



# Integrating theory and practice through industrial site visits at PT INALUM

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## ABSTRACT

The industrial site visit to PT Indonesia Asahan Aluminium (INALUM) was conducted to bridge the gap between theoretical knowledge and practical applications in metallurgical engineering education. This study employed a descriptive-analytical approach to evaluate the effectiveness of the visit in enhancing students' understanding of aluminum production processes, engagement levels, and career readiness. Data were collected through structured questionnaires and analyzed using both quantitative and qualitative methods. Results showed significant improvements in students' comprehension of metallurgical processes, particularly the Hall-Héroult process, casting operations, and quality assurance practices. Engagement ratings across activities were consistently high, and career interest in the aluminum industry increased from 56% before the visit to 82% after. The findings highlight the value of experiential learning in aligning academic curricula with industry demands. Future studies could explore larger sample sizes, longitudinal impacts, and the inclusion of hands-on activities to further enhance learning outcomes and career aspirations. This research underscores the importance of industrial partnerships in preparing skilled and sustainability-conscious metallurgical engineers.

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## INTRODUCTION

The metallurgical engineering discipline serves as a cornerstone for industries reliant on the transformation and utilization of metallic materials, including aluminum—a metal of unparalleled versatility and economic importance (Ashkenazi, 2019; Brough & Jouhara, 2020; Pistorius, 2003; Song et al., 2022). Aluminum production, particularly through the Hall-Héroult process, represents a key area where theoretical knowledge meets industrial application (Kvande, 2011; Ratvik et al., 2022). Despite its significance, many engineering students remain distanced from the operational realities of industries they are trained to serve. Bridging this gap is crucial to enhancing technical competence, inspiring innovation, and fostering a contextual understanding of industrial challenges (Buckley et al., 2022; Dwivedi et al., 2024; Gürdür Broo et al., 2022; Ju & Zhu, 2023; Magarian & Seering, 2022; Soupepez, 2023). Specifically, in Indonesia, the application of

metallurgical theory faces challenges such as the limited availability of advanced industrial facilities, gaps in sustainability practices, and a disconnect between academic curricula and real-world industry needs (Hannah & Hayes, 2016).

Experiential learning has long been recognized as a transformative approach in engineering education, where students gain insight by immersing themselves in real-world applications. Industrial site visits, as part of this experiential approach, provide a unique platform for students to witness the dynamic interplay between theoretical principles and practical execution (Behrendt & Franklin, 2014; Jusoh & Hadibarata, 2024; Soucie et al., 2024; Stern & Powell, 2020; Tembrevilla et al., 2024). These visits not only strengthen technical knowledge but also broaden understanding of industrial environments, including operational efficiency, sustainability practices, and safety protocols (Jusoh & Hadibarata, 2024). For students of IT Del, exposure to PT Indonesia Asahan Aluminium (INALUM)—the sole integrated primary aluminum producer in Southeast Asia—presents an exceptional opportunity to connect metallurgical theories with practical applications. However, the Indonesian metallurgical industry also highlights challenges such as insufficient integration of sustainability frameworks, reliance on imported technologies, and limited industry-academic collaborations to address emerging industrial demands (Abdul Baits Swastika, 2016; Lahadalia et al., 2024).

This study addresses the urgent need to contextualize academic curricula within industrial practices, particularly in metallurgical engineering. While prior research highlights the benefits of industrial visits for engineering students, limited attention has been given to their impact on fostering sustainability awareness and readiness for aluminum production industries. For instance, Jusoh & Hadibarata (2024) identified the pedagogical value of such visits but did not explore their implications within the Southeast Asian context or sustainability dimensions. There remains a need to examine how industrial visits can address challenges unique to Indonesia, such as adapting global metallurgical innovations to local contexts and preparing students for specific industry gaps, including workforce skill mismatches and environmental compliance pressures. This gap underscores the need for targeted research focusing on the convergence of engineering education, industrial practices, and sustainability.

Furthermore, this research offers a fresh perspective on aluminum production technologies and sustainability practices. Aluminum plays a pivotal role in global sustainability initiatives, such as lightweight construction and energy-efficient transportation, making it imperative for future engineers to understand its production processes (Hassan & Saeed, 2024; Trowell et al., 2020). As sustainability becomes an essential driver for innovation in the metals industry, integrating industrial visits into engineering curricula equips students with the skills and knowledge required to address these challenges effectively.

