Recruiting the Unknown: Engaging First-Year Engineering Students with Experiential Materials Science and Engineering

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Abstract

Materials Science and Engineering (MSE) may be new or unfamiliar to many first-year engineering students, as it is often one of the smallest undergraduate majors within many engineering colleges. To address this, a novel experiential learning activity was designed to introduce the discipline to incoming first-year students who may have little to no prior background in MSE concepts or laboratory skills. The concurrent goal was to create a hands-on experience that was both highly engaging and accessible. A themed, exciting activity was developed using molten metal, a historically significant and visually dramatic aspect of metallurgy that underpins many areas of MSE. A central feature allowed each student to safely cast a small aluminum part of their choosing. While awaiting their turn, students also had the opportunity to grow bismuth crystals from molten bismuth. Safety and logistical concerns were managed by hosting three shorter sessions to accommodate maximum student turnout within facility and training constraints. This work provides a practical model for developing engaging, safety-conscious experiential activities that can effectively introduce students to engineering disciplines that may be new to them.

Introduction

Materials Science and Engineering (MSE) remains a relatively small major compared to other engineering disciplines such as Mechanical, Electrical, or Computer Engineering. National and institutional data indicate that MSE enrollments are modest in absolute numbers with a declining trend that has been exacerbated since the 2019 COVID pandemic. In 2019, Metallurgical and Materials Bachelor's degrees awarded constituted 1.45% of all awarded engineering degrees. In 2024, this number dropped to 1.14% [1, 2]. This limited visibility constrains the pipeline of future materials engineers at a time when materials-related challenges in energy, electronics, healthcare, and sustainability are increasingly central to technological innovation [3].

In addition to familiarity and recruitment challenges, engineering education and career paths are undergoing rapid transformation with the rise of artificial intelligence (AI). It is essential to prepare MSE students to be competitive in a labor market increasingly shaped by AI and automation. As routine analytical and computational tasks are progressively augmented or replaced by AI tools, the distinctive value of engineers is expected to lie in their capacity to design, conduct, and interpret experiments, integrate physical intuition with data-driven methods, and translate abstract models into real materials and devices [4, 5].

Experiential learning offers a pathway to address the intersection of both above challenges. First, hands-on activities are a powerful outreach mechanism for attracting new students into MSE. Early, tangible engagement with core MSE concepts such as phase transformations and process-structure-property relationships can make the field more compelling to pre-college students and first-year undergraduates, who often have little prior exposure to MSE as a distinct discipline [6, 7]. Laboratory demonstrations, maker projects, and research oriented course modules can therefore function as recruitment tools that raise awareness of MSE and broaden participation in the major. Furthermore, MSE is inherently well positioned for the incorporation of experiential learning to make students better prepared for the future of industry with AI. MSE combines synthesis, processing, and characterization with simulation, data science, and emerging approaches in materials informatics [8, 9]. Intentionally designed experiential curricula can connect AI-enabled analysis to physical laboratory work, thereby cultivating a resilient, complementary skill sets.

In this context, investing in experiential learning in MSE serves both as a recruitment and outreach strategy as well as a pedagogical pathway to help ensure that graduates possess practical competencies that will differentiate them in the evolving engineering workforce. In this paper, we present a lesson plan used to introduce MSE to incoming first-year students who may have little to no prior background in MSE concepts or laboratory skills. The experience is hands-on, memorable, and customizable, so students can have a personalized experience. Students volunteered to participate in this optional MSE laboratory activity. The activity was evaluated using pre- and post-laboratory surveys to understand the familiarity and interest of the students in MSE before and after the event. This work provides a practical model for developing engaging, safety-conscious experiential activities that can effectively introduce students to engineering disciplines that may be new to them.

Methods

This study involved developing and implementing the experiential learning activity, recruiting participants, and surveying the participants before and after the activity. The following sections describe each of these components.

