Enhancing Perceived Value of Goal Setting in Engineering Education through a Simple Metacognitive Intervention

Dr. Joe Dallas Moore, Carnegie Mellon University

Joe teaches across the Civil and Environmental Engineering program at Carnegie Mellon University. After undergrad at Wabash College, where he studied biology and French, Joe taught high school science through Teach For America in the Chicago Public Schools. He found engineering by writing about water resources in the American Southwest. As a PhD student studying the interactions between engineered nanomaterials and bacteria, he earned a National Science Foundation Graduate Research Fellowship and was selected as a National Academy of Sciences and Engineering Science Ambassador. He is passionate about active and interdisciplinary engineering education, exposing students to career paths, building community among faculty around teaching, running, and his family.

Ms. Andrea Francioni Rooney, Carnegie Mellon University

Andrea Francioni Rooney is the Director of Undergraduate Programs for the Department of Civil & Environmental Engineering at Carnegie Mellon University. She serves as an academic advisor for undergraduate students and works closely with faculty on the und

Allison E. Connell Pensky, Carnegie Mellon University

Dr. Allison Connell Pensky is a Cognitive Psychologist and Neuroscientist by training. She is currently a Data Science Research Associate at the Eberly Center for Teaching Excellence & Educational Innovation at Carnegie Mellon University. She uses her training and years of experience as a faculty member to support graduate students, faculty, and programs on educational research projects and making data-driven improvements to courses.

Enhancing Perceived Value of Goal Setting in Engineering Education through a Simple Metacognitive Intervention

Abstract

In this full paper, we tackle a challenge we increasingly see in students, which is students arriving in our courses exhibiting unprofessional behavior. It is unclear if students recognize the importance of professional behavior. To combat this trend, we sought to encourage students to think about their own behavior and learning by emphasizing academic and professional goal-setting and monitoring progress towards goals. In our required undergraduate environmental engineering course, we tasked students with setting multiple goals related to their academic performance (e.g., I'd like to earn an A), course content to learn (e.g., drinking water, remediation), and their professional skills (e.g., build relationships with instructional staff). Students reflected on these goals and their progress toward them in a pre/post survey, three written assignments, and three class discussions. We found that students significantly grew in their valuation of professional behaviors, their ability to monitor these, and building professional relationships, all in alignment with the pedagogical goals of the course. Our results suggest that simply addressing professionalism, goal-setting, and metacognition may improve students' perceptions of these critical areas. Our work is readily adaptable to other engineering educators.

INTRODUCTION

Students were profoundly affected by the Covid-19 pandemic. Their physical health, mental health, and resilience in the face of adversity have diminished [1], [2], [3]. At our institution, we have witnessed this decline in our students, too. They ask for more flexibility. They struggle to pay attention in class. And they display reduced professional behaviors. For instance, they wear earbuds during class, they show up late to class, they are on their devices more during class, they do not work to establish meaningful relationships with the instructional team, or they miss class or assignments without communicating with the instructor. Problem-solving these common challenges is pertinent to all disciplines. We present an engineering education pedagogical strategy and assessment.

While the specifics of professionalism is debated [4], [5], [6], there is some consensus around "professional skills": communication, teamwork, and ethics [7]. Interpersonal skills have been highlighted as especially important in a more design-focused engineering curriculum [8]. In our view, the goal of improving students' professional behaviors and skills is to improve student academic success in the short term and professional success in the longer term.

In many fields, including engineering, faculty-student relationships are central to student success [9], [10], [11]. Christe [9] conducted a review of research on the impact of faculty-student interactions in STEM majors and found that faculty compassion and a nurturing environment show a positive effect on student success. Ingraham et al. [10] did a review of studies focused on

the experience of nursing students that saw a similar correlation between faculty-student interactions and student success. Newman's [11] study suggested that positive faculty-student interactions have a significant influence on African-American engineering students continuing in their majors. We argue that building these relationships is a valuable form of networking and therefore represents another important professional skill.

In the present study, we sought to help students identify what professional skills are important to them via reflective writing assignments and discussion. Additionally, we intentionally used metacognitive activities throughout the course to help students monitor their progress toward these goals. Metacognition has been defined "as any knowledge or cognitive activity that takes as its object, or regulates, any aspect of any cognitive enterprise […] its core meaning is 'cognition about cognition'" [12]. Goal setting and metacognition are highly related, and both positively correlate with academic success [13].

