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Bridging Theory and Practice: The Role of Site Visits in Environmental Engineering Learning

Muhammad Noor Hazwan Jusoh*, Tony Hadibarata

Department of Civil & Construction Engineering, Faculty of Engineering and Science, Curtin University, Miri, Sarawak, 98009, Malaysia

*Correspondence: mn.hazwan@curtin.edu.my

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ABSTRACT: In engineering education, experiential learning is essential as it allowed students to connect theoretical knowledge with real-world applications. This study explored the impact of industrial visits, a form of experiential learning, on engineering students' comprehension, critical thinking, and overall educational experience. We employed a mixed-methods approach, integrating questionnaire surveys, reflective writing exercises, and qualitative analyses to assess the learning outcomes and pedagogical implications of these site visits. Our findings demonstrated that industrial visits significantly enhanced students' understanding of engineering concepts by providing real-world context to theoretical knowledge. Through reflective exercises, students integrated their field trip experiences with classroom learning, fostering critical thinking abilities and a deeper comprehension of the subject matter. This study underscored the importance of curriculum integration. To nurture students as adept problem solvers and critical thinkers in both academic and practical engineering fields, fostering dynamic interactions between theoretical instruction and practical experiences was crucial. Our study encouraged further exploration of how experiential learning could enrich the educational journey, equipping students to tackle complex challenges in our ever-evolving environment as engineering education advanced.

KEYWORDS: Problem-based learning; engineering curriculum; site visit; undergraduate

1. Introduction

The world faces multi-layered challenges of global proportions that include not only engineering issues but also environmental, socio-political, and economic complexities. Through significant technological advances, engineers have the opportunity and the duty to steer society toward sustainability while promoting social well-being and a positive environmental impact [1–3]. Therefore, when they graduate and enter the industry, they are prepared to work with their employers. However, if they lack the ability to effectively apply this knowledge to real-world engineering challenges, it places an additional burden on the companies that employ them to invest time and resources in developing the skills of these newly graduated engineers [4].

Problem-Based Learning (PBL) is an innovative educational approach that has gained significant traction in recent years, particularly for undergraduate engineering students. At its core, PBL shifts the traditional classroom paradigm by placing students in the driver's seat of their learning journey [5, 6]. Instead of passively absorbing lectures, students are presented with real-world, open-ended problems that are relevant to their field of study. These problems serve as the focal point of their learning experience. Through collaborative efforts, students delve deep into these complex challenges, applying theoretical knowledge to devise practical solutions. This approach not only promotes a deeper understanding of engineering principles but also cultivates critical thinking, problem-solving, and teamwork skills—essential attributes for future engineers [7, 8]. As a result, undergraduate engineering students exposed to PBL are better prepared for the ever-evolving demands of the engineering field, fostering a lifelong passion for learning.

In the context of undergraduate engineering education, the integration of PBL with industrial visits represents a promising pedagogical approach [9,10]. However, a noticeable research gap exists in exploring the effective implementation of PBL during these crucial learning experiences. Many engineering students graduate with a strong theoretical foundation but lack the ability to apply this knowledge effectively to real-world engineering challenges [11]. Industrial visits offer students valuable exposure to real-world engineering practices; however, there is a dearth of systematic studies examining how PBL can be seamlessly integrated into these immersive environments. Current literature tends to focus more on traditional classroom settings for PBL, leaving a critical knowledge void regarding its adaptation and impact in the dynamic and unstructured context of industrial visits [12, 13].

This study aimed to address this knowledge gap by developing and implementing effective methods for evaluating student performance and learning outcomes during experiential learning opportunities provided by industrial visits. It was designed to explore the perspectives and experiences of students who participate in PBL during industrial visits, understanding how they perceive its impact on their education and preparedness for the industry. Developing tailored assessment methodologies that align with the unique challenges and objectives of industrial visits is an uncharted territory. Bridging this gap is not only essential for optimizing the educational value of industrial visits but also for informing curriculum development and pedagogical strategies that better prepare engineering graduates for the ever-evolving demands of the industries.

