Fostering metacognition development through Industry Speaker Series

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Abstract

This complete research aimed to foster metacognition development by integrating an industry speaker series into the undergraduate curriculum in the School of Mechanical and Materials Engineering (MME) at the author's university. Metacognition is generally defined as thinking about one's own thinking, which is an essential skill to develop as an engineering student. The mechanical engineering discipline requires problem-solving, continuous learning, creativity, and self-improvement skills – to name a few. Metacognition development enables students to become better learners, which is critical to becoming a successful student and a successful engineer. Supporting mechanical engineering freshman students in developing a strong sense of purpose and direction is critical to their academic success and professional growth.

The motivation for starting this speaker series and this study came from an analysis of student exit interviews and surveys, internship data, and our team's experience with distressed students. Each semester, MME conducts exit interviews and surveys with graduating students to gather their views and experiences with the MME program as part of the MME curriculum assessment process. In these exit interviews and surveys, many voiced a desire to connect academic learning with industry expectations, professional practices, and career opportunities. Additionally, it was found that students begin their professional development process too late to fully optimize their potential for a successful transition to professional life after graduation. There is also a growing concern raised by alumni and employers about students' readiness for real-world engineering challenges and career pathways. To address these issues, the MME Industry speaker series has been introduced for seven semesters since the Fall semester of 2022.

The industry series invites one external speaker every week for a 50-minute presentation delivered either in-person or remotely. The speakers are experienced engineers from different sectors who share their professional journeys, offer advice on academic success, and transition to a professional career. Most of these speakers are mechanical engineers. This series aims to bridge the gap between academic learning and industry realities. It helps students build context for their studies, foster career awareness from the outset, and inspire them to engage more deeply with their discipline by exposing them to the types of projects they could encounter in the workplace. This study also helps students learn about the importance of networking. Networking often leads to internships, mentorship, and job offers. Understanding the implementation of classroom concepts in real-world settings motivates them to do better in their academic journey. Hearing personal stories and career journeys from speakers can motivate students and increase their sense of purpose and belonging in the engineering field. Discussions often highlight essential soft skills—such as communication, teamwork, and adaptability—that are critical for success but not always emphasized in early coursework. Early engagement with industry can help students feel more confident in their choice of major, potentially improving retention and academic performance.

To assess the effectiveness of this initiative, pre- and post-speaker series surveys were conducted among freshman students and graduating seniors. Analysis of those survey data captured the

positive impact of this initiative, such as (1) Improved communication skills with industry professionals, (2) Improved understanding of industry expectations, (3) Improved awareness of diverse mechanical engineering career paths, (4) Enhanced motivation to pursue internships and experiential learning opportunities. (5) Growth in metacognitive skills, including self-reflection, goal-setting, and strategic thinking.

Through this MME industry speaker series, metacognition development is achieved by encouraging students to reflect on their learning, career goals, and personal growth. By hearing how professionals navigate their own paths, students begin to think critically about their strengths, interests, and strategies for success—fostering self-awareness and intentional learning. We will continue collecting data and feedback about the speaker series, making it a catalyst for deeper engagement, improved academic performance, and a more purposeful transition from student to engineer.

Introduction

Computer Aided Design and Visualization (ME 116) is the first mandatory course for mechanical Engineering majors at the authors' school which is a land grant university. Usually, students take this class during the first year of their academic program, a time when they are also learning to navigate the university system, manage their time effectively, and develop their habits to become successful students. When we teach students the course contents, it is equally important to ensure students retain and apply what they learn. Retention of knowledge is critical for becoming a successful engineer. Retention of knowledge is a foundation for lifelong learning. Lifelong learning is emphasized in ABET as one of the ABET outcomes states [1] – "An ability to acquire and apply new knowledge as needed, using appropriate learning strategies". Developing lifelong learning skills is closely tied to metacognition – an ability to be aware of and regulate one's own thinking [2]. Metacognitive skills enable students to monitor their understanding, adjust strategies, and take ownership of their learning process. In the context of engineering education [3], these skills are critical for keeping pace with rapid technological advancements and for fostering both personal and professional growth. The importance of metacognition in engineering design projects has been highlighted in recent studies [4] where success often depends on reflective thinking and strategic problem-solving.

Perceptions of metacognition among graduate students in the College of Engineering and Computing during collaborative work to develop and implement applied research in both in-person and online learning environments were investigated, and more than 80% of students reported positive perceptions of metacognition and overall satisfaction [5]. Research by [6] demonstrated a strong influence of student age on metacognitive thinking skills, revealing that these skills tend to improve as engineering students progress through their academic programs. Given the developmental nature of metacognition, it is critical to implement targeted interventions at multiple stages of engineering education to support sustained metacognitive growth.