Teaching metacognitive skills to undergraduate engineering students has been found to help them take charge of their own learning [14]. Metacognition has led to improvements in engineering students' problem-solving and self-directed learning [15], [16]. Marra et al. [15] introduced metacognitive activities in a problem-based learning engineering program. Students showed increased understanding of self-directed learning as a result of the metacognitive activities and over half of the students in the study continued to use the metacognitive activities on their own. Meter et al. [16] found that students in an introductory thermodynamics class showed more gain in conceptional learning when given metacognitive activities along with homework assignments than students who only received the traditional homework. We sought to study the experience of students engaging in goal setting and metacognition and the value they place on professional skills.

The present study examines the effect of goal setting and metacognition within an engineering classroom. We sought to address the following research questions:

1. What are students' attitudes about goal setting and professional skills? Do these attitudes change across the semester in a course that utilizes reflective goal setting and metacognitive activities?
2. What is the nature of students' goals at the beginning of the semester? How do these evolve across a semester in which they engage in intentional reflective and metacognitive activities?

We used a mixed methods approach to capture the students' attitudes toward professionalism and goal-setting quantitatively and examine any themes that emerged from the students' reflections qualitatively. A survey was given at the beginning and end of the semester to track any change in attitudes. Those results were used in conjunction with a thematic analysis of the student reflections to see not only if the students' attitudes toward professionalism and goal-setting had changed but also to see what may have influenced any change by looking for common themes within their reflective writing.

METHODS

Participants

Participants were 49 junior Civil Engineering majors and sophomore Environmental Engineering majors enrolled in a required 14-week Environmental Engineering course during the spring 2024 semester. The course took place at a mid-sized, private institution in Pennsylvania. Data were collected under an Institutional Review Board approved protocol.

Materials

Students engaged in three reflective metacognitive writing activities (see Appendices A-C). The first of these taught students about the concept of metacognition and told them that they would be engaging in metacognitive activities within the course. Students then articulated a learning goal, personal goal, and professional goal for the course. They wrote a plan for meeting these goals, what support they would need, and what concerns they have about the course. They were also instructed that they would be discussing their reflective writing with peers in-class.

The second reflective metacognitive writing activity required student participants to reflect on their learning so far and to assess their progress toward their stated goals. Additionally, students were asked to evaluate where they need to put more effort toward meeting their goals, to outline a strategy that would support their continued progress toward their goals, and what support from the instructional team would benefit them. Finally, they were given the chance to articulate new goals for themselves and were reminded about the value of such metacognitive reflection.

The third, and final, reflective metacognitive writing activity prompted students to reflect on their entire semester in the course, specifically thinking about their experiences, challenges, and growth. They were asked to reflect on their course content learning. They were asked to reflect on their goals, progress toward these, what aided them, and what may have hindered them. They were asked to apply these reflections to planning for their future learning by articulating strategies that would enhance their future learning experiences or success toward their future goals. They had the opportunity to share feedback to the instructional team about what would have further supported them in the course and any obstacles they experienced while taking this course. Lastly, they were reminded about the value of self-reflection.

In the class session immediately following the first two reflective metacognitive writing activities' due date, students were put in groups to discuss their reflections and goals. They were instructed to discuss their reflections for the first 10 minutes of class. Then they were asked to volunteer takeaways in a class-wide discussion. Groups were kept the same over the semester.

The initial ("pre") survey contained 10 seven-point Likert items to measure student participants' attitudes about goal setting, other professional skills, and metacognition. A sample item is, "It is valuable to display professional behavior in my courses." These items were designed to align with the pedagogical goals of the metacognitive intervention and the professional goals identified by Beagon and Bowe [7]. As such, the survey has strong face validity. The pre and post survey

demonstrated good internal consistency (Cronbach's alpha = .86 for both). Additionally, students were asked if they had set goals for themselves in any of their other courses and why or why not. The full survey is available in Appendix D.

The final ("post") survey contained the same items from the pre survey as well as a question about whether or not they intend to set goals for themselves next semester and why or why not. Additionally, students were asked to reflect on their experience in the course and share what they perceived as the strengths of the course and instructional team and what suggestions they have. Finally, students self-reported which learning supports (e.g., lecture slides, practice exam) they utilized. The full post survey is available in Appendix D.