This paper contributes to the field of engineering education in several ways. First, it demonstrates the efficacy of industrial visits as a complementary educational tool for enriching comprehension of complex metallurgical processes (Kulkarni & Dandge, 2024; Sen, 2013). Second, it links the challenges and opportunities of aluminum production in Indonesia to broader discussions on sustainability and industry readiness (Alamdari, 2017; Liu & Müller, 2012). Lastly, it proposes actionable insights for leveraging industrial partnerships to enhance the preparedness and adaptability of engineering graduates. In particular, this study highlights the need for enhanced collaboration between academia and industry to bridge theoretical gaps, improve the contextual relevance of education, and address Indonesia's industrial challenges such as resource inefficiencies and limited infrastructure for advanced metallurgical processes.

By presenting a detailed analysis of the INALUM visit, this study emphasizes the necessity of aligning educational outcomes with evolving industry demands. It underscores that the meaningful convergence of theory and practice is not merely an educational aspiration but a necessity for preparing metallurgical engineers to meet global challenges in sustainability and innovation (Brinegar et al., 2022; Radović et al., 2021).

## RESEARCH METHODOLOGY

This study adopts a descriptive-analytical approach to evaluate the effectiveness of an industrial site visit to PT Indonesia Asahan Aluminium (INALUM) in enhancing students' understanding of aluminum production processes. The methodology integrates systematic data collection and analysis through structured questionnaires to capture students' perceptions, learning outcomes, and overall experiences. The research framework ensures the chronological flow of preparation, implementation, and evaluation stages, supported by relevant references for scientific acceptability.

### Research Design

The research design is divided into three main stages: preparation, implementation, and evaluation. This clear chronological sequence facilitates systematic data acquisition and analysis, ensuring that the outcomes effectively reflect the impact and effectiveness of the study tour.

In the preparation phase, a comprehensive questionnaire was developed to assess students' experiences and perceptions. The questionnaire included both closed-ended and open-ended questions, categorized into four focus areas: the relevance of study tour content, which examined the alignment between site visit experiences and theoretical concepts taught in the classroom; learning opportunities, which explored insights into aluminum production technologies and industrial practices; engagement and interaction, which assessed the quality of student interactions with industry professionals; and the perceived impact on career readiness, which evaluated how the visit influenced students' interest and confidence in pursuing careers in metallurgical engineering. Ethical considerations were also addressed by informing participants about the study's purpose and ensuring voluntary participation and confidentiality (Holmes, 2023).

The site visit was conducted on October 23, 2024. To ensure comprehensive preparation, questionnaires were distributed to participants starting October 16, 2024, one week prior to the visit. This approach allowed students to familiarize themselves with the focus areas of the study. After the visit, additional questionnaires were distributed immediately to capture students' immediate impressions and insights. Responses from both distributions were collected by October 30, 2024, providing a robust dataset for subsequent analysis.

The implementation phase involved a structured site visit to INALUM, where students experienced real-world metallurgical engineering applications. Key activities included a guided industrial tour, during which students observed the Hall-Héroult reduction process, casting operations, and quality assurance procedures (Ashkenazi, 2019). Interactive sessions were also conducted, where industry professionals provided valuable insights into aluminum production challenges, innovations, and sustainability practices. Additionally, students engaged in field observations, recording their reflections to deepen their understanding of industrial operations.

The evaluation phase involved analyzing responses from the post-visit questionnaire, focusing on three key areas. First, learning outcomes were assessed by having students rate their understanding of aluminum production processes and their relevance to metallurgical engineering (Ismail et al., 2021). Second, satisfaction with the visit was evaluated through feedback on the organization and effectiveness of the activities during the site tour. Lastly, the perceived value of industrial exposure was examined to understand how the visit influenced students' motivation and aspirations for pursuing careers in the metal industry.

### Data Analysis

Quantitative data from closed-ended questions were analyzed using descriptive statistics to identify trends in learning outcomes, satisfaction levels, and career impact. Qualitative responses from open-ended questions were thematically coded to capture recurring themes such as learning enhancement, engagement, and career readiness (Chintakrindi et al., 2022; Mishra & Dey, 2022; Vaughn & Turner, 2015). To ensure scientific rigor, reliability and validity of the questionnaire were tested using Cronbach's alpha (Sürücü & Maslakci, 2020). Potential bias in the

data obtained through the questionnaire was mitigated by providing respondents with training on objective answering, conducting a preliminary study to test the clarity and neutrality of questions, and involving an independent party in data collection to minimize researcher influence.

### Research Framework

The research framework consists of three key phases: preparation, implementation, and evaluation. The preparation phase involved designing a comprehensive questionnaire and making logistical arrangements for the site visit. Questionnaires were initially distributed to participants on October 16, 2024, one week prior to the visit, to gather baseline data and prepare students for the focus areas of the study. During the implementation phase, the study tour at INALUM was conducted on October 23, 2024, comprising a guided industrial tour, interactive sessions with experts, and observation activities where students recorded data to enhance their understanding. In the evaluation phase, additional questionnaires were distributed immediately following the visit to capture students' immediate impressions and insights. All responses were collected by October 30, 2024, and subsequently analyzed to assess learning outcomes, engagement, satisfaction, and the visit's impact on career aspirations.