The implementation of a Problem-Based Learning (PBL) curriculum at Iron Range Engineering [7] showed promising results in introducing foundational concepts of metacognition. Similarly, research on the development of metacognition skills using Cooperative Problem-Based Learning (CPBL) among chemical engineering undergraduates [8] established a positive correlation

between CPBL methodologies and metacognitive skill development. A metacognitive intervention designed to improve problem-solving skills in first-year engineering students [9] concluded that engaging students with open-ended and complex problems can enhance their metacognitive monitoring and overall performance.

The investigation of metacognition development in second-year chemical engineering students identified four key areas of growth: (1) concept-based learning, (2) organizing one's learning, (3) monitoring learning, and (4) preparing for learning beyond the immediate subject [10]. A unique approach to supporting metacognitive development in first-year students was presented in [11], in which interactive online videos were used as the primary intervention. Students reported that this format was both helpful and impactful for their learning.

Finally, instructors' perspectives on integrating metacognitive development into their courses were examined in [12], using Eccles' expectancy-value theory (EVT) framework [13], [14]. Findings indicated that instructors felt confident in their ability to teach metacognition, but they also expressed a desire for additional support and emphasized the importance of ease of implementation.

To support metacognitive development, initiatives such as an industry speaker series can help students connect classroom learning to real-world applications, cultivate a sense of purpose, and strengthen their professional identity. By integrating metacognitive strategies into ME 116, we can empower students not only to master CAD tools but also to become self-directed learners prepared for lifelong success.

Motivation

Each semester, graduating seniors complete a mandatory exit survey to share their experiences at the university. A recurring concern expressed by students is the lack of industry exposure and insufficient opportunities to gain current, relevant knowledge. MME also collects survey data from our alumni with industry experience. The majority of our alumni also voiced similar concerns. To better understand these issues, the School of Mechanical and Materials Engineering (MME) analyzed exit survey data collected from 2021 to 2025.

Faculty often interact with distressed students who begin the career development process too late, limiting their ability to optimize opportunities before graduation.

This gap between academic preparation and industry readiness underscores the need for curricular strategies that not only deliver technical content but also develop metacognitive skills and provide authentic industry engagement. Addressing these concerns is essential for equipping students with the ability to adapt, self-regulate, and thrive in dynamic engineering environments.

Methodology

This land-grant institution operates on a semester system, with 15 weeks of instruction during the fall and spring semesters. The industry speaker series is not implemented during any summer courses. The series begins in Week 2 and concludes in Week 12 of the semester. We typically have 10 speakers in one semester.

The speaker series is integrated into two core courses: ME 116 (Engineering Computer-Aided Design and Visualization) and ME 216 (Integrated CAD Design). Offering the series in both courses ensures that all students— including transfer students who often bypass ME 116 and enroll directly in ME 216—experience this intervention. Both courses are lab-based CAD classes, typically meeting three hours per session.

Structure of the Speaker Series

- Duration and Format: Each speaker session is allocated approximately one hour within the class schedule. A typical session includes:
    - 30-minute presentation by the speaker
    - 15 minutes Q&A
    - Additional time if needed for extended discussion
- Delivery Mode: Most talks are conducted virtually via Zoom, though some speakers are present in person.
- Frequency: Each semester includes 4–5 live speaker sessions, supplemented by recorded talks for weeks without a live session.
- Access and Accountability: Recorded talks are shared with sections that did not have a live speaker that week. Students were required to listen outside of class time. Students complete a short quiz (worth 5% of the course grade) to ensure engagement with recorded content.

Course Logistics

- ME 116 typically has 3 sections, and ME 216 has 2–3 sections per semester, each with approximately 30 students.
- Across both courses, there are 5–6 sections weekly, with some meeting concurrently and others at different times.
- To accommodate the speaker series within class time, in-class activities were adjusted without compromising core learning objectives.

Speaker Selection and Preparation

- The majority of speakers are mechanical engineers with significant industry experience. Most of them are our alumni. To ensure diversity in the Mechanical engineering field, we check their current position, the type of company (aerospace, automotive, manufacturing, oil and gas, etc.) they work for.
- We also invite one graduate student every semester to give a talk about their graduate school experience.

- Faculty meet with each speaker prior to their session, providing:
    - A template and guidelines for structuring the talk
    - Clarification of the purpose and learning goals
    - Background of students in terms of engineering knowledge.

