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Bridging the Gap: Industry Integration in MSE Undergraduate Lab Courses Enhancing Student Learning

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Abstract:

In today's educational landscape, preparing students for an ever-evolving and demanding workforce is of paramount importance. Collaborations between industry and academic institutions have consistently demonstrated positive outcomes for all involved parties, including students, instructors, and industry professionals. This article examines the guest presentations delivered by materials manufacturers in two undergraduate lab courses within the field of Materials Science and Engineering (MSE). Additionally, it presents findings from a survey study conducted to evaluate the impact of the guest lecture initiative, involving an average class size of 55 undergraduate students in each of the two courses.

In Fall and Spring of 2022 and 2023, industry presentations were integrated into MSE 3021 and MSE 4022 materials properties and processing laboratory courses to enhance the students' understanding of real-world applications and industry practices. Presenters were invited from diverse sectors of industry, including metal, ceramic and polymer processing (Applied Ceramics, Solvay, Novelis) in addition to battery testing company (Element Assurance). The lectures offered direct insights into various facets of MSE, such as aluminum manufacturing to battery testing, ceramic production, and polymer processing. In addition, a collaborative effort with one company has resulted in the creation of technical videos that serve as supplemental resources for students. These pedagogical endeavors have been thoughtfully aligned with the MSE paradigm, focusing on materials processing, properties, and performance. The goal of the initiative is to demonstrate the practical significance of the theoretical concepts and processes taught in the classroom, rendering academic knowledge tangible and relevant.

This work in progress paper presents preliminary results of a survey study where the positive student responses validate the constructive impact of these industry collaborations on their educational journey. The study investigates aligning industry guest lectures with specific laboratory experiments within an engineering lab course. It addresses a critical gap in current research by exploring the strategic integration of guest lectures to enhance the learning experience in MSE lab courses. The survey results demonstrated that students not only welcomed the guest lectures but also acknowledged their effectiveness in establishing tangible links to the real world. These endeavors have sparked their curiosity and cultivated enthusiasm for the subject matter, fostering a deeper comprehension of its broader implications for industry and society.

In the future, the aim is to enhance these efforts by diversifying the pool of industry speakers, including representatives from startups, in addition to guest lectures that would be scheduled strategically to minimize any disruptions to the core course material. Furthermore, the focus on gathering more extensive feedback from both students and industry partners were will emphasized to ensure ongoing improvements in the integration of industry engagement within MSE education.

Background and Introduction:

In the dynamic world of education, where preparing students for the ever-evolving and demanding workforce is paramount, the significance of cultivating robust partnerships between academic institutions and industry cannot be overstated [1, 2]. Out of the four key stakeholders (students, faculty, industry and society) in engineering education, industry is considered a major one as it is a ultimate customer for the students universities graduate [3]. Not only does the industry set the requirements for the engineering education but also plays a pivotal role in shaping the curriculum to meet the evolving needs of the workforce. The relationship between academia and industry relies on feedback between the stakeholders (students, faculty and industry) allowing educational institutions to align their programs with industry standards and advancements, ensuring that graduates are well-prepared and relevant in a rapidly changing consumer market space. This symbiotic partnership fosters a continuous cycle of improvement.

The author sees that the industry-academia partnerships yields multifaceted benefits for all stakeholders involved as illustrated in Fig. 1. For students, these collaborations provide valuable real-world exposure, bridging the gap between theoretical knowledge and practical applications. It also fosters networking opportunities, allowing students to establish connections needed for potential internships and future employment. Industry experts benefit from these partnerships by gaining access to emerging talent, fresh perspectives, collaborative research opportunities and also fulfil their corporate social responsibility [4]. Academic instructors, in turn, benefit from industry collaborations by enriching their teaching methodologies with real-world examples, fostering professional development and finding funding opportunities. The partnerships thus contribute to a dynamic learning environment, aligning academic curricula with industry needs and promoting a culture of innovation and continuous improvement.