Development and Implementation of the Activity

The activity was conducted at the host institution in the form of a one hour, hands-on session led by the author of this paper with two student facilitators. The activity was designed to target first-year engineering students at the beginning of their undergraduate studies in the fall semester. At the host institution, undergraduate students declare their majors at the end of their first year, making the timing of this event in the fall essential for recruitment. The event was coordinated within a university-level program that sponsors a series of events open to all university students, and especially those in their first-year. This program creates a wide variety of events that students may choose to attend which helps to create new social connections, and explore new interests. Working with this university-level program was essential because it enabled advertising of the event across the entire institution. This allowed the event to reach beyond the College of Engineering and include the College of Arts and Sciences, which houses the Physics and Chemistry departments at the host institution. These disciplines have a strong connection to MSE, and students enrolled in these programs may also benefit from the event.

Due to the intensive hands-on component of the event, attendance was capped at ten students per session to ensure a manageable environment with sufficient safety gear, and to allow the activity to be completed within one hour. Three sessions were held, and a total of 30 students attended.

Of those 30 students, three were from the College of Arts and Science. The remaining students were enrolled in the College of Engineering.

The activity began with a brief introduction to MSE describing core tenets of the field. This included the process-structure-property relationship, and fundamental differences between metals, ceramics, and polymers. The content was then expanded to include the crystalline nature of solids, which was especially pertinent to the aluminum casting and bismuth crystal growth activities. The casting and bismuth activities were directly linked by the concept of material crystallinity presented from two different perspectives: the polycrystalline structure of the cast metal, and the single crystalline nature of the grown bismuth crystals. To further augment the introductory content, a polished and etched aluminum sample cast using the same method as in the activity was prepared to show the polycrystalline nature of the aluminum. The introduction concluded with a description of various metal casting methods.

After the introductory presentation, the three hands-on activities were then reviewed. The primary activity was the aluminum casting. Since only one student could cast at a time, two other activities were also set up for students to engage in while awaiting their turn to cast. One activity involved growing single crystals from molten bismuth. The other involved combining activator with glue to create slime. Through these three activities, a variety of core MSE concepts were introduced including metallurgy, crystallinity, phase transformations, and polymer engineering.

Table 1. Description of the Event Agenda and the Activities

Event Item	**Duration (minutes)**	**Description**
Pre-lab survey	3	See Table 2
Intro to MSE	10	Students are introduced to core MSE topics, particularly: • Process-structure-property relationship • Difference between metals, ceramics and polymers • Crystalline nature of solids • How casting works
Overview of the activities	5	The three core activities are reviewed: • Casting aluminum parts • Growing bismuth crystals • Making slime
Safety review	10	The safety gear, how to safely cast, and how to safely work with liquid bismuth is demonstrated.
Students rotate through the three core activities	30	Students rotate through the three core activities. The instructor managed the casting station and worked with one student at a time. While awaiting their turn, the other students could interact with the other two modules managed by two helpers.
Post-lab survey	2	See Table 2

Participant Recruitment and Surveying

Participants were recruited for this study through the university-level programming portal. The event was also advertised in the primary first-year engineering courses. All participants volunteered to join this optional event. The events were scheduled to be held after daytime class sessions were over across three time slots so that students had several options to facilitate attendance. All three sessions were filled within one week of advertising, suggesting strong interest in such hands-on activities. Participants were asked to complete a pre-lab survey at the start of the session and a post-lab survey upon completion. The survey questions are provided in Table 2. Survey responses were anonymous.