Procedure

Students were informed about the educational research taking place in the course on the first day of the semester. During the first week of classes, students completed the first reflective metacognitive writing assignment. This was followed by an in-class discussion in which students shared their goals in small groups followed by an opportunity to share with the whole class. Student participants were tasked with completing the pre survey after the in-class discussion. The pre survey was due about two weeks after the discussion class session.

In the eighth week of the semester, students engaged in the second metacognitive activity in which they were asked to assess in writing their progress towards their goals and whether they would change any goals. Another group and in-class discussion followed.

During the last week of the semester, student participants completed the final metacognitive reflection on their goals. There was no in-class discussion for this final metacognitive activity. They then took the post survey on goal setting and professional behaviors, which also allowed them to share their perceptions and attitudes about their learning experiences in the course.

Qualitative Coding Method

A qualitative analysis of students' written responses to the metacognition writing prompts was conducted using MaxQDA. The analysis focused on identifying and categorizing themes related to students' learning goals, personal goals, and professional goals, which were tracked throughout the semester.

A coding scheme was developed to capture various aspects of the students' reflections. Primary codes included statements related to learning goals, personal goals and professional goals. Additional codes were applied to track mentions of key elements such as the importance and impact of reflective practices, engagements and collaborations with classmates and instructors, development and application of effective communication, and references to specific course content, including water, environmental justice, and air quality. This coding framework allowed for an analysis of the students' metacognitive processes and their evolving perspectives throughout the course.

RESULTS

Research Question 1 (attitudes about goal setting and professional skills) Results

Quantitative survey data were used to answer the first research question about students' attitudes about goal setting and professional skills, and how these attitudes change across the semester. As measuring change in attitudes was a primary goal of the project, responses were only included for analysis if the student had completed both the pre and post surveys. Each survey item was tested using a dependent-means t-test (see Table 1).

Table 1. Quantitative survey items, pre/post descriptive statistics, and statistical results.

Survey Item Scale: 1 (strongly disagree) to 7 (strongly agree)	**Pre Mean**	**Post Mean**	**Statistical Outcome**
It is valuable to reflect and set **personal goals** in a course.	5.9	6.0	$t(38) = .50$, $p = .62$, $d = .07$
It is valuable to reflect and set **professional goals** in a course.	5.7	5.7	$t(38) = .17$, $p = .43$, $d = .03$
It is valuable to reflect and set **learning goals** in a course.	6.1	6.3	$t(38) = 1.48$, $p = .15$, $d = .24$
It is valuable to display professional behavior in my courses.	5.9	6.4	$t(38) = 3.51$, $p = .001$, $d = .56$
I recognize how to build good working relationships with my peers.	5.8	6.0	$t(38) = .90$, $p = .38$, $d = .13$
I recognize how to build good working relationships with my instructional team (e.g., instructors, TAs).	5.6	5.9	$t(38) = 2.23$, $p = .03$, $d = .36$
I value communication as part of my professional skills.	6.3	6.5	$t(38) = 1.84$, $p = .07$, $d = .29$
I can think about what I want to get out of a course.	5.5	5.8	$t(38) = 1.87$, $p = .07$, $d = .30$
I can critically reflect on my strengths and growth areas.	5.7	5.9	$t(38) = 1.23$, $p = .23$, $d = .19$
I can monitor my progress toward my goals and adjust as needed.	5.5	5.9	$t(38) = 3.79$, $p < .001$, $d = .57$

At the beginning of the semester, students reported valuing goal setting, especially setting learning goals. Students also valued professional skills and metacognition. The strongest endorsed item was about valuing communication as a professional skill. At the end of the

semester, students reported similar or stronger positive attitudes with no item's mean being lower at post. Students' attitudes grew significantly more positive on three survey items: the value of displaying professional behavior, knowing how to build relationships with instructors, and monitoring progress toward goals. Valuing communication as a professional skill remained the most strongly endorsed item.

Most items showed some degree of growth with three significantly increasing and two marginally significantly increasing. Interestingly, one of the lowest endorsed items at pre "I can monitor my progress toward my goals and adjust as needed" showed significant increase with the strongest effect size. The other lowest endorsed item at pre showed marginally significant improvement with a moderate effect size.

Research Question 2 (nature of students' goals) Results

Students' written metacognitive reflections were used to answer the second research question about the nature of students' goals and how they change across the semester.