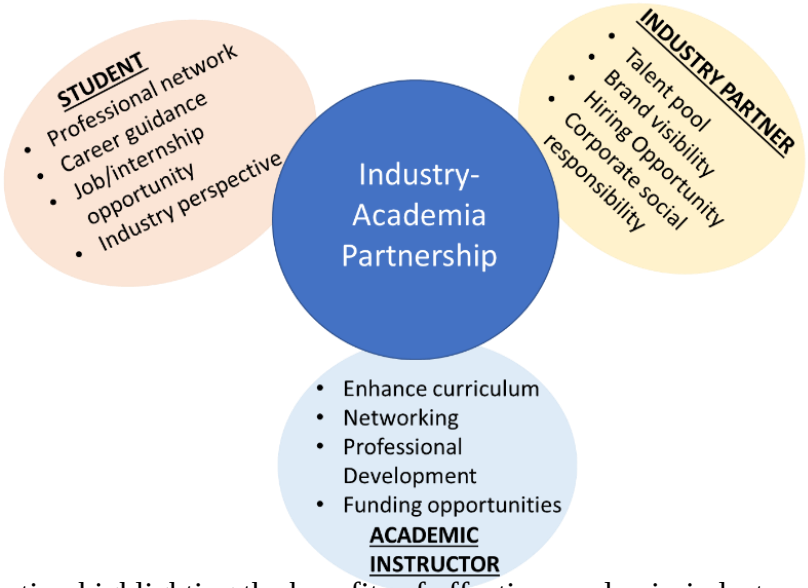

Figure 1: Illustration highlighting the benefits of effective academia-industry partnership among each stakeholder.

Conventionally a more common example of industry-academia collaborations is joint research projects, which commonly involve graduate students and, to a lesser extent, undergraduates [5]. While these collaborations offer valuable opportunities for experiential learning and exposure to real-world applications, a major drawback is that it only caters to a handful of selected undergraduate students. Recognizing the diversity of circumstances that undergraduates face during their academic journey, including limited opportunities, packed schedules, and personal commitments, it becomes evident that not all students can engage in traditional research experiences. This limitation extends to the exposure of students to the industry perspective, which is crucial for their holistic educational development. Therefore, integrating industry collaborations directly into undergraduate coursework emerges as a highly beneficial alternative [6], ensuring that a broader spectrum of students can access the advantages of practical engagement with industry. This approach aligns with the structured nature of courses, allowing students to gain valuable insights and experiences in a more manageable and integrated manner. Examples of such collaborations include industry-driven capstone projects, research seminars, plant tours and guest lectures [7].

In Materials Science and Engineering (MSE) undergraduate education, the integration of industry involvement within coursework has predominantly centered around capstone design courses [8]. Here, students engage in semester-long projects, collaborating with industry sponsors to address research problems and deliver comprehensive reports. Other more infrequent association involve instructors inviting guest lecturers to contribute industry perspectives to the coursework. However, aligning these industry talks precisely with the ongoing course content presents challenges, requiring considerable time commitments from both faculty and industry members. Furthermore, research on integrating industry expert-led lectures specifically tailored to lab course content is scarce. To address this gap, we targeted two specific lab courses to pilot a program with focused industry interaction for MSE undergraduate students.

Course Description and Industry-Engagement Initiative:

To advance industry engagement within MSE undergraduate education, two lab courses were identified to serve as pilot initiatives. The first of these courses, Materials Properties Lab (Lab-I), is primarily undertaken by third-year students, while the second, Materials Processing Lab (Lab-II), is typically pursued by students in their third or fourth year. Each lab typically accommodates an average of 60 students per semester. Given that these labs are mandatory core courses offered consecutively, students enrolled in both the 2022 and 2023 academic years had the opportunity to attend guest lectures in both Lab-I and Lab-II. Technically, Lab-I delves into the measurement of diverse material properties, including thermal, electrical, mechanical, and rheological studies. Lab-II, on the other hand, provides experiences with contemporary materials processing techniques. These courses were strategically selected as the initial focal points for this educational endeavor due to their foundational role in MSE curricula.