2. Methodology

2.1. Industrial visit survey.

The target respondents of the study were approximately 30 students enrolled in environmental courses, including Solid and Hazardous Waste Management and Environmental Considerations in Construction. It is important to note that the participation of students in this study was entirely voluntary, and their responses were collected for the purpose of data analysis. Data collection for this study was carried out using structured questionnaires designed specifically for this research. These questionnaires were distributed through an online survey conducted via Qualtrics. The main purpose of the survey was to determine students' perceptions of two specific components in enhancing their learning experiences through industrial visits. The structured questionnaires contained both closed-ended and open-ended questions, allowing us to gather both quantitative and qualitative data from the participants. To comprehend the study, qualitative data were also collected from the students' reflection exercise. Additionally, it is important to note that ethical considerations were paramount in this study. An ethical application was submitted and approved by the Curtin University Human Research Ethics Committee (HREC), ensuring that all research procedures met established ethical standards and guidelines. This approach aimed to protect the rights and privacy of participating students while maintaining the integrity of the research process.

2.2. Reflection exercise.

Participation in a site visit was mandatory for every student. Students were briefed on what to look for prior to the tour. Together with the students, the course lecturers visited an industrial site. Students were required to submit a report at the end of the semester that included a brief reflection on the industrial visit in response to a specific prompt. As part of the data analysis, Kember et al. [14] levels of reflection were applied to the reflection tasks. Following this analysis, students' reflections were guided by four levels of features of the theoretical framework, leaving room for intermediate categories such as habitual action, understanding, reflection, and critical reflection. The term habitual action or non-reflection refers to when students respond to a question without actively engaging their thoughts or making an effort to comprehend it. In contrast, understanding occurs when students attempt to grasp the underlying meaning or theory, although it may not be directly linked to personal experiences or practical applications. Deep learning occurs during understanding without the need for reflection. When students recognize the concept and relate it to their own experiences, and are able to apply the theory to real-world situations, they are engaging in reflective thinking. Critical reflection goes beyond reflection and involves a change in perspective, often challenging deeply ingrained beliefs. However, the frequency of critical reflection can vary depending on the context of the student’s experiences and the prompts used to facilitate this reflective process.

3. Results and Discussions

This section contains the findings of the study, which aimed to improve current teaching practices through industrial visit under the environmental engineering courses. The results are organized into two main categories, ‘Industrial Visit Survey’ and ‘Reflection Exercise’.

3.1. Perceived value of industrial visits.

Data from the industrial visit were collected through a questionnaire survey in which students rated a series of questions on a five-point Likert scale, with 1 indicating strong disagreement and 5 indicating strong agreement. It should be noted that respondents who participated in the survey were voluntary, and they had the option to answer each question at their discretion. Respondents were specifically asked to rate their satisfaction with the 'industrial visit' in the questionnaire. Their responses clarify the perceived impact of these experiences. Notably, our findings reveal that students overwhelmingly believed that the industrial visits enhanced the quality of the academic program (Table 1). This observation aligns with the notion that experiential learning, such as industrial visits, can contribute significantly to the enrichment of academic curricula [15]. It has been consistently highlighted those exposing students to industries enriches their educational journeys, offering several advantages [16]. These advantages include a deepened understanding of professional tasks and processes, increased prospects for employment and personal growth, the creation of valuable networks with potential employers, exposure to innovative ideas, the accumulation of practical experience, a significant boost in self-confidence, engagement with managerial activities, and the cultivation of competencies and skills highly sought after by employers [17–19].

Table 1. Student feedback statement in industrial visit.

Question	Strongly agree	Agree	Neutral
It was clear from the start what was expected to be learned from the site visit.	75%	25%	-
The evaluation of the site visit was well defined.	50%	50%	-
It was easy to understand the instructions on the assessment sheet.	-	100%	-
I had a clear idea of the tasks stated in the assessment sheet during the site visit.	-	100%	-
The site visit experience helped me to gain knowledge what I learned in class.	75%	-	25%
The site visit developed my analytical skills.	75%	-	-
The site visit experience developed my problem-solving skills.	50%	50%	-
The lecturer provided me with all the necessary support.	75%	25%	-
My site visit experience was interesting.	75%	25%	-
The feedback during the site visit developed my understanding on particular topics.	75%	25%	-
The location for the site visit was appropriate.	100%	-	-
"Overall, I was satisfied with my site visit."	100%	-	-

Note: Respondents used a scale of 1 (strongly disagree) to 5 (strongly agree) to respond to the questions, with the freedom to choose whether or not to answer each question.