We identified common themes in the initial student reflections that remained prominent in later reflections: (1) environmental justice, (2) opportunities to do group work and building working relationships with peers, (3) making use of course resources and working with the instructional team, (4) practicing writing and presenting, and (5) time management. Additional themes developed over the semester, most notably reflection and goal-setting as a valuable task and the impact of guest speakers on professional aspirations.

The enduring themes suggest that students are looking to develop professional skills such as relationship-building, communication, and time management. While these skills were present in many of the initial goals, the reflections later in the semester show recognition of the importance of growing these skills. Additionally, an increase of awareness of environmental justice was noted along with reflections on how to carry what they learned into future work. Table 2 shows samples from student reflections that align with these themes.

Table 2. Themed sample quotes from student reflections

Theme	**Student Quote(s)**
Relationship Building	"Another goal that I set forth for myself was to become acquainted with my peers who I had not taken classes with. I think this was something that I both struggled and succeeded with...Looking forward, this is something I need to continue to prioritize and put myself out there when it comes to forging new relationships." "As a professional goal, I want to get to know the professors and TAs for the course better to expand my professional network...In order to accomplish this goal, I will make an effort to attend both instructor and TA office hours, and will not hesitate to ask questions about things I am unsure of."

Theme	Student Quote(s)
Communication Skills	"A professional goal for me is to continue improving my professional writing and speaking skills…I am excited to explore that and be able to apply it to the various job applications and interviews that I am currently undergoing."
Time Management Skills	"In the future, I want to keep employing the work management strategies that I used this semester. Specifically, what helped was setting specific time windows to do work and not going over those time frames, unless absolutely necessary."
Environmental Justice	"When the guest speaker came to tell us about two different environmental injustices, I found the material very interesting and relevant. The takeaways from these stories can be applied to various practices and…I found myself thinking about how these current events have since affected or should affect future decisions." "At the beginning of the semester, I talked about how my goal was to have a better understanding of how EnvE can be used to help the public…I have learned numerous things revolving around the environmental ethics…, including how the person in charge has more power than people may realize when it comes to making ethical decisions for their project. If I am hoping to be in charge of a structures project in the future, I can apply the elements learned in this course."
Reflection and Goal-setting	"I think I will consider more metacognition in future courses because it is good to actually reflect on what you have been learning instead of just forgetting about it." "I have really enjoyed the structure of [the course] and how we set learning goals for ourselves that were separate from actual course grades. Often, I get so caught up in my course grades that I do not focus my learning attention on the skills I am developing." "In future classes, I would set my goals from a more holistic and comprehensive perspective, with consideration of other classwork, personal circumstances, and other commitments. It is easy to set a goal for a specific task, but balancing numerous (sometimes conflicting) objectives requires more thoughtful planning."

The reflection exercises gave students the space to connect the academic content of the course to their own lives and aspirations. The qualitative analysis showed evidence of this connection, especially after class discussions on environmental justice and visits by guest speakers.

These quotes complement the responses to the open-ended survey questions that were also used to answer this research question. On the pre survey, most of the class (n = 39 students) indicated that they had set a goal in another of their courses (n = 10 said they had not). Interestingly, the goal setting students showed significantly stronger endorsement of the quantitative survey items about goal setting and metacognition than did the students who chose not to set goals in their other courses ($p < .05$). Thirty-one of these goal setting students answered the follow up question about why they decided to set this goal. These responses were thematically coded by Microsoft Copilot using the prompt, "Undergraduate students were asked why they set personal,

professional, or learning goals for themselves in their classes. Code their responses into 3-6 meaningful themes. Give the count for each theme. Give 1 or 2 example responses for each theme. Here are the responses: [inserted]". Table 3 presents these results

Table 3. Thematic reasons for student goals in other courses with sample responses (pre).

1. **Motivation (Count: 7) -** Ex: "I set a goal for myself because it keeps me motivated and engaged in the course."
2. **Accountability (Count: 6) -** Ex: "I am trying to set more personal and learning goals to hold myself accountable and work towards maintaining good grades primarily by not procrastinating. To keep myself accountable."
3. **Direction (Count: 6) -** Ex: "Because it is difficult to have direction without goals."
4. **Learning Improvement (Count: 6) -** Ex: "Because I want to be able to maximize my learning."
5. **Reflection (Count: 5) -** Ex: "I always set personal goals, which often tie into learning and professional goals. I purposely reflect every day to determine how I can reach my goals."