- Speakers typically share:
    - Their career journey from student to professional
    - Insights into industry practices
    - Career advice and expectations for new graduates

This structured approach ensures that students gain exposure to real-world engineering contexts while reinforcing metacognitive strategies through reflection and engagement.

The structure of this intervention evolved over time. When we first implemented it in Fall 2022, we included 12 speakers, most of whom presented live. Because some ME 116 and ME 216 sections share the same class time, a live speaker presenting in ME 116 Section 1 would simultaneously present to ME 216 Section 1 via Zoom. Each speaker session used approximately one hour of the three-hour class period. Although we adjusted in-class activities to compensate for the reduced time, we observed that students continued to experience anxiety and pressure to complete their lab work. When assignments were open, some students attempted to work on them during the speaker sessions rather than listening. Students also expressed concerns about these issues in their end-of-course evaluations.

To address these challenges, we reduced the total number of speakers from 12 to 10 and decreased the number of live speakers to 4–5. The remaining speakers' talks were shared by recorded videos, which students were required to watch outside of class time. These adjustments significantly reduced student anxiety, and we no longer observed negative comments regarding this component in the end-of-semester evaluations.

Assessments

To evaluate the impact of the industry speaker series, we designed pre- and post-intervention surveys administered anonymously during class time. These surveys aimed to measure changes in students' awareness of career development, understanding of industry expectations, and motivation for self-improvement.

The primary goal of the speaker series was to help students recognize the importance of career awareness and proactive development early in their academic journey. By exposing students to the breadth of opportunities in the mechanical engineering field through the experiences of seasoned professionals, the intervention sought to inspire students to take ownership of their learning and professional growth. This motivation for self-improvement and metacognitive engagement is expected to support their transition from successful students to successful professional engineers. Assessments are conducted from Fall 2022 until Fall 2025. Although a number of questions were on those surveys, we wanted to evaluate the improvement of self-awareness and metacognitive engagement. Typical pre- and post-survey questions are attached to Tables 1 and 2.

Table 1: Pre-Speaker Series Survey Questions

Have you made a resume?
Would you rate the quality/professionalism of your current resume?
Have you ever had someone give you feedback on your resume?
How important do you think it is to have a relevant internship before graduating?
How qualified do you feel for an internship?
What would make you feel more prepared for an internship?
How prepared do you feel for an interview (for a job or internship)?
How comfortable do you feel interacting with representatives from industry?
How important do you think it is to attend the university Career Fair?
Do you plan to attend the University Career Fair this semester?
What is your gender?
What is your age?
Did you transfer to this university from another college or university?
Are you an international student?
Do you have a parent or guardian with a bachelor's degree (or higher)?
Which design course are you currently taking?

Table 2: Post-Speaker Series Survey Questions

From which industry speaker(s) did you learn the most? (select up to 3 speakers)
What did you gain from industry speakers? (select all that apply)
Do you have any comments or suggestions for improving the industry speaker series in ME 116 and ME 216?
Have you made a resume?
How would you rate the quality/professionalism of your current resume?
Have you ever had someone give you feedback on your resume?
How important do you think it is to have a relevant internship before graduating?
How qualified do you feel for an internship?
What would make you feel more prepared for an internship?
How prepared do you feel for an interview (for a job or internship)?
How comfortable do you feel interacting with representatives from industry?
How important do you think it is to attend the University Career Fair?
Did you attend the University Career Fair this semester (in February)?
Have you applied for an internship for 2023?
During which month(s) did you apply for internship(s)?
Have you received one or more internship offers for 2023?
Have you accepted an internship offer for 2023?
What company will you be interning for?
What is your gender?
What is your age?
Did you transfer to this university from another college or university?
Are you an international student?
Do you have a parent or guardian with a bachelor's degree (or higher)?

Which design course are you currently taking?
What mechanical engineering industry are you most interested in pursuing after graduating?

Students were asked to rate each speaker in the post-speaker series survey question, “From which industry speaker(s) did you learn the most? (select up to 3 speakers)”. After analyzing data from the past several years, we observed that the speaker from the aerospace industry consistently received the highest ratings. The second-highest ratings typically went to speakers from the automotive industry. These findings align with student interests. In 2024, we asked students in the post-speaker series survey, “What mechanical engineering industry are you most interested in pursuing after graduating?” Results from both 2024 and 2025 confirmed that aerospace is the most popular choice, followed by the automotive industry.

