Improving Student Soft Skills through Robotics-Based Active Learning: Insights from Learning Outcomes

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Abstract

In the Japan–Thailand Joint Robotics Project-Based Learning (PBL) Program hosted by Shibaura Institute of Technology (SIT) Japan and King Mongkut's University of Technology Thonburi (KMUTT) Thailand, the objectives are threefold: (1) to provide practical learning of hardware and software robotics based on Arduino ESP and Robot Operating System (ROS), (2) to develop communication and teamwork skills through English as a Foreign Language (EFL), and (3) to foster the soft skills required by the Washington Accord [1] and Thailand Accreditation Board for Engineering Education (TABEE) [2]. While some participating students prioritized improving their English proficiency due to a lack of confidence, the supervisors placed greater emphasis on encouraging students to overcome their anxieties, express their opinions without hesitation, identify their roles within teams, and contribute actively to group work. Through these experiences and peer-to-peer learning, the program intentionally sought to cultivate self-efficacy [3] as a core expected learning outcome. To facilitate such attitudes, students were required to maintain daily activity reports documenting their activities and reflections. This practice enabled them to generate data that they could later use as input for group discussions, thereby lowering barriers to participation. Moreover, throughout the program, students were encouraged to actively use AI tools [4] to assist with English translation and to supplement their technical and conceptual knowledge. Pre- and post-program surveys were conducted to capture changes in perceptions and awareness resulting from participation in the PBL. This study addresses the following four objectives:

1. To analyze the engineering and soft-skill learning outcomes achieved by both Japanese and Thai students through robotics-focused PBL.

2. To examine how structured guidance—requiring students to document their daily activities and reflections in writing and to use these records in group discussions—enhanced learner proactivity and self-efficacy. In particular, by analyzing the large corpus of written data

generated, this study explores which activities and extra-curricular experiences contributed to improvements in communication and teamwork.

3. To identify how students utilized Artificial Intelligence (AI) during the program through semi-structured interviews.

4. To incorporate the insights gained from this analysis into the next iteration of the PBL program scheduled for 2026, thereby further enhancing learning outcomes.

1. Background and Objectives

The Department of Mechanical and Functional Engineering at SIT a Japanese leading engineering institute, has been conducting an annual bidirectional global Project-Based Learning (PBL) [5] program in collaboration with KMUTT, a top-tier engineering university in Thailand. In this program, Thai students first visit Japan to jointly learn the fundamentals of robotics hardware and software, including Arduino ESP and the Robot Operating System (ROS), together with Japanese students. Approximately six months later, Japanese students travel to Thailand, where mixed teams collaboratively assemble a disaster-prevention robotics toolkit.

The expected learning outcomes of this active-learning, group-based program extend beyond the acquisition of engineering knowledge in robotics hardware and software. They include the ability to consider realistic applications of robotic technologies for disaster mitigation in students' home countries, as well as the development of soft skills through collaborative work in multicultural teams using EFL. Furthermore, this learning format is considered highly effective for fostering the Washington Accord 11 Graduate Attribute Profile (WA11GAP). Notably, the eleven accreditation criteria defined by the TABEE closely correspond to the WA11GAP. These skillsets are essential competencies for nurture future engineers with global mindset [6].

Table 1: Competencies defined by WA and TABEE

No.	WA11GAP	TABEE Criterion 3: Program Outcome
1	Engineering Knowledge	Knowledge of Mathematics, Science and Engineering
2	Problem Analysis	Engineering Problem Analysis
3	Design and Development of Solutions	Design and Development Solutions for Complex Engineering
4	Investigation	Investigation
5	Tool Usage	Modern Tool usage
6	The Engineer and the World	Individual and Team Work
7	Ethics	Communication
8	Individual and Collaborative Teamwork	Society, Environment, Sustainability, and Engineering Profession
9	Communication	Ethics
10	Project Management and Finance	Project management and finance

11	Lifelong Learning	Lifelong learning

To capture and evaluate these learning outcomes, pre-program surveys were conducted to identify students' motivations for participation and the specific WA11GAP competencies they aimed to develop. Subsequently, post-program surveys were administered to assess students' perceived learning outcomes and the competencies they ultimately acquired. In addition, during the program period, students were required to document their daily activities using text and images. This design intentionally embedded a self-reflection process, enabling students to articulate their experiences and allowing researchers to infer which specific learning activities and experiences contributed to the observed learning outcomes.