The shared learning outcomes across these lab courses emphasize the development of crucial skills in data analysis, encompassing both data acquisition and processing, coupled with effective communication through scientific writing. While the overarching goals remain consistent, the

technical outcomes diverge between the two lab courses. In Lab-I, the emphasis is on equipping students with the ability to discern and select appropriate measurement techniques, operate testing equipment proficiently, and conduct data collection and analysis. This course is divided into three modules and focuses on characterizing various classes of materials for properties testing, often utilizing ASTM standard samples to ensure standardized evaluation. For instance, within the electrical module of Lab-I, students engage in measuring the impedance of different systems, including store-bought rechargeable Li-ion batteries. Additionally, they test research-grade coin cells sourced from a battery research group on campus, comparing their Nyquist plots to those of commercially available batteries to predict potential differences in battery life. This approach not only hones their technical skills but also instills a practical understanding of the significance of materials characterization in real-world applications, aligning with the broader objectives of MSE education. This laboratory experiment served as an ideal juncture to seamlessly integrate industry insights and practices into the core content of the in-lab coursework. Therefore, a battery testing company was invited to share their expertise with the students in Spring ‘23 for the first time. During a dedicated session, the guest speakers from the company elucidated the intricacies involved in testing batteries at a commercial level. The lecture covered a spectrum of essential aspects, ranging from testing techniques to safety considerations, providing students with valuable insights into industry practices. In a proactive approach to hands-on learning, the guest speakers arranged for practical demonstrations, offering props for students to construct their own batteries. This interactive session allowed students to apply their theoretical knowledge in a tangible setting, fostering a deeper understanding of battery testing methodologies. Importantly, the demonstration emphasized non-destructive testing techniques, enabling students to engage in comparative assessments without compromising the integrity of the tested batteries.

In Lab-II, students engage in a more comprehensive and hands-on experimentation, starting with the processing of materials to fabricate testable components. Similar to Lab-I, this course is structured into three independent modules, each specifically targeting a distinct material class—ceramic, metal, or polymer. Within each module, students delve into the intricacies of processing techniques tailored to assigned material. The experimental journey then progresses to testing measurable quantities of the processed parts, followed by the correlation of results to construct the microstructure-process-property relationship within each material class.

The nature of Lab-II often sparks students' curiosity, leading them to question whether the processes they perform in our labs align with industry practices for producing consumable parts. A particularly intriguing module focuses on metal processing, where the objective is to observe the impact of a unidirectional temperature gradient during the cooling of molten metal on the resulting microstructure of the metal alloy. This modified microstructure, in turn, influences the mechanical strength of the alloy, adding another layer of complexity to the lab's goals. Engaging in discussions with students about how industries manufacture homogenized microstructures in ingots that are several feet long inspired the idea of collaboration with aluminum manufacturers. This collaborative endeavor aims to provide students with more in-depth insights into industrial

processes, offering a bridge between academic exploration and real-world applications in materials processing and alloy development.

In the Fall of 2020, an exciting collaboration was initiated with a global leader in aluminum processing, involving an enthusiastic team from the company. The expert engineers demonstrated a keen interest in establishing a robust educational relationship with our school, specifically targeting the Lab-II Materials Processing Lab. As the first stride in this collaborative venture, the engineers embarked on creating educational video content designed to serve as a precursor to the module within the course. Three meticulously crafted videos were curated, offering detailed technical insights and discussing strategies frequently employed in the industry to address challenges encountered during the casting of aluminum alloys. During pandemic, industry experts delivered synchronous online lecture and engaged students with live quiz based off an interesting automotive case study. For the second phase of the collaboration, starting Fall 2022 the engineers were invited to our campus to deliver a guest lecture during the weeks dedicated to metal processing. During this visit, our esteemed guests brought along props to enrich the learning experience for the students. These props included both unfinished and finished beverage cans, as well as automobile parts crafted from aluminum alloys.