Students were also invited to share concerns or comments about the series using the prompt, “Do you have any comments or suggestions for improving the industry speaker series in ME 116 and ME 216?” Overall, the speaker series was well-received. Most comments were positive, and students expressed appreciation for the opportunity to hear from professionals. Some representative student remarks included:

- “I don't have any suggestions, I came into this class thinking it was only going to be CAD work and these speakers surprised me in the best way. They helped me learn more about what I am getting into.”
- “Not really, I enjoyed all of the speakers and the zoom format worked well for when the speaker was not in our lab.”
- “No suggestions. I thought that all the speakers provided good insights into their industries and kept a good pace that kept my interest the whole time.”
- “I thought all the speakers were great, I liked the diversity of careers they all had and could share with us.”

Student preferences regarding format varied. Some preferred in-person speakers, while others were satisfied with the online format. Most of our speakers presented via Zoom, with only occasional in-person visits.

Metacognition reflection

Accurate self-assessment and reflection are essential foundations for lifelong learning and professional development. Geringer et al. [15] examined the metacognitive processes used by high-performing physicians to maintain or recalibrate accurate self-assessment, particularly in relation to challenges such as imposter syndrome. The intention of the present work aligns with that perspective: to help students develop metacognitive awareness by improving their own thinking processes, ultimately supporting their growth into successful engineers.

In this context, our intervention focused on fostering early self-awareness and self-reflection so that students begin engaging in professional development as early as their freshman year. Using pre- and post-assessments, we examined students’ self-awareness and professional awareness

before and after the intervention. Survey results revealed mixed outcomes. In some areas, the intervention had a positive impact, while in others the effect was less evident.
For example, we assumed that most students already had a résumé, but did they know that a résumé should be evaluated by professionals? Pre- and post-speaker series survey responses to "Have you ever had someone give you feedback on your resume?" are presented in Figure 1. Mechanical Engineering students are required to take ENGR 120, a course designed to provide all engineering majors with exposure to different engineering fields. In that course, students receive instruction on résumé development. Despite this background, Figure 1 shows that 10–18% of students had never had their résumé evaluated, which we interpret as an indicator of limited self-awareness.

During the speaker series, industry professionals emphasized the importance of using campus career services, résumé workshops, and other resources to obtain meaningful feedback and strengthen their résumés. After the intervention, in figure 1, we observed improvements in students' use of career services and in the proportion of students who had their résumés reviewed. In the "other" category of the pre-speaker series survey, most students mentioned receiving résumé help exclusively from their ENGR 120 class. In contrast, post-speaker series survey responses indicated that students sought assistance from a broader range of sources, including résumé workshops, career centers, and professors. We interpret this change as evidence that some students reflected on their existing practices and took deliberate steps to improve them.

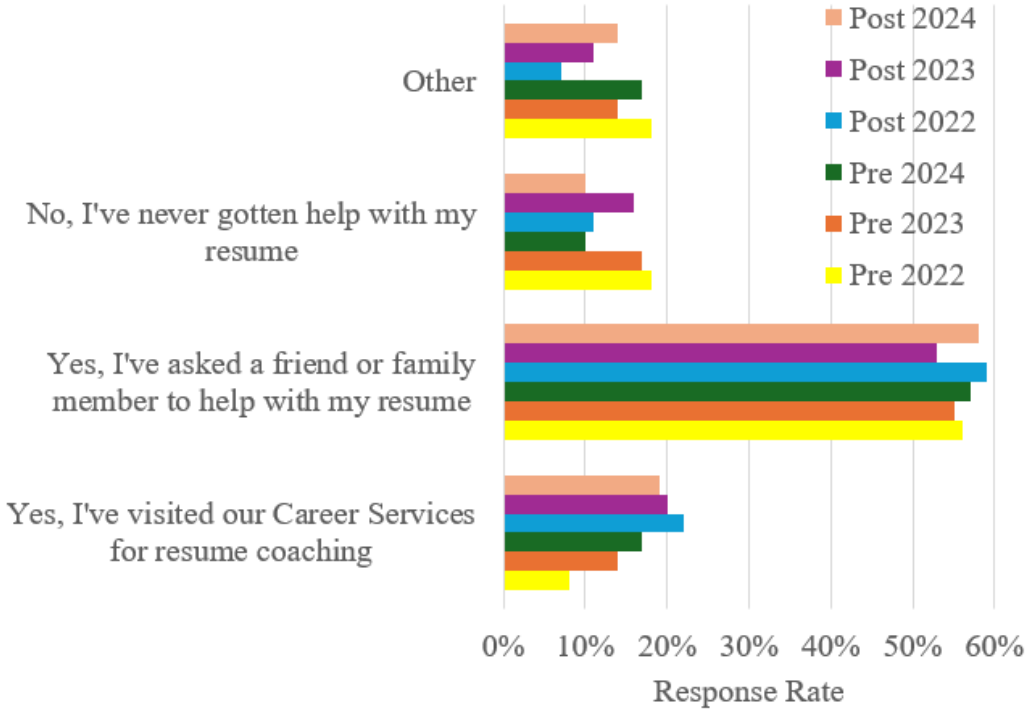

Figure 1: Outcome of survey question – "Have you ever had someone give you feedback on your resume?"