In the context of the rapid advancement of artificial intelligence (AI), the skills that humans are expected to acquire are shifting from the passive memorization of knowledge toward active learning methodologies for higher-order competencies. These include the ability to define real-world problems, formulate hypotheses for potential solutions, and collaboratively design concrete implementation strategies through group work. From this perspective, PBL provides an effective learning environment for cultivating such applied and integrative skills.

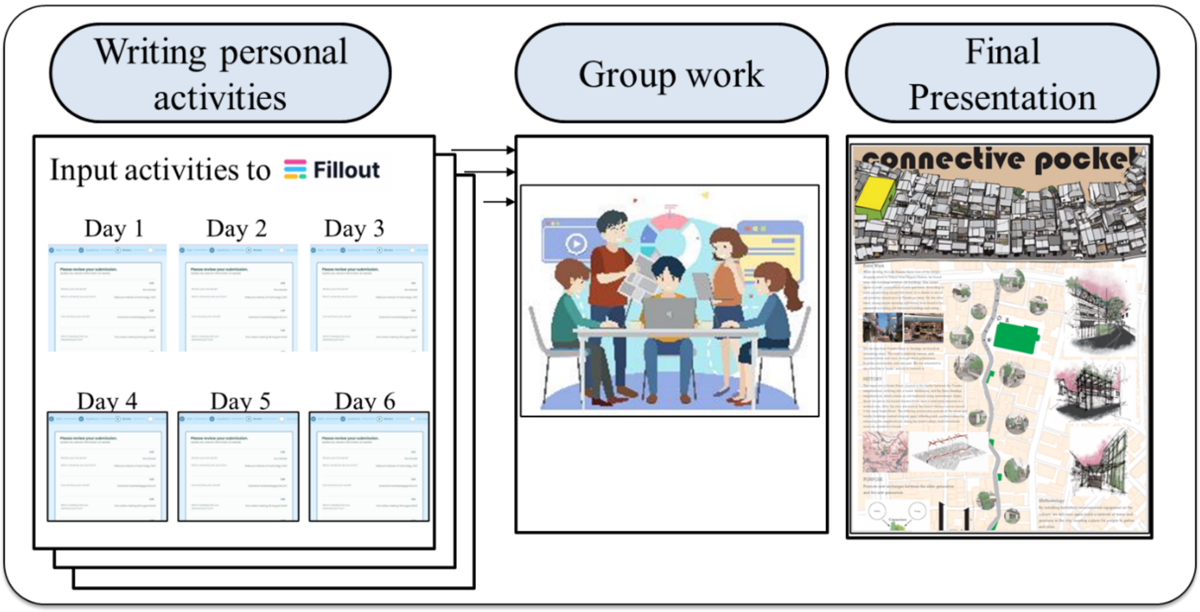
Accordingly, this study analyzes the learning process in which Japanese and Thai students engage in intercultural group work using English as a Foreign Language, focusing on engineering education and interdisciplinary learning for developing global competencies [7]. Specifically, it examines the types of skills and self-efficacy that students ultimately acquired, as well as the experiences that appear to have contributed to their development. Based on these findings, the study further discusses what forms of active learning are likely to be effective in the emerging AI-driven era.

The research questions addressed in this article are as follows:

- RQ1: What motivated Japanese and Thai students to participate in this PBL program despite the significant time and financial costs associated with international travel, and what learning outcomes did they expect?
- RQ2: Through this robotics- and disaster-focused PBL program, what types of engineering knowledge and which competencies aligned with the WA11GAP did participating students acquire?
- RQ3: What learning experiences did participating students perceive as irreplaceable by AI?

Figure 1 illustrates the process of daily report writing for self-reflection, group work for exchanging own opinions, and the collaboration for developing final presentation through teamwork efforts.