In the post survey, most of the class (n = 36 students) indicated that they plan to set a goal for themselves next semester (n = 3 said they would not). Twenty-eight of these goal setting students answered the follow up question about why they plan to set this goal. Their responses were thematically coded by Microsoft Copilot using the same type of prompt. Table 4 presents these results.

Table 4. Thematic reasons for students' future goal plans with sample responses (post).

1. **Motivation and Focus (9 responses) -** Setting goals helps students stay motivated and focused throughout the semester. Ex: "It helped me stay motivated in classes that I wasn't extremely enthusiastic about because I could see better what I was going to get out of it for myself."
2. **Reflection and Self-Improvement (8 responses) -** Goals provide a tool for self-reflection and personal growth. Ex: "Based on this past semester, setting these goals allowed me to reflect on how my coursework benefits me and what I take away from the learning process."
3. **Guidance and Accountability (6 responses) -** Goals guide students through their courses and hold them accountable. Ex: "Setting learning goals and personal goals makes you accountable in regards to learning the material."
4. **Future Planning and Professional Development (5 responses) -** Goals help students plan for their future and think about their professional development. Ex: "To ensure I am setting myself up for success regarding my future outside of college."
5. **Habit and Routine (4 responses) -** Setting goals is seen as a beneficial habit or routine. Ex: "It is a good habit to set and continue to do beyond school."
6. **Stress Management and Productivity (3 responses) -** Goals help manage stress and increase productivity. Ex: "To continue to manage stress in my courses and to increase my motivation in my courses."

Course Feedback Results

In the post survey, 36 students responded to the open-ended question about what they perceived the strengths of the course to be. Microsoft Copilot was used to code these responses into themes about the course and themes about the instructor. The course-related themes emphasized the value of having guest speakers in the course, the final project, hands-on activities, real-world

applications, group work, and the overall course structure. The instructor-related themes highlighted the caring and supportive relationship formed with the instructor, the value of good communication, and appreciation for the instructor's openness to feedback.

DISCUSSION

In the face of students displaying less professional behavior, we emphasized goal setting and metacognition, which have been found to positively affect student outcomes [15], [16]. "Professional skills" include communication, teamwork, and ethics [7]. We surveyed students about the value they place on professional behavior and relationships before and after this emphasis and analyzed those data for statistically significant differences. We also investigated student reflections collected at the beginning, mid-point, and end of the semester for common themes.

We found statistically significant improvements in students' valuations of displaying professional behavior, establishing professional relationships, and in their self-reported ability to monitor their progress towards goals. Since we did not use an experimental design and do not have attitude data from a comparison group, we cannot infer a causal impact between our pedagogical intervention and this growth in students' attitudes. It is possible, though unlikely, that students could have shown similar attitude growth in the absence of the teaching intervention. We therefore interpret these findings to suggest that a relatively simple intervention, such as repeatedly emphasizing goals and professional behavior, may help students place more value on them. This teaching strategy is likely applicable to any engineering field as it helps students see the discipline-specific skills that are valued.

We completed this field study in a real classroom with real students, a strength in ecological validity. To do so, we added three writing assignments where students identified goals for the semester, made time for two brief (~15 minute) in-class discussions of these goals, and surveyed students at the beginning and end of the semester. We had a relatively large sample size, with 39 students completing both the pre and post survey. Those students were predominantly sophomores and juniors in Civil Engineering and Environmental Engineering, but included a few seniors and students in other engineering fields, e.g., Chemical Engineering, too. We collected both quantitative and qualitative data to more fully capture students' attitudes about their professional skills, setting goals, and monitoring progress toward goals. The goals students set matched what we would like them to focus on, and these data showed alignment in attitudinal change over time.

Our study had many strengths and some weaknesses. We wonder, for example, if having students take the pre survey after our initial in-class goal conversation might have led to higher pre attitudes. While we did not do psychometric testing of our survey it has face validity measuring the specific student attitudes that we were interested in. Additionally, both the pre and post survey demonstrated good internal consistency (Cronbach's alpha = .86 for both). As a field study with no comparison group we cannot casually attribute the growth in students' attitudes to

our pedagogical intervention. However, it is quite clear that students engaging in such goal setting and metacognitive activities demonstrated increased appreciation for their professional behaviors, their professional relationships, and their ability to monitor their goal progress.