To further assess the respondents' statements, we conducted one-sample t-tests. One-sample t-tests offer a comprehensive view of respondents' perceptions and provide a basis for understanding the nuanced aspects of their experiences and satisfaction levels. These tests examined if there was a significant difference between the mean responses for each questionnaire item and the neutral point (3 on the Likert scale). The results of these tests provide valuable insights into the level of agreement or disagreement with each statement, helping to quantify and interpret the strength of statements.

Respondents expressed their perceptions of various aspects of the industrial visit within the industrial visit experiences. Notably, they strongly agreed that the 'site visit experience was interesting', with a mean rating of 4.75 and a standard deviation of 0.50. This rating showed the difference was significantly larger than the scale median ($t = 13$, $p < 0.05$), underlining the high level of interest and engagement experienced during the visits. This response is in line with Kirn and Benson [20], who claimed that engineering students place the greatest importance on school experiences directly related to their intended career pathways. Additionally, this rating is also influenced by students' physical interactions, as they have the opportunity to directly observe, touch, and contemplate the systems in practical use on-site [21].

Respondents also acknowledged the educational value of the interactions during the site visit. They strongly agreed that these learning interactions 'developed their understanding of particular topics', with a mean rating of 4.75 and a standard deviation of 0.5. This result, again, significantly exceeded the scale median ($t = 13$, $p < 0.05$), indicating the efficacy of these interactions in promoting understanding. This is because during the industrial visit, students enable to translate theoretical knowledge into practical application, observe its relevance in real-world contexts, seek guidance directly from professionals, analyze diverse work environments, and effectively bridge the divide between academic theory and professional practice [22]. However, participants expressed a bit less confidence in their agreement that the industrial visit helped them 'gain knowledge related to what was learned in class', with a mean rating of 4.50 and a standard deviation of 1.00. Although slightly lower, this rating was still significant ($t = 7$, $p < 0.05$), suggesting that while participants found value in the visit, they may have perceived a gap between classroom learning and the industrial experience. Similarly, participants provided a rating of 4.50 ($SD = 0.58$) for the statement that the exposure from the industrial visit 'developed their problem-solving skills'. This rating indicated a significant difference from the scale's median ($t = 13$, $p < 0.05$), affirming the positive impact of the visits on problem-solving abilities. According to Carbone et al. [15], these results may indicate that students use the knowledge acquired on field trips to create tailored learning resources and enhance their personal development, which is beneficial for their future careers. Parsons and Stephenson [23] recommended that students use 'other knowledge, theoretical principles, and alternative interpretations' when analyzing their experiences, suggesting that people should be able to recognize a range of knowledge and take the right course. Moreover, this implies that the learners have the ability to effect change.

Industrial visits often serve as bridges between theoretical classroom learning and practical industry insights. Our respondents strongly agreed that the quality of this bridge, represented by the level of 'what was expected to be learned from the site visit' ($M = 4.75$, $SD = 0.5$, $t = 7.2$, $p < 0.05$) significantly influences the extent to which knowledge gained during the visit is effectively adopted. Respondents who strongly agreed with the statement 'the lecturer provided me with all the necessary support' ($M = 4.75$, $SD = 0.5$, $t = 13$, $p < 0.05$) emphasized that these preparatory efforts created a foundation of understanding that made it easier to grasp and apply the knowledge encountered during the visit. Adequate preparation not only primes individuals for what they are about to experience but the 'evaluation of the site visit was well defined' ($M = 4.5$, $SD = 0.58$, $t = 12.12$, $p < 0.05$) also facilitates meaningful connections between new information and existing knowledge frameworks. This underscores the pragmatic importance of integrating site visits into engineering education, as the way we impart knowledge may prove to be as important or even more important than the content and extent of our teachings [24].