Table 2. Questions in the Pre-Lab and Post-Lab Surveys

<table>
<tr><th></th><th>Questions</th><th>Answer Options</th></tr>
<tr><td rowspan="5">Pre-Lab Survey</td><td>1. How familiar are you with the field of Materials Science and Engineering?</td><td>a) Very familiar
b) Somewhat familiar
c) Heard of it but don’t know much
d) Not familiar at all</td></tr>
<tr><td>2. How interested are you in learning more about Materials Science and Engineering?</td><td>a) Very interested
b) Somewhat interested
c) Neutral
d) Not very interested
e) Not interested at all</td></tr>
<tr><td>3. Have you ever participated in a hands-on engineering lab or activity before?</td><td>Yes or No</td></tr>
<tr><td>4. What do you think materials engineers do? (Short answer)</td><td>Open response</td></tr>
<tr><td>5. What are you most curious about for today’s activity? (Multiple choice, select all that apply)</td><td>a) How metal casting works
b) How crystals grow
c) What materials engineers study
d) Working with molten metals
e) Other</td></tr>
<tr><td rowspan="4">Post-Lab Survey</td><td>1. After participating in this event, how interested are you in Materials Science and Engineering?</td><td>a) Much more interested
b) Somewhat more interested
c) About the same
d) Less interested</td></tr>
<tr><td>2. How would you rate your understanding of what materials engineers do?</td><td>a) Strong understanding
b) Moderate understanding
c) Basic understanding
d) Still unsure</td></tr>
<tr><td>3. What part of the activity did you enjoy the most? (Short answer)</td><td>Open response</td></tr>
<tr><td>4. What is one thing you learned today that surprised you? (Short answer)</td><td>Open response</td></tr>
</table>

	5. Would you consider exploring more about Materials Science and Engineering in future courses or activities?	a) Definitely yes b) Probably yes c) Not sure d) Probably not e) Definitely not

Laboratory Procedure and Materials

The aluminum casting activity was performed using a TOAUTO TGF3000, 1400 W, 2000F, 110 V digital electric melting furnace with a graphite crucible in a well-ventilated space. It is important to note that graphite crucibles have finite lifetimes, and their use should adhere to the vendor instructions. Safety procedures required students to wear a full face shield, fire-resistant apron, steel shoe covers, and heat-resistant gloves. Safety also included adherence to fundamental laboratory safety rules, such as wearing long pants and closed-toe shoes, and having long hair pulled back.

Low purity aluminum cut into small pieces that could fit within was crucible was used. Once the aluminum became molten, the students lifted the graphite crucible from the furnace with tongs, poured the molten aluminum into their selected graphite mold, and then returned the crucible to the furnace. The facilitator guided each student through the pour and was responsible for refilling the furnace with aluminum. Figure 1 shows the melting furnace with the associated graphite crucible and tongs. Figure 2 shows the graphite molds the students could choose between: either a star, skull, or heart shape. Each student could make two casting attempts. The pour occurred in a large sand box in case there were any overpours. Upon solidification, the cast parts were removed from the graphite molds, quenched in water to ensure they were safe to handle, and then returned to the students to keep.

Figure 1. The aluminum melting furnace with the associated graphite crucible and tongs to lift the crucible.

Figure 2. The graphite molds and their associated casted aluminum parts. Students could choose which mold to use, and they had the opportunity to cast twice.

The bismuth crystal growth activity involved the use of hot plates with pots of bismuth. Stainless steel pots were used to avoid concerns related to thermal shock. Once the bismuth melted, the pot was removed from the hot plate and placed on a ceramic tile to slow the cooling process. Upon nucleation of a crystal, students then used stainless steel tweezers to remove the grown single crystal. With this method, students could experiment with different cooling rates to grow the largest possible crystal. Safety procedures were similar to the aluminum casting activity.

To engage as many student interests as possible, polymers were also introduced through a slime activity. The lab involved the use of glue and an activator that students combined to create the slime. A variety of glues, including different colors, sparkles, and glow-in-the-dark options, were provided so that students could personalize their slime. They could also experiment with the glue and activator ratios to create different textures. This activity provided a fun, low risk activity the students could engage in while waiting for a turn with the more safety intensive casting and bismuth activities. This was essential to keeping students engaged throughout the entire one hour period. In addition, a description of polymers and the cross-linking process was taught in the introductory material, providing new, deeper insight into an activity and material that these students may already have encountered.

