categories that dovetail with your personal interests and with your project. Topics and focus areas outside of these categories will be accepted - please propose them as part of this assignment.

The strengths and opportunities identified in this assignment should have a short timeline (you need to self-assess by PD6), and should be aligned to your values (defined in PD1 - Values), skills you want to develop, and your project needs.

Please be specific and include a clear outcome. You do not need to do the actual activity you plan to do in the "how to show" column - that will come with PD6 - Self Assessment. Sample submissions are included below in the Example Assignments section.

Notes:

- This should feel different than most assignments – in any job (industry, academia, military, medical) a performance review will likely occur on an annual basis. As part of this process you may have to set goals for yourself that relate to your company's goals, and you may also have an opportunity to set personal professional development goals. When thinking about what to improve on and how to show improvement in the areas you select for yourself, consider what you would do in the workplace.
- Consider resources that are available to you. Books, podcasts, mentors, courses, etc.
- This assignment involves goal setting for yourself. In PD6 - Self Assessment, you will be assessing how well you met the goals that you set for yourself. The "right fit" goal will depend on many factors, but try to keep things short and measurable.

Example Assignments

This is a sample proposal assignment, following the template.

Area of practice: Intellectual/Technical		Activity to cultivate growth and improvement [PD2]	Self-assessment (after completing activity) [PD6]
Strength to improve on	Statistical analysis	Complete the first six weeks of ENGS 93 this term	
Growth opportunity	Data visualization	Create at least two visuals from data we gather this term for our pre-proposal or proposal presentations	
Area of practice: Social/Emotional		Activity to cultivate growth and improvement [PD2]	Self-assessment (after completing activity) [PD6]
Strength to improve on	Leadership	Lead team meetings and social events to build camaraderie with teammates	
Growth opportunity	Inclusion	Attend 1 event from Dartmouth/Thayer's DEI committee	
Area of practice: Physical/Experiential		Activity to cultivate growth and improvement [PD2]	Self-assessment (after completing activity) [PD6]
Strength to improve on	CAD drawing	Create a complete assembly in Solidworks of the bike I built over the summer	
Growth opportunity	Benchtop testing	Get training in the Biotech Lab	

Professional Development Assignment 6 (PD6 - Self-Assessment)
Fall 2024 - Winter 2025

Engineering professionalism arises from living our values with integrity. Our values help to guide us in determining right versus wrong in our thoughts, speech, and actions. Learning to practice engineering with integrity begins by becoming aware of how we think, speak and act in relation to our values. This awareness arises from self-reflection and gives us the opportunity to identify our strengths and where we have room for improvement.

None of us are perfect and our reactions to situations where we see particularly large gaps between our values and actions are often driven by what we **d**on't **k**now we **d**on't **k**now (DKDK), strong emotions that may arise, and a lack of prior experience. To help organize a constructive response around this multitude of conditions, we have organized this assignment into areas of (1) intellectual/technical, (2) social/emotional, and (3) physical/experiential.

Instructions

Update your matrix from PD2 - Proposal with your self-assessed results. How did you do relative to your goal? A brief answer (i.e., "Met goal" or "Only 70% complete by 11/1") will suffice. Submit your completed template as a pdf to Canvas by 11/1/2024. Please do not include your name on the document you upload.