Future work could follow students into the future to see if the attitudinal changes we measured persist. Such a study could also aim to detect changes in student behavior. For instance, one could measure whether or not students set goals in their future classes or their participation in office hours. In order to identify which aspects of our intervention were the most impactful, we would recommend breaking down our intervention into its component parts across multiple courses and comparing resultant attitudes and student reflections. Another idea for future work would be to target larger classes so that the results could be disaggregated across student demographic groups to determine whether this approach inclusively serves students regardless of their background and characteristics. It could also be informative to switch the order of the initial in-class conversation and attitudinal survey to see if students' perceptions are affected by that single experience.

Using both quantitative and qualitative analysis in this study provides a more comprehensive understanding of students' learning processes. Quantitative analysis offers measurable data that can easily highlight trends, patterns, and correlations. Qualitative analysis provides a deeper look into students' personal experiences, reflections, and perceptions, providing insights into their thought processes and the contextual factors influencing their learning. These approaches help to provide a holistic view of how metacognitive practices affect students' reported learning, personal development, and professional growth. Even when we did not note a difference in quantitative data, we could see growth in the qualitative results. For example, the survey did not detect a change in students' perception of the value of setting professional goals in a course (p = .43), while the qualitative data showed that students did in fact see the advantage of professional goal setting in an academic context. In particular, they noted the importance of reflecting on course material and guest speaker talks in relation to their own professional aspirations. It is possible that the timing of the pre survey, which happened after the first metacognitive writing activity, already increased students' attitudes, making it harder to detect further increases on the post survey. Nevertheless, our study highlights the value of a mixed method approach that collects complementary quantitative and in-depth qualitative data.

In total, by the end of the course and following simple, repeated metacognitive and goal-setting interventions, students significantly grew in their beliefs that professional behaviors are valuable, their metacognition about building relationships with instructors, and their metacognition for their goals. Instructors are welcome to implement our simple intervention (described above) or modify it as appropriate for their teaching preferences and context. This is a positive first step in building students' professional development and getting them ready with the skills necessary to begin their careers as engineers.

REFERENCES

[1] J. E. Barkley, A. Lepp, E. Glickman, G. Farnell, J. Beiting, R. Wiet, and B. Dowdell, "The Acute Effects of the COVID-19 Pandemic on Physical Activity and Sedentary Behavior in University Students and Employees," Int. J. Exerc. Sci., vol. 13, no. 5, p. 1326, 2020. [Online]. Available: https://pmc.ncbi.nlm.nih.gov/articles/PMC7523895/

[2] W. E. Copeland, E. McGinnis, Y. Bai, Z. Adams, H. Nardone, V. Devadanam, J. Rettew, and J. J. Hudziak, "Impact of COVID-19 Pandemic on College Student Mental Health and Wellness," J. Am. Acad. Child Adolesc. Psychiatry, vol. 60, no. 1, pp. 134-141.e2, 2021. [Online]. Available: https://doi.org/10.1016/J.JAAC.2020.08.466

[3] J. F. Huckins et al., "Mental Health and Behavior of College Students During the Early Phases of the COVID-19 Pandemic: Longitudinal Smartphone and Ecological Momentary Assessment Study," J. Med. Internet Res., vol. 22, no. 6, p. E20185, 2020. [Online]. Available: https://doi.org/10.2196/20185

[4] R. McCuen and K. Gilroy, *Ethics and Professionalism in Engineering*, 2010. [Online]. Available: https://books.google.com/books/about/Ethics_and_Professionalism_in_Engineerin.html?id=i0gRldg2rG8C

[5] J. A. Stieb, "Understanding Engineering Professionalism: A Reflection on the Rights of Engineers," Sci. Eng. Ethics, vol. 17, no. 1, pp. 149–169, 2011. [Online]. Available: https://doi.org/10.1007/S11948-009-9166-X/METRICS

[6] R. Van Der Vorst, "Engineering, Ethics and Professionalism," Eur. J. Eng. Educ., vol. 23, no. 2, pp. 171–179, 1998. [Online]. Available: https://doi.org/10.1080/03043799808923496

[7] U. Beagon and B. Bowe, "Understanding professional skills in engineering education: A phenomenographic study of faculty conceptions," J. Eng. Educ., vol. 112, no. 4, pp. 1109–1144, 2023. [Online]. Available: https://doi.org/10.1002/JEE.20556