In order to continue engaging industry professionals in each module of the processing lab, a local ceramic industry leader, was invited as guest speakers for the ceramics module. Our guests delivered an insightful and enriching lecture to the course, providing students with a deep understanding of the casting process, firing techniques, and post-processing steps involved in ceramics manufacturing. Going beyond the lecture, the collaboration took an exciting turn when Applied Ceramics generously offered a plant tour to the MSE student body. While logistical challenges prevented the organization of an undergraduate class tour, a group of graduate students, who also served as technical Teaching Assistants (TAs) for the course, took advantage of this opportunity.

The third module in Lab-II, focusing on polymer processing, marked another significant collaboration with a local branch of a leading polymer processing company. What set this partnership apart was the unique involvement of engineers who were alumni from our department. This added a special dimension to the interaction since these engineers had been students in Lab-II few years ago. This collaboration not only aligned with the goals of previous industry partnerships, offering students insights into real-world polymer processing, but it also fostered a more personal connection. Students had the opportunity to interact with speakers who had walked the same academic path, providing a relatable perspective on career paths and professional journeys. The younger professionals, having recently transitioned from being students in the same lab, became approachable mentors.

Harnessing the presence of field experts on campus provided an excellent opportunity to cultivate more personalized interactions for the students. Once the groundwork was laid for inviting the engineers, a distinctive approach was adopted by allowing students to volunteer as hosts for our esteemed guests. This empowered students to take charge of planning logistics and establishing email communications with the industry professionals. As hosts, students went

above and beyond by organizing tours of Materials Science and Engineering (MSE) maker spaces and other sites of engineering significance on campus in addition to escorting and joining them for lunch. This not only created a conducive environment for meaningful exchanges but also offered students a chance to inquire about work culture in industry, explore internships/job opportunities and gain insights into the practical aspects of their field.

Assessments and Discussion:

The initial assessment was conducted in Fall 2023 and marked a crucial evaluation point for the students who had completed both Lab-I and Lab-II attending guest lectures from battery testing, metals and polymer processing companies. The assessment was done in a form of a brief, ungraded survey consisting of following five questions. It sought to capture students' reflections on the degree to which guest lectures bridged the gap between course-work and industry, and to serve as a foundation for future studies to assess the impact of industry guest lectures in MSE lab courses.

1. To what extent do you believe the inclusion of industry speakers in the course enhanced your understanding of materials processing?
2. Do you feel that the industry presentations positively influenced your engagement and interest in the course material?
3. In what ways did the industry speakers contribute to bridging the gap between academia and manufacturing scale production of materials?
4. How effectively did the industry speakers address sustainability considerations within their respective fields during their presentations?
5. Please comment on your experience of these invited lectures. Do you have any suggestions on how these could be enhanced further to promote student learning? Any particular industry that should be invited for the presentation?

Notably, out of a class comprising 51 students, about 55% of the class responded. The survey results from 26 participating students provide valuable insights into the impact of guest lectures on bridging the gap between academia and industry [9] and are discussed herewith.