Pre- and post-speaker series survey response to the question "How important do you think it is to have a relevant internship before graduating?" is shown in figure 2. Students were asked to be rated using 1 to 10 scale with 1 being least important and 10 being extremely important. Outcome is shown in figure 2 where the impact of this intervention is minimum as most of the students are already rated 7 or above in pre survey indicating that they already understand this important aspect of career development. Although they understand, historical data from the senior exit survey and alumni survey conducted by our department shows the lack of industry exposure from our graduating seniors which translates to not enough initiative to gain professional experience. We hypothesized that they start their career development process too late to optimize their potential.

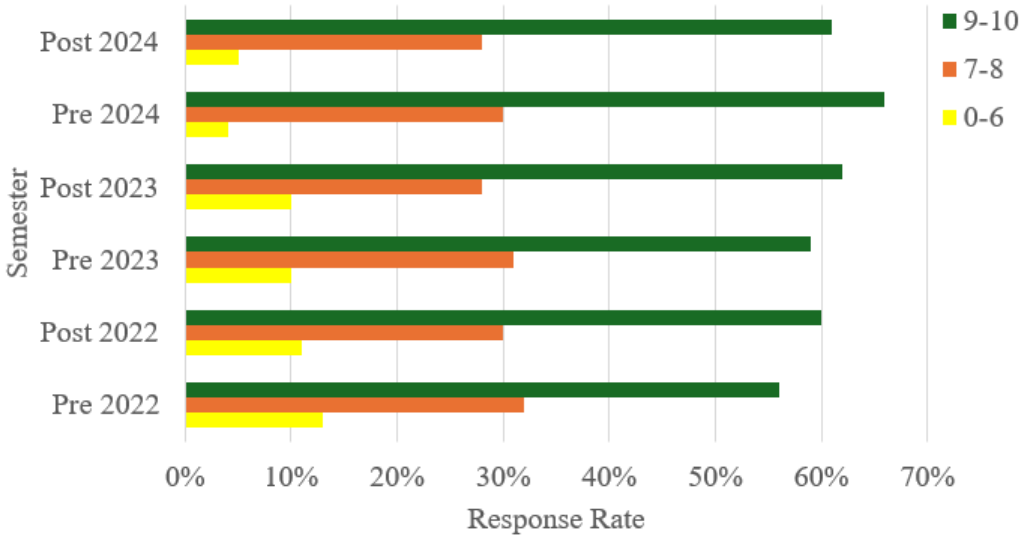

Figure 2: Outcome of survey question – "How important do you think it is to have a relevant internship before graduating?"

Even though students recognize the importance of obtaining an internship, as shown in Figure 2, this awareness does not necessarily translate into taking initiative when opportunities arise—such as attending the career fair held once each semester. According to Figure 3, the pre-speaker series survey question "Do you plan to attend the University Career Fair this semester?" shows that only about 42% or fewer students intended to attend. We interpret this as an indication of limited metacognitive development: students understand *what* is important but do not always act on that knowledge.

The industry speaker series intervention contributed to supporting this developmental process. The post-speaker series survey question "Did you attend the University Career Fair this semester?" (also shown in Figure 3) revealed a positive impact during the fall semesters, though not during the spring semesters. Historically, summer internship opportunities are significantly more abundant at the fall career fair compared to the spring fair, which may contribute to lower attendance in the spring. In addition, the region typically experiences harsh winter weather,

including heavy snow and low temperatures, which may also have influenced spring participation rates.