Figure 1: Learning Process Outlook



2. Literature Review

2.1 PBL in Engineering Education

PBL has been widely recognized as an effective pedagogical approach in engineering education, particularly for fostering higher-order cognitive skills and professional competencies. Unlike traditional lecture-based instruction, PBL emphasizes student-centered learning through engagement with open-ended, authentic problems that resemble real-world engineering practice. Prior studies have consistently reported that PBL enhances students' conceptual understanding, problem-solving ability, and motivation by situating learning within meaningful contexts [8]. In engineering education, PBL has been shown to be especially effective in integrating technical knowledge with non-technical skills, such as teamwork, communication, and project management. Graham [5] notes that PBL aligns well with outcome-based education models adopted by international accreditation frameworks, as it allows students to demonstrate competencies through performance rather than through examinations alone. As a result, PBL has been increasingly adopted in capstone design courses, laboratory-based subjects, and interdisciplinary engineering programs worldwide.

Moreover, inductive learning approaches such as PBL have been found to support deeper learning by encouraging students to actively construct knowledge rather than passively receive information [9]. This characteristic makes PBL particularly suitable for rapidly evolving technological fields, such as robotics, where students must continuously adapt existing knowledge to new tools and contexts.

2.2 Effectiveness of Global and Intercultural PBL for Acquiring WA11GAP

With the globalization of engineering practice, there has been growing interest in global and intercultural PBL as a means of preparing students for international collaboration. Prior research has demonstrated that PBL environments provide unique opportunities for students to develop intercultural competence, ethical awareness, and communication skills, which are difficult to cultivate in domestic or mono-cultural settings [6]. The WA11GAP emphasizes competencies such as teamwork, communication, problem analysis, ethical responsibility, and lifelong learning. These competencies closely correspond to the learning outcomes frequently reported in PBL studies. For example, multinational team-based projects require students to negotiate meaning, manage cultural differences, and coordinate tasks across linguistic and social boundaries, thereby fostering attributes related to collaboration and professionalism [7].

Several studies have highlighted that participation in international PBL programs enhances students' awareness of the societal and contextual dimensions of engineering problems. By engaging with themes such as disaster mitigation or sustainability, students are encouraged to consider local constraints and stakeholder perspectives, supporting the acquisition of competencies related to societal impact and engineering judgment. Furthermore, the use of EFL in PBL settings has been shown to promote functional communication skills and confidence, even when linguistic proficiency is initially limited [10].

These findings suggest that PBL is an effective pedagogical strategy for fostering WA11GAP-aligned competencies and provides a strong foundation for evaluating learning outcomes in international engineering education programs.

2.3 Reflection and Self-Efficacy in PBL

Reflection has been identified as a critical component of effective experiential and project-based learning [11]. Schön [12] conceptualized professional learning as a reflective process in which individuals continuously examine their actions and experiences to improve future performance. In PBL contexts, structured reflection has been shown to deepen learning by enabling students to articulate their reasoning, recognize challenges, and connect experience with theory. From the perspective of Social Cognitive Theory [13], reflection also plays an important role in the development of self-efficacy. Bandura (1997) argues that self-efficacy is strengthened through mastery experiences and cognitive processing of those experiences. By documenting daily activities and reflecting on successes and difficulties, students can reinterpret challenges as learning opportunities, thereby enhancing their confidence and willingness to engage in future tasks.

Empirical studies in engineering education have reported positive relationships between reflective practices and students' perceived competence, motivation, and engagement [14]. Reflection-based interventions, such as learning journals or activity reports, have been shown to lower barriers to participation, particularly in team-based and intercultural settings, by providing students with opportunities to prepare their thoughts before discussion [15]. This is especially relevant in EFL environments, where spontaneous verbal participation may be constrained by language anxiety.

Accordingly, reflection is increasingly viewed not only as a metacognitive tool but also as a mechanism for fostering self-efficacy and learner proactivity in PBL environments.

2.4 AI and Future Engineering Skills

The rapid advancement of AI has prompted renewed discussion regarding the skills that engineers must acquire in the future. Rather than emphasizing routine knowledge recall, recent frameworks highlight competencies such as problem definition, creative solution design, collaboration, and ethical judgment—skills that are difficult for AI to fully replicate [16]. In educational contexts, AI is increasingly positioned as a learning support tool rather than a substitute for human learning. Luckin et al. [4] argue that AI can function as a cognitive and linguistic scaffold, assisting learners by reducing extraneous cognitive load and enabling greater focus on higher-level thinking. In international PBL settings, AI-based translation and information retrieval tools have been reported to lower linguistic barriers and support equitable participation among team members.