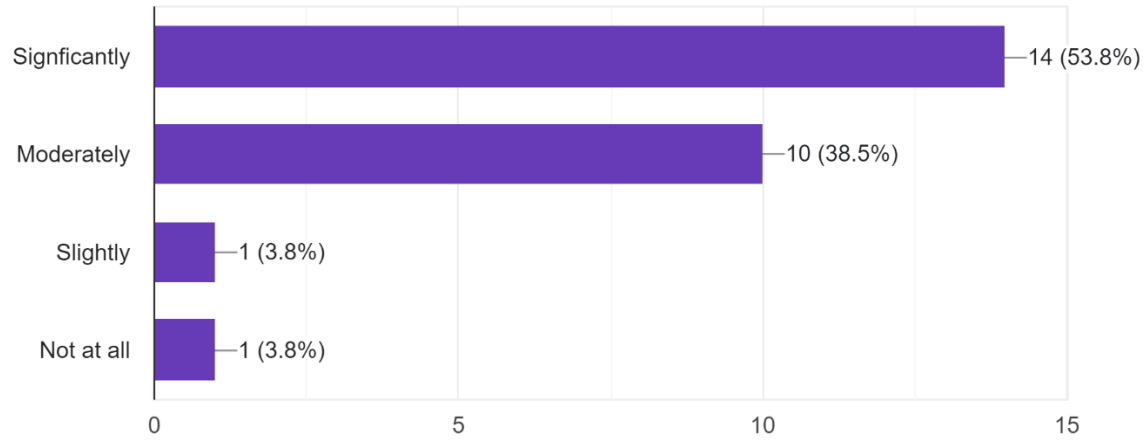

Figure 1: Results from survey Q1: to what extent inclusion of industry speakers enhanced students understanding of materials processing

As depicted in Fig. 1, over 90% of the participants believed that the inclusion of industry lectures at the least moderately enhanced their understanding of materials processing. Additionally, as seen in Fig 2, majority of students (53.8%) reported feeling positively influenced to some extent by the industry presentations in terms of their engagement and interest in the course material. A substantial portion of the class (42.3%) indicated that the presentations had a significant positive impact on their engagement and interest. The impact was also evident through verbal as well as written student feedback, one of which read "*I learned a lot in a little time about what the companies do*".

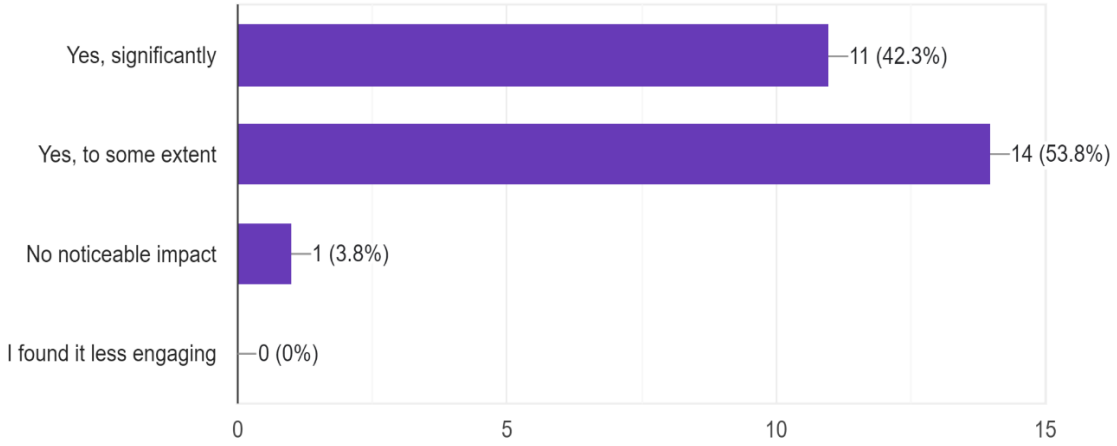

Figure 2: Survey results to Q2- if industry presentations influenced student engagement and interest in the course material?

In response to Q.3, 50% of students acknowledged that the industry speakers made notable contributions by sharing the challenges and solutions faced by the industry highlighting the practical insights gained during the lectures, as shown in Fig. 3. Additionally, ~42% of students emphasized the effectiveness of the lectures in conveying clear, direct, and relevant examples. This indicates that the use of tangible examples, props, videos shown during the lectures, case studies discussed resonated well with the student audience. About 8% of students noted that the lectures facilitated the

connection between theoretical knowledge acquired in academia and its practical application in manufacturing. Notably, none of the respondents felt that the lectures failed to achieve the objective of bridging the gap, underscoring the overall positive impact of industry lectures in their course.