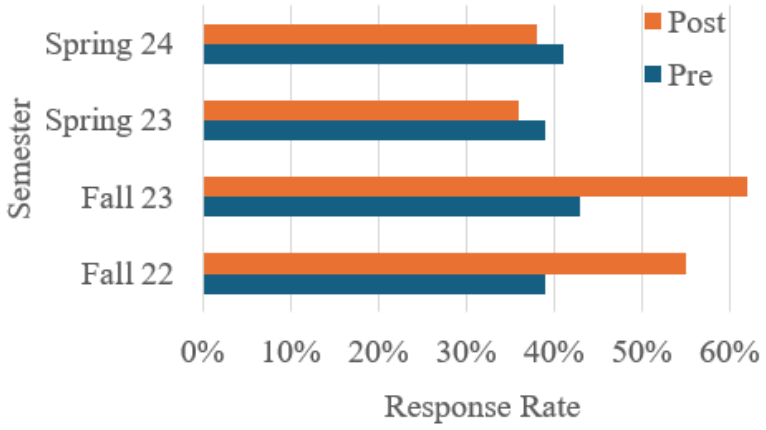

Figure 3: Outcome of survey question: Pre: "Do you plan to attend the career fair", Post: "Did you attend the career fair?"

Analysis of the pre and post-speaker series survey question "How comfortable do you feel interacting with representatives from industry?" indicates that, overall, students do not feel comfortable engaging with company representatives. This intervention did not significantly improve this aspect of their communication skills. We also observed similar behavior during the Q&A portion of the live speaker sessions. Although 15 minutes were allocated for this activity, almost no students volunteered to ask questions. To address this issue, we implemented a structured approach: each student receives a blank note card and is required to write at least one question for the speaker. Students attending via Zoom may also submit their questions through the chat. Our intention was that having a prepared question would reduce hesitation and encourage participation. This strategy did improve engagement; however, not to the extent we hoped for, suggesting that further refinement or additional interventions may be necessary.

The target audience for this study is freshman and sophomore students. Figure 4 shows an improvement in the number of students attempting to secure internships. It is true that internship opportunities for freshmen are limited, and many students do not feel ready for such experiences because they are still early in their academic coursework. In the pre-speaker series survey, students were asked, "What would make you feel more prepared for an internship?" Many responded that they felt unprepared due to a lack of experience, often noting that they needed to take more classes before feeling confident enough to apply.

By contrast, students' responses in the post-speaker series survey demonstrated more maturity and specificity. Although many still indicated the need to gain additional experience, their answers were more focused and actionable. Examples included: "More field specific knowledge."," Complete more classes to get a better understanding of the basics of engineering," "Confidence in my skills," and "clear and established expectations," etc. This shift in the pattern

of responses suggests that the speaker series contributed to increased self-awareness and self-reflection about a clearer understanding of professional development pathways.

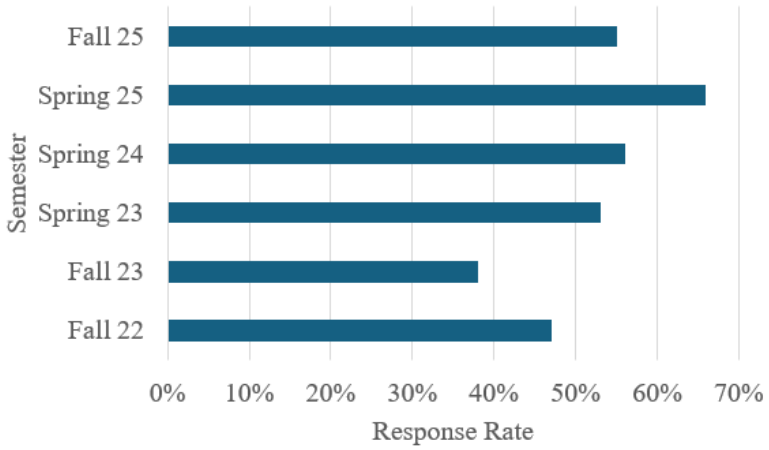

Figure 4: Outcome of survey question: "Have you applied for an internship?"

Figure 5 summarizes the responses to the question, "What did you gain from the industry speakers? (Select all that apply)." Because the overall trends remained consistent across semesters, four representative terms were selected for inclusion in this study. Across all four datasets, the impact of the speaker series was notably positive. A substantial proportion of students (greater than 75%) reported an improved understanding of engineers' responsibilities in the workplace. More than 68% of students indicated that they found the career advice helpful. Approximately 39% or more reported increased motivation to pursue internships. While this percentage was lower than anticipated, it is important to note that the majority of participants in these introductory-level courses were freshmen, for whom confidence and career readiness naturally develop over time.