At the same time, prior research emphasizes that meaningful learning experiences—such as negotiating ideas within a team, dealing with ambiguity, and collectively designing solutions—remain fundamentally human-centered. These experiences contribute to the development of professional identity and self-efficacy [3] and are therefore regarded as irreplaceable by AI.

From this perspective, PBL provides an effective learning environment for cultivating future-oriented engineering skills by combining human-centered collaboration with strategic use of AI as a supportive resource.

2.5 Summary

The reviewed literature indicates that PBL is a well-established and effective approach in engineering education, particularly for fostering both technical knowledge and professional competencies. Global and intercultural PBL further enhances these outcomes by aligning closely with the WA11GAP. Reflection serves as a key mechanism for transforming experience into learning and for strengthening self-efficacy [3], while AI functions as an enabling tool that supports, rather than replaces, human learning. Together, these studies provide a strong foundation for the present research and justify the analytical focus adopted in this study.

3. Theoretical Framework

This study is grounded in multiple complementary learning theories that collectively explain the effectiveness of PBL in international, multidisciplinary engineering education contexts: Experiential Learning Theory [13] Writing-to-Learn theory [17], Sociocultural Learning Theories [14], [15], and Social Cognitive Theory with a focus on self-efficacy [3]. For competency development, WA11GAP and Global Engineering Competency [7] are adopted. Together, these frameworks provide a coherent theoretical basis for analyzing technical learning, soft-skill development, learner proactivity, and the use of artificial intelligence (AI) tools within these Japan–Thailand Joint Robotics PBL Programs.

3.1 Experiential Learning Theory

Experiential Learning Theory conceptualizes learning as a cyclical process in which knowledge is created through the transformation of experience. According to Kolb, effective learning occurs through four iterative stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation. The instructional design of the robotics PBL program closely aligns with this experiential learning cycle [13]. Students engaged in concrete experiences by developing hardware and software systems using Arduino, ESP, and the Robot Operating System (ROS). To promote reflective observation, students were required to maintain daily activity reports documenting their tasks, challenges, and personal reflections. These written records subsequently served as inputs for group discussions, supporting abstract conceptualization through collective sense-making and knowledge sharing. Finally, insights gained from reflection and discussion informed subsequent design decisions and team actions, enabling active experimentation in an iterative manner.

Within this framework, reflection is not treated as a supplementary activity but as a critical mechanism that transforms hands-on experience into meaningful learning. By lowering barriers to participation and providing structured opportunities for reflection, the program aimed to enhance learner proactivity and deepen both technical understanding and soft-skill development. The large corpus of written reflection data [17] generated by students provides empirical evidence for analyzing how experiential learning [13] processes contributed to observed learning outcomes.

3.2 Writing-to-Learn theory and reflective practice

Writing and reflection through daily report is grounded in Writing-to-Learn theory [17] and reflective practice [12]. Through structured activities such as daily reports and reflective journals, learners externalize their thoughts and experiences. This process enables the transformation of tacit knowledge into explicit understanding. Simultaneously, writing promotes metacognition and self-regulated learning [18], [19] allowing learners to monitor, evaluate, and adjust their cognitive processes.

3.3 Social Cognitive Theory and Self-Efficacy

Social Cognitive Theory posits that learning occurs through the reciprocal interaction of personal factors, behaviors, and environmental influences. Central to this theory is self-efficacy, defined as an individual's belief in their capability to organize and execute actions required to achieve specific goals. Extensive prior research has demonstrated that self-efficacy strongly influences learners' motivation, persistence, willingness to participate, and performance, particularly in challenging or unfamiliar learning environments.

In the context of the international robotics PBL program, many students—especially those using EFL—initially experienced anxiety and low confidence when expressing ideas or engaging in group discussions. Rather than prioritizing linguistic accuracy, the program supervisors emphasized psychological safety, encouraging students to express opinions without hesitation, identify their roles within teams, and contribute actively to collaborative tasks. These design choices were intended to enhance students' self-efficacy through mastery experiences (successful completion of robotics tasks), social persuasion (peer and instructor feedback), and the reduction of affective barriers such as fear of making mistakes.