Results and Discussion

Figure 3 (a)-(d) shows the results of the pre-lab participant survey. Figure 4 (a)-(c) shows the results of the post-lab participant survey. Table 3 shows the short answer responses to question 4 from the pre-lab survey and to questions 3 and 4 from the post-lab survey. Repetitions of short answer responses provided by more than one student are not included. Details regarding the content of each question and the possible answers are provided in Table 2. Some students did not respond to every question in the survey. Percentage values in the following analysis are calculated using the total number of 30 attendees, causing some discrepancies where percentage totals do not sum to 100%.

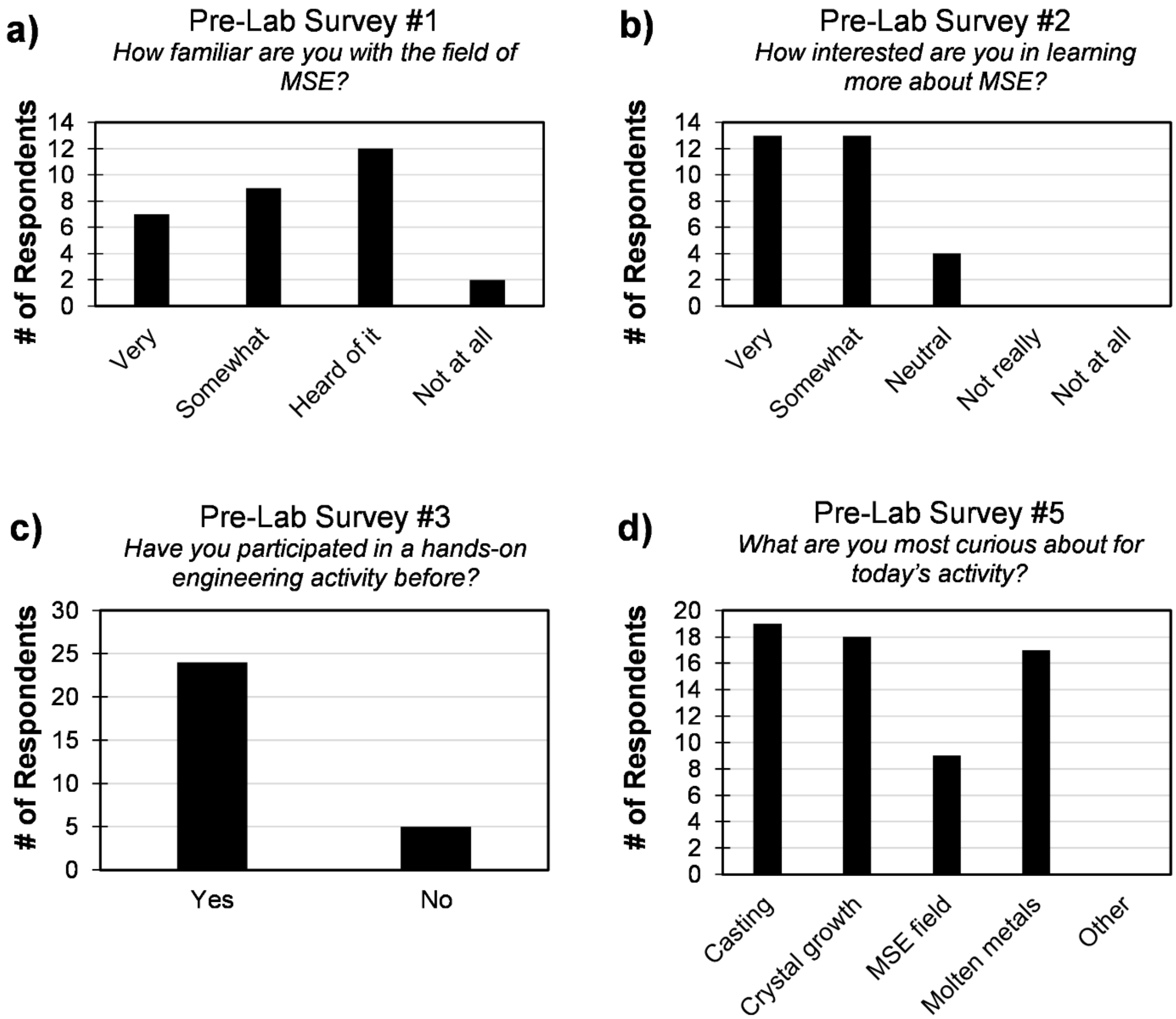

Figure 3. The results of the pre-lab survey questions 1, 2, 3, and 5. Details regarding the content of the questions and the possible answers are provided in Table 2.

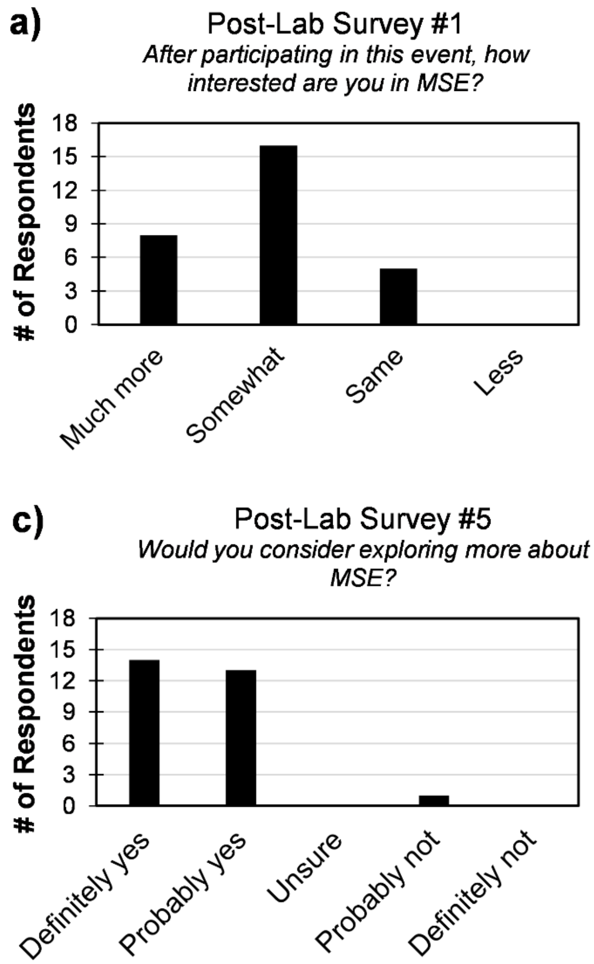

Figure 4. The results of the post-lab survey questions 1, 2, and 5. Details regarding the content of the questions and the possible answers are provided in Table 2.

Table 3. Reponses to open answer questions in the pre- and post-lab surveys. Additional details regarding the questions can be found in Table 2.

	Question	Open answer responses
Pre-Lab Survey	#4 - What do you think materials engineers do?	• Design materials to be used in other disciplines • Metal casting and alloying • Analyze and optimize materials for construction • Provide materials for safety and efficiency • Make new materials that are better • Study/design materials for new applications such as polymers and ceramics • Explore how things are created
Post-Lab Survey	#3 - What part of the activity did you enjoy the most?	• I liked the bismuth crystals • Casting • Talking to the professor • I liked the bismuth (crystal growth) because it wasn't guaranteed it would work
	#4 - What is one thing you learned today that surprised you?	• A lot of MSE is hands on • Why we quench metals • The metal crystals • Low melting point of bismuth • How easy metal casting is • Interesting viscosity of molten metal • How fast aluminum cools • Turbine blades are single crystals

Figure 3(a) shows that the audience was roughly split in half in terms of familiarity with MSE, where 53% of the attendees had appreciable familiarity with MSE (answer options a and b), and 47% had limited familiarity (answer options c and d). Figure 3(b) shows that 87% of the attendees wished to learn more about MSE (answer options a and b), and 13% were neutral. Figure 4(a) shows the reported change in interest that the attendees have in MSE due to the event. After the activity, 80% of the attendees were more interested in MSE (answer options a and b), and 20% had the same amount of interest (answer option c). None of the attendees became less interested in MSE after the activity. In addition, Figure 4(b) shows that 70% of the attendees rated themselves as having an appreciable understanding of what materials engineers do (answer options a and b), and 20% rated themselves as having a basic understanding.