The feedback obtained from participants in our study provides valuable insights into their perceptions of the industrial site visit experience. Notably, all respondents overwhelmingly agreed that the site visit was essential to the 'development of their analytical skills', as evidenced by a mean rating of 5.00 with a standard deviation of .00. This unanimous consensus underscores the substantial impact of such educational experiences on skill enhancement. Similarly, participants' overwhelmingly positive feedback regarding the appropriateness of 'the location for the site visit' aligns with their course on educational field trips. A favourable environment and context can significantly enhance the educational value of such experiences. The consensus here reinforces the notion that a well-chosen location can contribute to a more meaningful and effective learning experience. Moreover, the overall satisfaction of participants with their site visit experience also garnered unanimous agreement. This suggests that participants found the visit to be not only educational but also enjoyable and fulfilling. High levels of satisfaction are indicative of a successful educational endeavour, as they reflect engagement and alignment with participants' expectations. The positive feedback received in these areas carries implications for educational practitioners and institutions. It emphasizes the importance of carefully planning and executing site visits, paying particular attention to location selection and the incorporation of activities that foster analytical skills. These findings reinforce the value of experiential learning and the potential for site visits to serve as catalysts for both skill development and overall satisfaction. These responses align with Bates et al. [25] assertion that site visits can contribute to the development of students' professional purpose, encompassing four essential mindsets: curiosity, initiative, collaboration, and progress.

3.2. Reflection exercise.

The ‘Report Essay’ section contained responses to short reflective prompts aimed at encouraging students to reflect on their site visit experiences (not critical reflection). This qualitative data provided another perspective on students' experiences within the industrial visit. One of the questions posed to students asked them to compare their on-site experiences with what they had been learning in class. This question provided valuable qualitative data that allowed us to gain insights into participants’ reflections on the alignment (or lack thereof) between classroom learning and on-site experiences. This approach prompted students to connect the engineering concepts emphasized during the visits to their personal experiences [14]. These reflective prompts constituted a graded assignment where students reported what they learned and observed through their interactions during the visit.

In this study, all students have responded to the reflective questions, however, not all statements indicated to each reflection level. It was recorded that 67% of students' reflection exercises have not achieved the level of critical reflection. We conducted a detailed review of assignments categorized at the reflection level to gain a deeper understanding of what students learned from the industrial visits. In these reflective activities, students linked their site visit observations to their own experiences, connecting classroom learning to real-life engineering situations. For instance, one student applied the theory they learned in class to what they observed engineers doing in the industry, drawing connections between their site visit observations and personal experiences within their course:

“Most of the processes that were implemented in the treatment plant have aligned with what I have been learning in class especially in the ENEN4009 Environmental Engineering Design and ENEN4003 Environmental Integrated Design Project. Based on the conversation with the person in charge of the treatment plant, the influent only comprises of residential wastewater and does not include wastewater from industries.”

In this quote, the student is reflecting on the alignment between the concepts that they have learned in their academic courses and the actual processes they observed during the site visit. They are making connections between theory and practice [26], which is a form of reflective thinking. During site visits, students often had the opportunity to engage with professionals and discuss different approaches to problem-solving. The student is reflecting on the information they obtained during their conversation with the person in charge of the treatment plant. One student mentioned:

“I had a conversation with the plant’s engineer, and he shared an alternative approach to a common engineering problem. It made me realize that there’s not just one right way to solve a problem. This encouraged me to think critically and consider alternative perspectives, which is crucial in the field of engineering."

This statement shows the student foster critical thinking through the site visit by exposing them to diverse viewpoints and problem-solving strategies. They are considering this information and incorporating it into their understanding of the plant's operations. This reflects the concept of reflection because it involves a thoughtful consideration of new information. While the statement acknowledges the educational aspect of the visit, it could benefit from a more detailed exploration of the specific learning processes, strategies, and challenges the student encountered during the visit. A more detailed exploration of the learning activity would provide a deeper insight into the development of understanding and reflection. The concept of understanding is subjective and can vary from person to person. The responses from students reflected this subjectivity as they engaged with the question in diverse ways. The student stated:

"Understanding how each component works and how the plant is designed with care and efficiency in mind is quite fascinating. Having a real visual on how each process and part of the system look like allows better memory retention when compared with theories and words read on paper."