[8] C. L. Dym, "Learning Engineering: Design, Languages, and Experiences," J. Eng. Educ., vol. 88, no. 2, pp. 145–148, 1999. [Online]. Available: https://doi.org/10.1002/J.2168-9830.1999.TB00425.X

[9] B. L. Christe, "The Importance of Faculty-Student Connections in STEM Disciplines," J. STEM Educ. Innov. Res., vol. 14, no. 3, 2013. [Online]. Available: https://www.jstem.org/jstem/index.php/JSTEM/article/view/1797

[10] K. C. Ingraham, S. J. Davidson, and O. Yonge, "Student-faculty relationships and its impact on academic outcomes," Nurse Educ. Today, vol. 71, pp. 17–21, 2018. [Online]. Available: https://doi.org/10.1016/J.NEDT.2018.08.021

[11] C. B. Newman, "Engineering success: The role of faculty relationships with African American undergraduates," J. Women Minor. Sci. Eng., vol. 17, no. 3, pp. 193–207, 2011. [Online]. Available: https://doi.org/10.1615/JWOMENMINORSCIENENG.2011001737

[12] J. H. Flavell, "Cognitive development: Children's knowledge about the mind," Annu. Rev. Psychol., vol. 50, pp. 21–45, 1999. [Online]. Available: https://doi.org/10.1146/ANNUREV.PSYCH.50.1.21

[13] F. Gul and S. Shehzad, "Relationship Between Metacognition, Goal Orientation and Academic Achievement," Procedia - Soc. Behav. Sci., vol. 47, pp. 1864–1868, 2012. [Online]. Available: https://doi.org/10.1016/J.SBSPRO.2012.06.914

[14] P. Cunningham, H. M. Matusovich, D. A. N. Hunter and R. E. McCord, "Teaching metacognition: Helping engineering students take ownership of their own learning," 2015 IEEE Frontiers in Education Conference (FIE), El Paso, TX, USA, 2015, pp. 1-5, Available: https://doi.org/10.1109/FIE.2015.7344080

[15] R. M. Marra, D. J. Hacker, and C. Plumb, "Metacognition and the development of self-directed learning in a problem-based engineering curriculum," J. Eng. Educ., vol. 111, no. 1, pp. 137–161, 2022. [Online]. Available: https://doi.org/10.1002/JEE.20437

[16] P. N. V. Meter, C. M. Firetto, S. R. Turns, T. A. Litzinger, C. E. Cameron, and C. W. Shaw, "Improving Students' Conceptual Reasoning by Prompting Cognitive Operations," J. Eng. Educ., vol. 105, no. 2, pp. 245–277, 2016. [Online]. Available: https://doi.org/10.1002/JEE.20120

APPENDICES

Appendix A: Metacognition Prompt #1

Metacognition involves thinking about your thinking and learning. Throughout this course, you will be asked to complete three metacognition written exercises and small group discussions.

For the first written response, consider what you've learned about the course from the first week of classes and from the syllabus. Write a response of at least two paragraphs that includes the following items:

Clearly state a learning goal, a personal goal, and a professional goal for the course.
Explain how you plan to work toward these goals.
Describe what support you will need from the instructional team to achieve your goals.
Identify any concerns you may have about the course.

Your written response will be graded for completeness and thoughtfulness and is due before class. At the beginning of class that day, you will join a small group to discuss your written response. These groups will remain the same for all three metacognition exercises.

Appendix B: Metacognition Prompt #2

As we pass the midpoint of the semester, please pause and reflect on your learning journey so far. Take a look back at the reflection you wrote at the beginning of the semester. Address your experiences, challenges, and growth so far in a written response of at least two paragraphs. Consider the following points:

Course Progress Assessment:
Reflect on what you've learned from the course material, discussions, and assignments up to this point.
Consider any shifts in your understanding, new insights, or areas where you've excelled.

Revisiting Goals:
Revisit the learning, personal, and professional goals you set at the beginning of the semester. Evaluate your progress toward these goals. Have you made strides? Are there areas that need more attention? Do you have any other goals you would like to add for the second-half of the semester?

Adjustments and Strategies:
Based on your assessment, outline any adjustments you plan to make for the remainder of the semester.
Describe specific strategies you'll employ to Course Concerns:
Share any concerns, enhance your learning experience and achieve your goals.