The research framework, depicted in Figure 1, illustrates the chronological flow of activities, from preparation to evaluation. The questionnaire used in this study was designed to address key areas, as summarized in Table 1, which includes categories such as learning outcomes, engagement, career impact, and satisfaction.

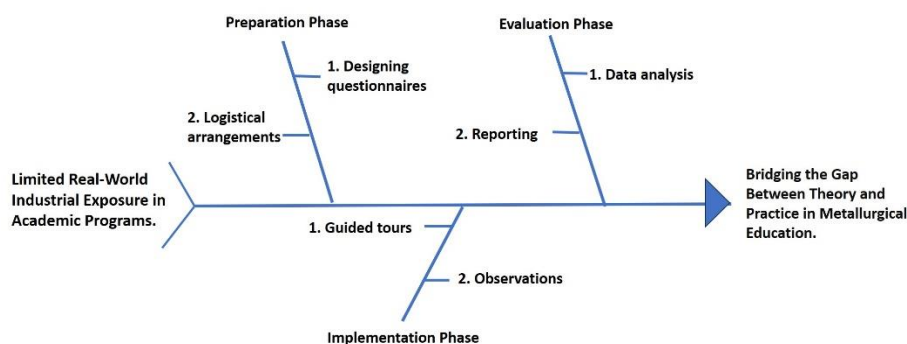


Figure 1. Research framework

Table 1. Key components of the questionnaire for evaluating the study tour

Category	Focus Area	Example Questions
Learning Outcomes	Understanding aluminum production processes	"How well do you understand the Hall-Héroult process after the site visit?"
Engagement	Interaction with industry professionals	"How effective were the discussions with INALUM experts in enhancing your knowledge?"
Career Impact	Motivation and aspirations	"Has this visit influenced your interest in pursuing a career in the aluminum industry?"
Satisfaction	Quality and organization of the study tour	"How satisfied are you with the overall organization of the study tour?"

## RESULTS AND DISCUSSIONS

### Overview of Findings

The industrial site visit to INALUM involved 34 students, comprising 19 males (55.9%) and 15 females (44.1%). The visit provided an immersive learning experience, with significant improvements observed in understanding aluminum production processes, engagement levels, and career readiness. This section presents detailed results supported by quantitative and qualitative data.

### Learning Outcomes

The visit significantly enhanced students' understanding of critical metallurgical processes. Table 2 provides descriptive statistics, including mean scores, standard deviations, and 95% confidence intervals before and after the visit.

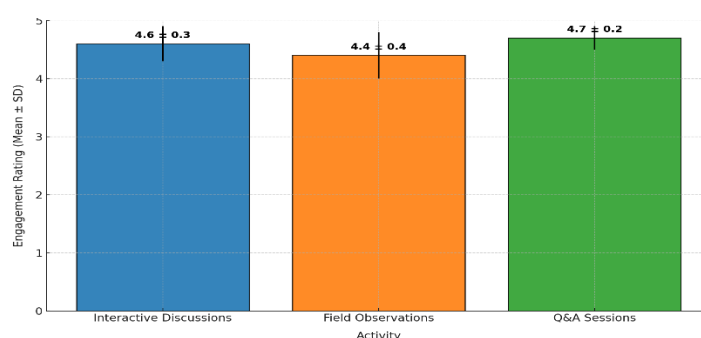
**Table 2.** Descriptive statistics of students' understanding before and after the visit

Topic	Before Visit (Mean $\pm$ SD)	After Visit (Mean $\pm$ SD)	95% CI Before Visit	95% CI After Visit
Hall-Hérault Process	2.8 $\pm$ 0.6	4.3 $\pm$ 0.5	(2.6, 3.0)	(4.1, 4.5)
Casting Operations	3.0 $\pm$ 0.7	4.5 $\pm$ 0.5	(2.8, 3.2)	(4.3, 4.7)
Quality Assurance	2.9 $\pm$ 0.6	4.4 $\pm$ 0.5	(2.7, 3.1)	(4.2, 4.6)

A paired t-test was conducted to evaluate the significance of the differences between pre- and post-visit scores. Results revealed a statistically significant improvement in all categories ( $p < 0.001$ ). For example, the mean score for understanding the Hall-Hérault process increased by 1.5 points (95% CI: 1.3–1.7,  $t = 20.23$ ), highlighting the effectiveness of real-world exposure in reinforcing theoretical knowledge. Further analysis revealed no significant differences in the improvement scores between male and female students ( $p = 0.12$ ), suggesting that the site visit was equally effective in enhancing learning outcomes and engagement for both groups.