They showed a keen interest in the design and operational efficiency of the plant. This demonstrates a level of understanding that extends beyond mere surface-level awareness. However, understanding can be challenging to quantify, making it difficult to assess the depth of comprehension gained from the visit. In the statement mentions a 'real visual' but does not elaborate on how this visit deepened the understanding of engineering concepts related to wastewater treatment. Further elaboration of the technical aspects and engineering principles behind the processes would be beneficial. According to Rieckmann [27] it is essential to develop skills like self-awareness, systems thinking, normative understanding, and forward thinking to enhance students' comprehension and readiness.

Critical reflection often involves considering multiple perspectives or viewpoints on a subject. The statement does not mention whether the student explored alternative viewpoints or engaged in discussions with others during the visit, limiting the scope of critical reflection. For instance, one student shared their observations about what they heard from the plant instructor:

"Something that surprised me was the process and procedures that may occur if the plant is experiencing bad weather. Rain can cause dilution to the wastewater being treated as the entire process of the treatment plant is open-spaced. Dilution to the wastewater reduces the overall MSS (Mixed Suspended Solids) of the sludge which in turn requires more bacteria to break down and separate the water with the sludge. Therefore, the process will be halted to wait for the MSS of the sludge to rise back up to do dewatering of the sludge."

Within this critical reflection, perhaps the most significant statement is the revelation about the impact of inclement weather on the wastewater treatment process. Specifically, the statement highlights how rainfall can dilute wastewater and disrupt the treatment process, necessitating operational halts until conditions improve. This change in viewpoint represents a fundamental transformation in how we perceive the challenges faced by wastewater treatment plants. In engineering education demanding students to bridge the theoretical concepts in practical application to become proficient engineers. Actively observing the latent environmental changes resulting from evolutionary phenomena in natural environments can facilitate a deeper understanding of the core principles by engaging and stimulating learners' cognitive processes [28]. Yet, this statement, while acknowledging the surprising impact of weather on wastewater treatment, only scratches the surface of its engineering implications. A comprehensive critical reflection in an engineering context would include a deeper analysis of weather-related challenges and possible engineering solutions. This process of reflection goes beyond simply assessing the situation; it stimulates metacognition in students [29]. Not only does it encourage students to think critically about their learning processes, but it also helps them recognize the interconnectedness of subjects within the engineering curriculum. It is important to acknowledge a limitation in this study, which is that the prompts for the reflective exercise did not explicitly encourage students to engage in critical reflection; instead, they focused on general reflection. However, it should be noted that this approach still provided a valuable starting point for observing subtle changes in students' perspectives following the visit.

3. Conclusion

Problem-based learning is a pedagogical approach that emphasized active exploration and the solution of real-world problems as a means of fostering deeper understanding, critical thinking, and practical skills development. The interactions during the site visits were found to be very valuable for students' understanding of specific topics precisely because they allowed students to connect theoretical knowledge with real-world applications. Qualitative analysis of the reflection tasks highlighted how differently students interpreted their experiences, reflecting the reflective and self-directed nature of learning fostered by PBL. The perceived gap between knowledge gained during industrial visits and classroom learning highlighted the potential for curricular integration. Integrating experiential learning components with academic content could promote a seamless and purposeful learning journey. However, integrating site visits with the curriculum also presented a challenge, requiring careful planning to ensure that experiential learning aligned with specific learning objectives and added value to the academic program. Our study not only underlined the value of industrial visits as powerful tools for engagement and learning but also positioned them as examples of experiential learning within a problem-based learning framework. It highlighted the importance of recognizing the subjectivity of understanding and underscored the versatility of experiential learning that PBL principles promoted. Moving forward, this study served as a bridge between the experiential learning paradigm and the problem-based learning approach, demonstrating how the integration of authentic experiences and problem-solving opportunities enriched pedagogical experiences. Therefore, outlining what students were expected to gain from the experience and how it connected to their academic coursework needed to be clear. It encouraged further exploration of how PBL could be used in different types of experiential learning, such as site visits, internships, and simulations, to enhance the educational experience and enable students to become adept problem solvers and critical thinkers in both academic and real-world contexts. They invited us to understand the dynamic interplay between the individual and the collective and to cultivate an educational environment that fostered lifelong learning and prepared students to meet the complex challenges of our world.

Competing Interest

The author declares that there is no conflict of interest.

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