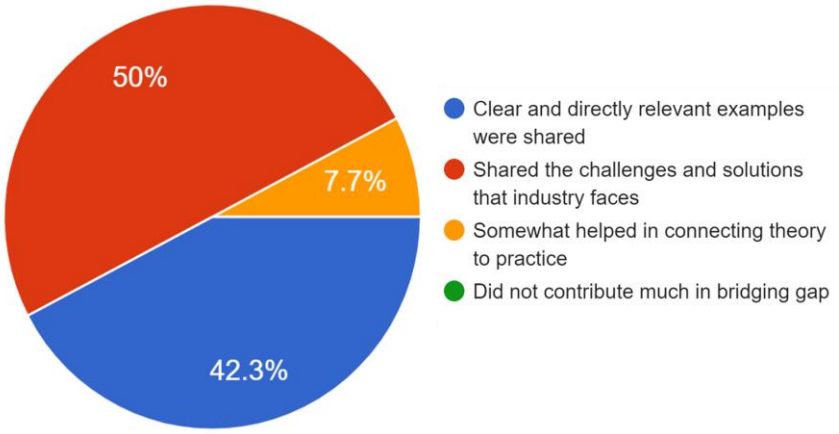

Figure 3: Pie-chart showcasing the results of Q3 on the survey- In what ways did the industry speakers contribute to bridging the gap between academia and industry?

The survey results also indicated that a significant portion of students found the industry speakers to be effective in addressing sustainability considerations within their respective fields during their presentations as shown in Fig. 4. Specifically, 34.6% of respondents felt that the speakers addressed sustainability considerations very effectively, while 38.5% found them to be moderately effective in this regard. Additionally, 23.1% of students perceived the speakers to be somewhat effective, while only a small minority (3.8%) felt that the speakers did not effectively address sustainability considerations. It is worth noting that a majority of respondents felt that the industry speakers effectively addressed sustainability which indicates that students value industry's responsibility in promoting sustainable practices. This suggests that students are not only interested in learning about the technical aspects of materials processing but also in understanding the environmental and social implications of these processes.

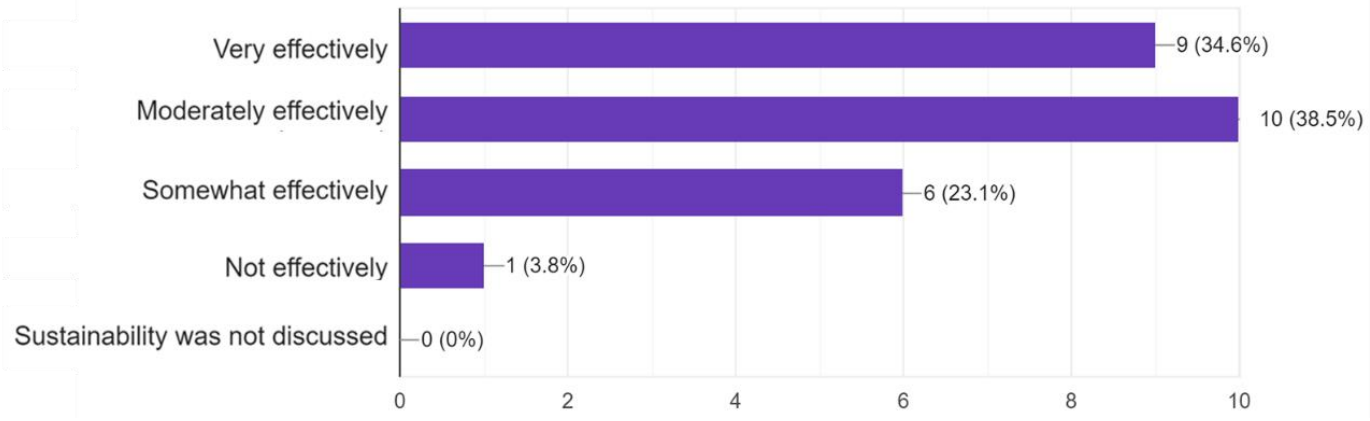

Figure 4: Survey response when asked if the industry speakers address sustainability effectively in their respective fields (Q.4)

The last question on the survey was a reflection prompt that students provided their comments on. Based on the initial survey responses, four main insights emerged and are summarized below.