Support Needed:
Identify any support or resources you require from the instructional team. Is there anything you need clarification on? Are there challenges you're facing?
Be specific about the type of assistance you seek.
or obstacles you've encountered during the first half of the semester, whether related to workload, understanding course content, or personal circumstances.

Remember that this reflection is an opportunity for self-awareness and growth. You will be gathering in your metacognition reflection groups on Thursday, March 14, to discuss your mid-semester reflection.

Appendix C: Metacognition Prompt #3

Please pause and reflect on your learning journey in 12-351. Take a look back at the reflections you wrote at the beginning and mid-point of the semester. Address your experiences, challenges, and growth in a written response of at least two paragraphs. Consider the following points:

Course Progress Assessment:
Reflect on what you learned from the course material, discussions, and assignments.
Consider any shifts in your understanding, new insights, or areas where you excelled.

Revisiting Goals:
Revisit the learning, personal, and professional goals you set at the beginning of the semester.
Evaluate whether you achieved these goals. Did you make strides? Are there goals you did not achieve? Why?

Adjustments and Strategies:
Based on your assessment, outline any adjustments you would make in future courses.
Describe specific strategies you would employ to enhance your learning experience and achieve your goals.

Support Needed:
Identify any support or resources you would have liked from the instructional team. Is there anything you needed clarification on? Are there challenges you faced?
Be specific about the type of assistance you sought.

Course Concerns:
Share any concerns or obstacles you encountered this semester, whether related to workload, understanding course content, or personal circumstances.

Remember that this reflection is an opportunity for self-awareness and growth.

Appendix D: Reflection Surveys

Pre survey

Instructions: Please respond to the following statements regarding your level of agreement or disagreement with the following statements. If you aren't sure, just go with your first instinct. There are no right or wrong answers!

- It is valuable to reflect and set **personal goals** in a course. (Likert)
- It is valuable to reflect and set **professional goals** in a course. (Likert)
- It is valuable to reflect and set **learning goals** in a course. (Likert)
- It is valuable to display professional behavior in my courses. (Likert)
- I recognize how to build good working relationships with my peers. (Likert)
- I recognize how to build good working relationships with my instructional team (e.g., instructors, TAs). (Likert)
- I value communication as part of my professional skills. (Likert)
- I can think about what I want to get out of a course. (Likert)
- I can critically reflect on my strengths and growth areas. (Likert)
- I can monitor my progress toward my goals and adjust as needed. (Likert)
- This semester, did you set personal, professional, or learning goals for yourself in any of your other courses? (yes/no)
- Referring to the above question, why or why not? (open-ended)

Post survey

Instructions: Please respond to the following statements regarding your level of agreement or disagreement with the following statements. If you aren't sure, just go with your first instinct. There are no right or wrong answers!

- It is valuable to reflect and set **personal goals** in a course.
- It is valuable to reflect and set **professional goals** in a course.
- It is valuable to reflect and set **learning goals** in a course.
- It is valuable to display professional behavior in my courses.
- I recognize how to build good working relationships with my peers.
- I recognize how to build good working relationships with my instructional team (e.g., instructors, TAs).
- I value communication as part of my professional skills.
- I can think about what I want to get out of a course.
- I can critically reflect on my strengths and growth areas.
- I can monitor my progress toward my goals and adjust as needed.
- This semester, did you set personal, professional, or learning goals for yourself in any of your other courses? (yes/no)

- Referring to the above question, why or why not? (open-ended)
- Next semester, will you set personal, professional, or learning goals for yourself in your courses? (yes/no)
- Referring to the above question, why or why not? (open-ended)

- What were the STRENGTHS of this course and of your instructor's teaching? In other words, what contributed most to your learning? Please include details and examples, and feel free to list multiple things. (open-ended)
- What specific SUGGESTIONS do you have for changes that your instructor could make to improve future students' learning? Please include details and examples, and feel free to list multiple things. (open-ended)
- Which of the following did you do to help you prepare for the exams? Check all that apply
    - I went back over the lecture slides
    - I reviewed my notes
    - I viewed course recordings
    - I consulted the textbook
    - I completed the practice exam
    - I reviewed in-class assignment questions or solutions
    - I was part of a study group
    - I attended office hours
    - Other – please describe ___