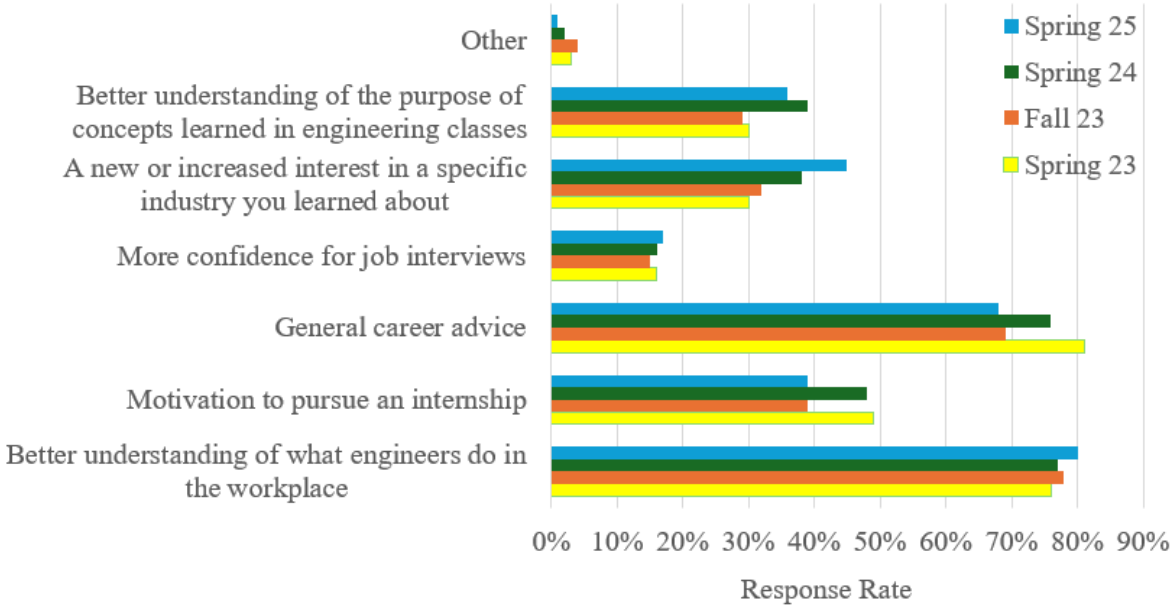

Figure 5: Outcome of survey question "What did you gain from the industry speakers? (Select all that apply)"

The industry speaker series was first introduced in Fall 2022. By Fall 2025, students who had experienced the speaker series in their lower-division courses were seniors preparing to graduate. To assess longer-term impacts, an additional survey was carried out to senior-level students enrolled in ME 415. Results are included in Figures 6 and 7. Seniors reported similar trends to their earlier academic years, including increased understanding of engineering career pathways and professional expectations. When importance of internship is highly emphasized, students were highly encouraged by the speakers to pursue other avenues such as actively working in engineering clubs, doing research with professors, even working in hands on personal technical projects etc. Figure 7 shows that about 39.7% of students became interested in clubs/extracurricular activities and 48.5% became interested in hands-on project-based activities.

The surveys were conducted anonymously; therefore, pre- and post-intervention responses could not be linked at the individual level. As a result, the pre- and post-survey datasets were treated as independent samples. Differences in response distributions for the data shown in Figure 1 were analyzed using chi-square tests. Although changes between pre- and post-intervention behaviors were observed, as discussed in the *Metacognition Reflection* section, the associated statistical significance was too small to warrant formal reporting.