1. **Positive Feedback**: The industry lectures were well-received, with students finding them engaging and informative. The lectures were also found relevant to other courses like Capstone Design. Relevant student comments that demonstrate positive impact;
    - *Both of the industry lectures were excellent! They were engaging and I learned from both of them. Several people also said the Solvay lecture related well to our Capstone design course.*
    - *I really enjoyed the Solvay lecture because it highlighted the different roles that MSE students can enter into after graduation.*
    - *I thought they were very in depth in detail, however, some of the detail scopes were beyond me.*
    - *It would be cool if they could walk us through a specific engineering solution from problem to result, if its not IP protected*

2. **Sustainability Considerations**: Some students noted that sustainability considerations discussed in the lectures seemed to come after the fact, for established industries. There was an interest in hearing from startups that may have begun with sustainability considerations from the outset, offering a different perspective on industry practices. Relevant student comments that demonstrate positive impact;
    - *Unfortunately, I think most of the sustainability considerations that industry came up with in the lectures, is after the fact, so they find what they want to do and then present the ways in which it could be sustainable, I'm assuming some startups might have begun with sustainability considerations, and then moved to what they want to do, so they could be interesting to hear from, but they are not necessarily established industry*

3. **Suggestions for future speakers**: Students showed interest in inviting speakers from a diverse range of industries including professionals from emerging fields start-ups.
    - *I think ceramics module should also have a speaker! Maybe from Verco Materials or Applied Ceramics*

4. **Challenge of balancing instructional time with enriching activity**: Few students mentioned the loss of content-related instructional time during the guest lectures
    - *I enjoyed learning about industry. Except it took away from learning about the lab topics*
    - *More time was taken away from class stuff, maybe these lectures could be offered during a lab period instead of lecture*

Overall, the feedback indicated a positive reception of the industry lectures and a desire for a broader range of speakers. The suggestion for more in-depth exploration of engineering solutions and perspectives from sustainability-focused startups reflects a keen interest in practical applications and diverse industry practices among the students. While the general feedback from

students have been positive, concerns regarding the trade-off between instructional time and enriching activities like these were also raised. Addressing these insights offers a chance to enhance the integration of industry perspectives into the curriculum, ensuring that guest lectures complement the core course content further, thus fostering more effective student learning experiences.

Future Plans:
Looking ahead, the plan is to employ a comprehensive approach to further enhance the integration of industry perspectives in the MSE undergraduate lab courses. Qualitative insights will be sought through open-ended survey questions, in-depth interviews or focus group discussions with students for detailed feedback. Quantitative data will be gathered through expanded surveys with structured questions, allowing for statistical analysis of key indicators such as perceived learning outcomes, career readiness, and the influence of industry collaborations on academic performance. Incorporation of pre- and post-assessment measures will also be added to enable a longitudinal analysis of students' development throughout the lab courses. These initiatives aim to provide a holistic understanding of the effectiveness of industry integration in MSE lab courses, allowing for continuous refinement and improvement in future implementations.

In summary, to enhance industry involvement in Materials Science and Engineering undergraduate education at course level, initiatives were undertaken to integrate industry speakers into lab courses Materials Properties Lab (Lab-I) and Materials Processing Lab (Lab-II). The outcomes of these efforts were largely positive, with students expressing appreciation for the industry lectures and their relevance to course content. However, some challenges were identified, such as the need to balance instructional time with enriching activities and ensuring sustainability considerations are adequately addressed. Moving forward, a plan to further refine these initiatives by inviting speakers from a diverse range of industries, including startups, and optimizing the timing of guest lectures to minimize disruptions to core course content will be put in place. Additionally, efforts will be made to gather more comprehensive feedback from students and industry partners to continually improve the integration of industry involvement in MSE education.

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