The final question of the post-lab survey gauges the original goals of the activity by evaluating whether students would like to learn more about MSE, thereby determining the success of the recruitment and experiential learning event. 90% of the attendees would consider continuing to explore MSE (answer options a and b). 3% of the attendees would likely not continue to pursue MSE (answer option d). This emphasizes the importance of such hands-on activities early in the undergraduate degree. They not only introduce students to new pathways, such as MSE, but also provide early information to students so they can make informed decisions on how to best navigate their undergraduate careers, where deciding what one does not want to pursue is just as important as deciding what to pursue.

In summary, at the start of the activity, roughly half of the attendees were not entirely familiar with MSE, and after the event, 90% of the attendees would consider further exploration of MSE. Overall, the data show that the activity met its goals of introducing first-year students to MSE as a recruitment event and providing critical experiential learning experiences.

Pre-lab question 3 evaluated the experiential background of the students upon starting the activity, with the results shown in Figure 3(c). 80% of the attendees had previously participated in hands-on engineering or lab activities, but 17% indicated that they had not. This emphasizes the importance of safety review and individualized attention from the facilitators. This recruitment event was the first time 17% of the participants had ever engaged in a hands-on engineering or lab activity, making this event not only a recruitment tool, but also a key learning experience to introduce students to the laboratory skills and help to build their identities as engineers [10].

The results of the open response questions, shown in Table 3, provide critical insight into the first-hand accounts of the students in their own words. In the pre-lab survey question 4 responses, students described the role of a materials engineer from a variety of perspectives. These responses ranged from very general ("explore how things are created") to very specific ("metal casting and alloying"), suggesting an array of understandings of what would be considered a typical role of a materials engineer.

In the post-lab survey question 3 responses, one student reported enjoying the individual conversation with the professor conducting the lab, which aligns with research showing that more relaxed, less structured learning environments are critical to breaking down barriers between faculty and students to create better learning outcomes [11]. Students also enjoyed the trial-and-error aspect of the activities, in which success with the bismuth crystal growth was not guaranteed. In the post-lab survey question 4 responses, students reported being surprised by some of the core MSE concepts, such as crystallinity, nuances of the casting process, and how approachable and hands-on both the activities and the MSE discipline are.

This module can be adapted for institutions with different resources, facilities, and class sizes by offering multiple implementation levels. At institutions without metal casting facilities, the activity could be modified to use low-temperature metals such as tin that can be melted on a hot plate or small stove, or non-metal analogs such as wax, plaster, resin, or even foods like chocolate to demonstrate mold preparation and defect formation. Where budgets are limited, recycled aluminum scrap can be used, and students can work in teams to reduce material and equipment needs. For larger cohorts, a station-based format or instructor-led batch pouring can allow many students to participate while maintaining safety and efficiency. Even in settings where molten metal processing is not feasible, students can still engage with the learning objectives through casting design exercises, video demonstrations, and analysis of finished castings to evaluate shrinkage, defects, and the relationship between processing and material properties.

Conclusion

This work describes the design, implementation, and assessment of an experiential activity introducing first-year students to MSE. Through metal casting, bismuth crystal growth, and polymer slime activities, students engaged with core MSE concepts in a structured, safety-conscious, and hands-on environment. Pre- and post-lab surveys show increased interest in MSE, improved understanding of materials engineering careers, and strong willingness to further explore the field. Open-ended responses highlight the value of informal faculty interaction and trial-and-error learning, indicating that such experiential activities are effective as recruitment tools, and in developing critical hands-on engineering skills.

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