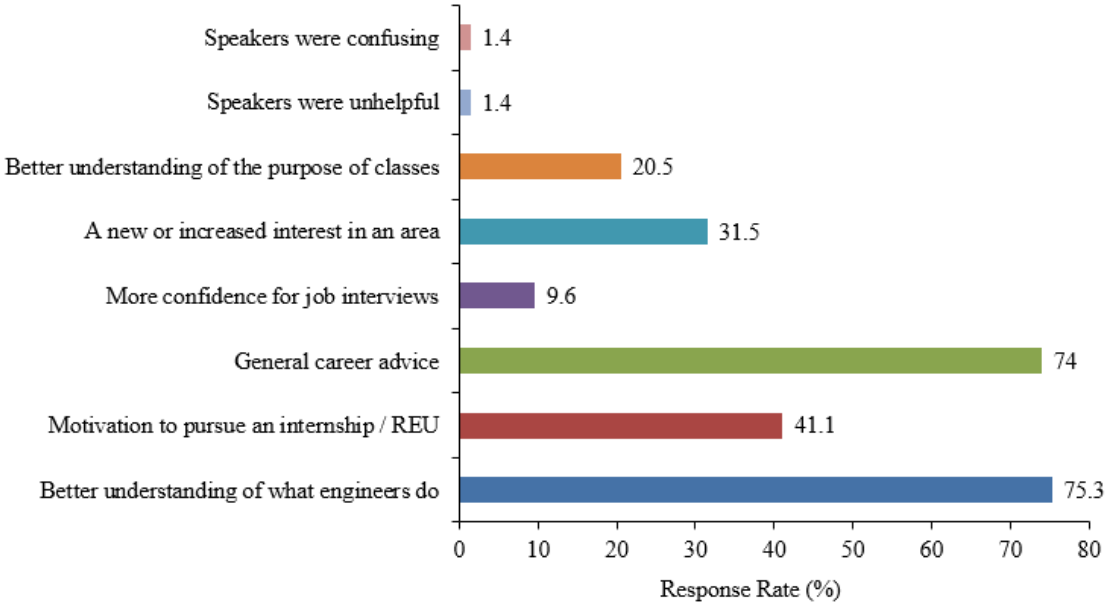

Figure 6: Fall 2025 survey outcome of "What did you gain from industry speakers? (Select that all apply" from ME 415 class from 73 students.

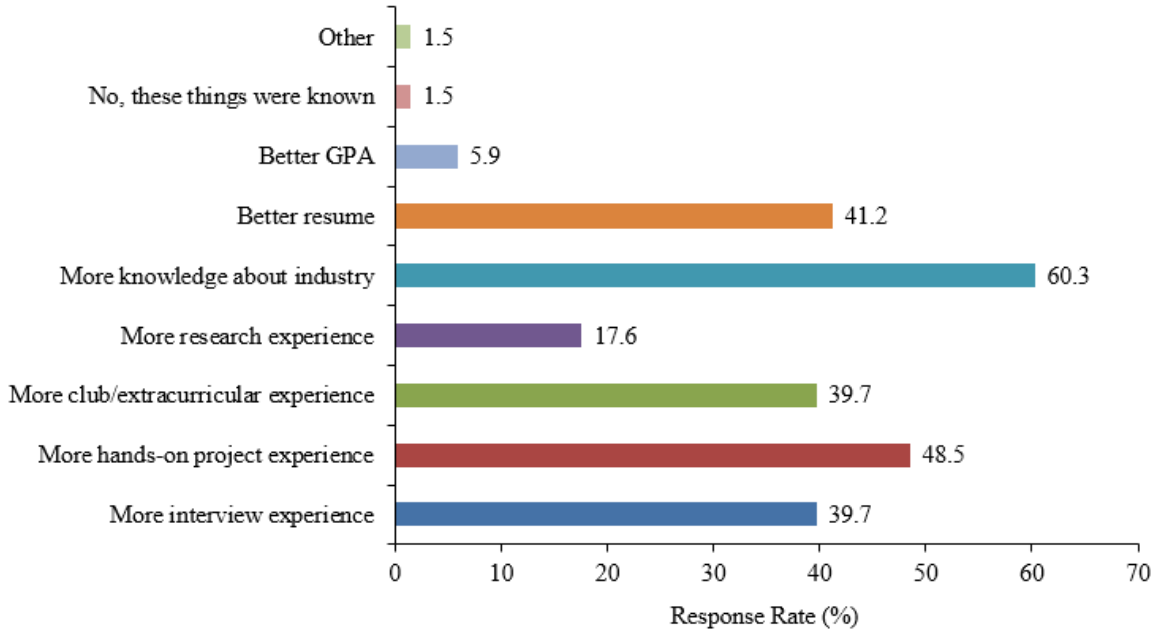

Figure 7: Fall 2025 survey outcome of "Did the industry speaker series encourage you to improve in any of the following areas?" from ME 415 class from 68 students.

Conclusions

Analysis of data collected from 2022 to 2025 across ME 116, ME 216, and ME 415 courses indicates that the industry speaker series intervention has had a positive impact on students' career awareness, motivation, and preparedness for professional practice at some level. Students reported increased understanding of industry expectations and greater appreciation for proactive career development. In addition to these professional outcomes, the intervention appears to support students' metacognitive development by prompting them to reflect on their learning, evaluate their evolving career goals, and recognize gaps between their current skills and industry needs. Such reflective engagement is a critical component of lifelong learning and professional growth in engineering education. These findings suggest that integrating authentic industry engagement into the curriculum, alongside technical instruction, can effectively bridge the gap between academic preparation and real-world engineering challenges. Continued refinement and expansion of this model may further strengthen students' professional identity formation, metacognition skills, and career readiness. Currently ENGR 120 (mandatory class for all engineering freshman) is changing to two new classes ENGR 101 and 102. For future work, we would like to analyze more data using these two classes to assess the impact of earlier intervention.

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