### Engagement and Interaction

Students reported high levels of engagement during the visit, as reflected in Figure 2. Activities such as interactive discussions, field observations, and Q&A sessions received consistently high ratings. A detailed analysis of engagement ratings by gender, as shown in Table 3, revealed no significant differences between male and female students. For example, the combined mean engagement score for interactive discussions was  $4.6 \pm 0.3$ , with males and females reporting similar levels of satisfaction. These findings suggest that the activities were equally engaging for both groups. Qualitative feedback further supported this, with students frequently highlighting the interactive discussions as particularly valuable for understanding industrial challenges.



**Figure 2.** Engagement ratings during the visit

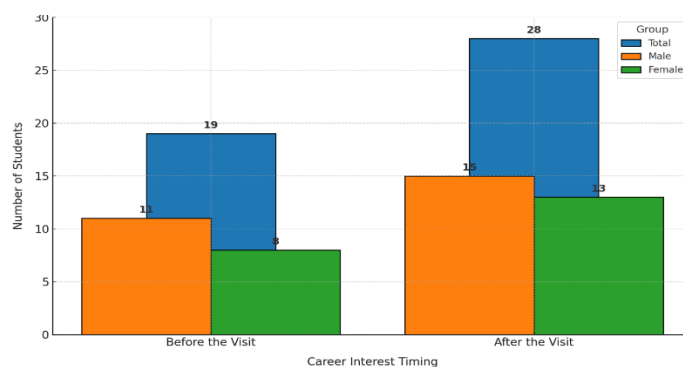
**Table 3.** Engagement ratings by gender

Activity	Males (Mean $\pm$ SD)	Females (Mean $\pm$ SD)	Combined (Mean $\pm$ SD)
Interactive Discussions	4.6 $\pm$ 0.4	4.5 $\pm$ 0.3	4.6 $\pm$ 0.3
Field Observations	4.4 $\pm$ 0.5	4.3 $\pm$ 0.4	4.4 $\pm$ 0.4
Q&A Sessions	4.7 $\pm$ 0.3	4.7 $\pm$ 0.2	4.7 $\pm$ 0.2

### Career Readiness

The visit substantially increased students' interest in pursuing careers in the aluminum industry. As shown in Figure 3, career interest rose from 56% (19 students) before the visit to 82%

(28 students) afterward. The bar graph illustrates the significant increase in the number of students interested in pursuing careers in this field following the site visit.



**Figure 3.** Career interest before and after the site visit

Gender analysis further revealed that career interest among male students increased from 11 (58%) to 15 (79%), while among female students it rose from 8 (53%) to 13 (87%). A McNemar's test confirmed the statistical significance of this shift ( $p < 0.001$ ), indicating the positive impact of the visit on both groups. Open-ended responses emphasized the role of real-world exposure in shaping career aspirations. For instance, one female student remarked, "The visit made me more confident in pursuing a career in metallurgical engineering, especially in industries like INALUM."

### Discussion

The results demonstrate that the industrial site visit successfully enhanced students' learning outcomes, engagement, and career readiness, with significant improvements in understanding aligning with Suwarno (2019) experiential learning theory, which highlights the value of real-world exposure in bridging the gap between theory and practice. High levels of engagement observed during the visit further validate the effectiveness of interactive and immersive activities, consistent with findings by Stern & Powell (2020). Gender comparisons revealed that the program was equally impactful for male and female students, reflecting its inclusivity and broad applicability. Moreover, the increased career interest among participants, confirmed through McNemar's test, underscores the visit's role in inspiring future metallurgical engineers and addressing the industry's demand for skilled professionals. Despite these positive outcomes, the study faced certain limitations, such as the relatively small sample size of 34 students, which, while insightful, limits the generalizability of the findings. Expanding the program to include larger cohorts across multiple industrial sites would enhance its applicability. Additionally, incorporating hands-on workshops into future programs, as suggested by qualitative feedback, could further enrich the learning experience by complementing observational activities.

## CONCLUSION

The industrial site visit to INALUM effectively bridged the gap between theory and practice, as outlined in the Introduction. The study demonstrated significant improvements in students' understanding of metallurgical processes, high engagement levels, and increased career interest, validating the value of experiential learning in engineering education. These results highlight the importance of integrating site visits into curricula to align academic concepts with industry practices. To integrate the results into engineering education curricula, regular industrial site visits should be included, supported by case-based learning modules derived from real-world industry challenges, and strengthened by partnerships with industrial stakeholders to provide continuous exposure to practical applications and sustainability practices. Future studies should explore

longitudinal impacts, larger samples, and multi-site visits to enhance applicability. Incorporating hands-on activities could further strengthen learning outcomes. This research underscores the critical role of experiential learning in preparing skilled, innovative, and sustainability-conscious metallurgical engineers to address global industry demands.

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