Accordingly, self-efficacy is positioned as a core expected learning outcome of this PBL program and serves as a primary analytical lens in this study. Changes in students' perceptions and confidence, captured through pre- and post-program surveys and reflective writings, are interpreted as indicators of self-efficacy development.

3.4 Sociocultural Learning Theory (Vygotsky; Lave & Wenger).

Sociocultural Learning Theory emphasizes that learning is inherently social and is constructed through interaction, dialogue, and collaboration with others. From this perspective, knowledge is not transmitted unidirectionally from instructor to learner but emerges through participation in shared activities within a sociocultural context. Closely related to this view, the concept of Communities of Practice describes learning as increasing participation in a community engaged in authentic practices [15].

This Japan–Thailand Joint Robotics PBL Program functioned as a temporary international community of practice, in which students with diverse linguistic, cultural, and technical backgrounds collaborated toward shared engineering goals. Even students with limited English proficiency were able to participate meaningfully through peer-to-peer learning, shared artifacts such as code and hardware prototypes, and structured discussion based on written reflections. This environment allowed students to engage in "legitimate peripheral participation" and gradually move toward more central roles within their teams [14].

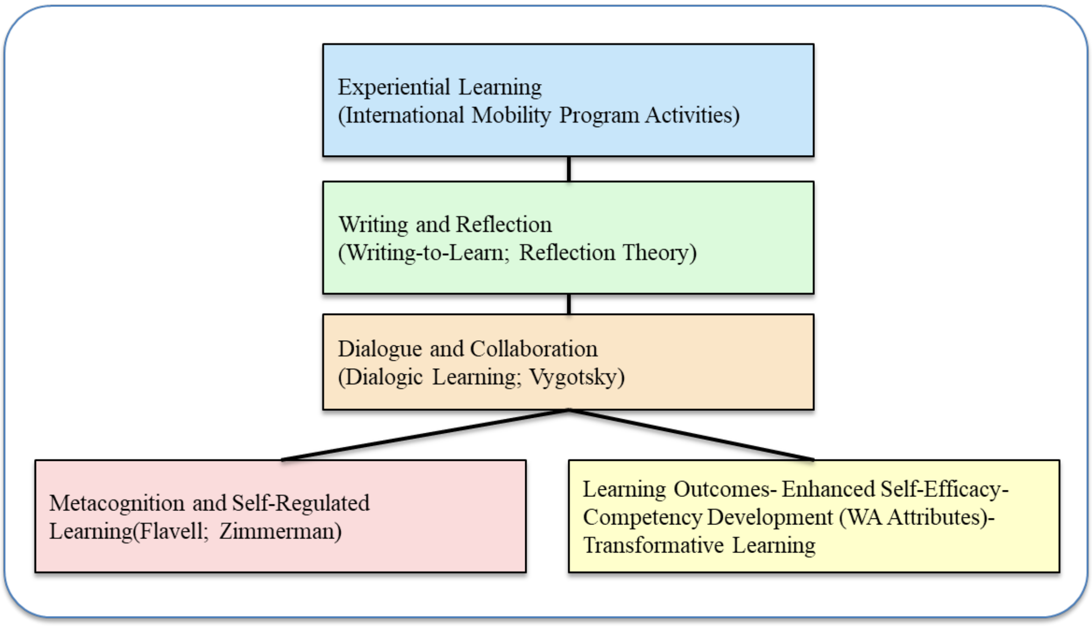
The active use of AI tools for translation, technical clarification, and conceptual understanding can be interpreted within this framework as the use of mediating artifacts that scaffold participation. Rather than replacing learning, AI tools supported students' engagement in collaborative knowledge construction by reducing linguistic and cognitive barriers, thereby enabling more equitable participation in team activities.

3.4 Integrated Framework for Analysis

By integrating experiential learning theory, self-efficacy theory, reflection theory, and sociocultural learning theory, this study adopts a holistic framework for examining learning in international robotics-focused PBL. Experiential learning theory accounts for the role of structured reflection and iterative practice; self-efficacy theory explains changes in students' confidence and willingness to participate; writing-to-learn theory and reflection theory stabilize what students empirically acquired regardless of their awareness; and social constructivism elucidates how teamwork, peer interaction, and AI-mediated support contributed to learning outcomes.

This integrated framework shown in Figure 2 guides the analysis of survey data, written reflections, and interview transcripts in addressing the four research objectives of the study, and it informs the design improvements planned for the next iteration of the PBL2 program in March 2026.

Figure 2: Integrated Theoretical Framework



4. Methodology

4.1 Research Design

This study adopted a mixed-methods research design to comprehensively examine learning outcomes, competency development, and self-efficacy in an international robotics-focused PBL program. Quantitative data were collected through pre- and post-program surveys using Likert-scale items, while qualitative data were obtained from students' daily activity reports and post-program group interviews. This combination enabled both measurement of changes in students' perceptions and in-depth exploration of the learning processes underlying those changes.

4.2 Participants and Program Context

Participants were undergraduate and postgraduate engineering students from SIT and KMUTT. Students took part in a ten-day intensive PBL program conducted in EFL, working in multinational teams on robotics projects related to disaster-prevention applications. The program involved hands-on development using Arduino ESP and the ROS, daily group activities, and structured reflection.

4.3 Data Collection Methods

4.3.1 Pre-program Survey

Prior to the start of the program, a pre-program survey was administered to capture students' motivations for participation, expected learning outcomes, and target competencies aligned with WA11GAP using a Google Form questionnaire. Survey items were measured using a five-point Likert scale, allowing students to indicate the degree to which they agreed with statements related to technical learning, soft-skill development, and personal growth.

4.3.2 Post-program Survey

After completion of the program, a post-program survey was conducted to assess students' perceived learning outcomes and the competencies they believed they had actually acquired through participation. The post-program survey included items parallel to those in the pre-program survey, enabling direct comparison of expectations and outcomes. Additional open-ended questions were included to capture students' reflections on their learning experiences and the role of AI tools during the program.

4.3.3 Daily Activity Reports

Throughout the ten-day program, students were required to submit daily activity reports documenting their activities, challenges, insights, and reflections in textual form, supplemented with images where appropriate. This practice was intentionally designed to promote self-reflection and to externalize students' learning processes. The resulting corpus of written data was used to analyze how specific activities, interactions, and experiences contributed to the development of technical skills, soft skills, and self-efficacy.

4.3.4 Additional Questionnaire Survey about AI Usage

Following the program, additional surveys were conducted with students who had provided particularly detailed or reflective responses in the post-program survey. These semi-structured and open-ended questionnaire focused on students' perceived learning gains, experiences they regarded as irreplaceable by AI, and the role of intercultural collaboration in their learning. The questionnaire served to triangulate survey findings and deepen understanding of patterns identified in the quantitative and textual analyses.

4.4 Data Analysis

Quantitative and qualitative data were analyzed separately and then integrated to address the research questions. Survey data were analyzed to identify changes between pre- and post-program responses, while qualitative data from daily reports and questionnaire were coded thematically. By triangulating findings across multiple data sources, the study aimed to enhance the validity and credibility of the results.

5. Analysis and discussion

The following survey was conducted in conjunction with two PBLs. The first one was held from September 15th to 23rd, 2025, during which 1 SIT professor and 10 students traveled to Thailand. The second one was held February 23rd to March 2nd , 2026, during which 1 KMUTT professor and 9 students visited Tokyo and SIT professor and 16 Japanese students hosted the program. Both surveys were administered as part of group-based PBL activities at KMUTT in Bangkok and SIT in Tokyo. In addition to the academic program, extra-curricular activities were organized to promote Japanese–Thai cultural exchange. These included visits to historical landmarks in and urban area tours guided by the local students in each city.

5.1 RQ1: Students' Initial Motivation for Participation and Actual Learning Outcomes

Table 1 shows the pre-post comparison of motivations for both Japanese and Thai students. In terms of country-level trends, the average scores of Thai students were higher than those of Japanese students in both the Pre-Program and Post-Program surveys, with differences ranging average with 0.56 and 0.60 points, respectively. Although identifying the underlying causes of this difference is beyond the direct scope of the present study, it is plausible that cultural or national characteristics may be correlated with survey response patterns, e.g., Japanese tend to be conservative to express their personal thoughts, and that such tendencies may be reflected in these results. The initial motivations for attending this PBL are [No. 5] Teamwork skills, [No. 4] Communication and presentation skills, [No. 6] New and international friends, and [No. 8] English practice. The results of the post-program survey were almost the same with the highest 3 of [No. 5], [No. 6], and [No. 8]. This means these engineering students had relatively higher interests in soft skills and international friends than in technological knowledge or engineering hard skills.

Table 1: Pre-post comparison of participants' motivations for the PBL 1 in Thailand

No.	J: Japanese student T: Thai student	Pre (N=35)			Post (N=36)		
		All	J: 11	T: 10	All	J: 11	T: 10
1	To understand new technologies	3.43	2.80	3.68	3.56	3.20	3.69
2	To enhance engineering skills	3.49	3.00	3.68	3.64	3.10	3.85
3	To understand social problems	3.09	2.50	3.32	3.44	2.70	3.73
4	To improve commination and presentation skills	3.74	3.70	3.76	3.61	3.40	3.69
5	To develop teamwork skills	3.74	3.50	3.84	3.83	3.70	3.88
6	To make new and international friends	3.66	3.40	3.76	3.83	3.70	3.88
7	To interact with international professors	3.51	3.10	3.68	3.31	2.60	3.58
8	To practice English	3.66	3.70	3.64	3.75	3.50	3.85
9	To prepare for future jobs	3.54	3.20	3.68	3.47	2.90	3.69
10	To receive a certificate and credits	3.06	2.00	3.48	3.42	2.70	3.69
Average		3.49	3.09	3.65	3.59	3.15	3.75

Table 2 represents the same pre-post comparison for the PBL2. Once again, Thai students have a tendency to put higher scores than Japanese for both Pre (0.59) and Post (0.42). The new item [No.11] "To have international experience" achieved the highest score for both Pre and Post program. [No. 4], [No. 5], [No. 6] were also high for both Pre and Post survey, just the similar to the PBL 1. Thus, these items are commonly effective to encourage new students to attend the PBL, regardless of the venue country or ethnicity.

Table 2: Pre-post comparison of participants' motivations for the PBL 2 in Japan

No.	J: Japanese student T: Thai student	Pre (N=21)			Post (N=21)		
		All	J: 11	T: 10	All	J: 11	T: 10
1	To understand new technologies	2.95	2.58	3.44	3.38	3.17	3.67
2	To enhance engineering skills	3.14	2.92	3.44	3.52	3.50	3.56
3	To understand social problems	2.90	2.58	3.33	2.95	2.67	3.33
4	To improve commination and presentation skills	3.52	3.50	3.56	3.57	3.58	3.56
5	To develop teamwork skills	3.62	3.50	3.78	3.62	3.58	3.67
6	To make new and international friends	3.62	3.33	4.00	3.57	3.50	3.67
7	To interact with international professors	3.38	3.17	3.67	2.71	2.00	3.67
8	To practice English	3.52	3.58	3.44	3.48	3.42	3.56
9	To prepare for future jobs	3.05	2.50	3.78	2.95	2.58	3.44
10	To receive a certificate and credits	2.62	2.00	3.44	3.24	3.17	3.33
11	To have international experience	3.76	3.67	3.89	3.81	3.67	4.00
Average		3.28	3.03	3.62	3.35	3.17	3.59

5.1.1 Analysis of Initial Motivation (Pre-program Survey)

The pre-program survey revealed that students participated in these Japan–Thailand PBL programs with multiple, overlapping motivations, rather than a single dominant objective. First, students demonstrated strong interest in technical learning, particularly in acquiring new knowledge related to robotics hardware and software, such as Arduino ESP and ROS. This indicates that participants perceived the program as an opportunity to complement their university coursework with hands-on engineering experience. Second, a high level of motivation was observed regarding soft-skill development, especially teamwork, communication, and collaboration in in an international environment. Many students expressed a desire to improve their ability to work in multicultural teams and to communicate engineering ideas in EFL. This suggests that students were already aware of the importance of non-technical competencies for future engineering careers. Third, students showed notable interest in international exposure, including interacting with overseas peers, faculty members, and industrial experts. Compared with extrinsic motivations such as obtaining certificates or academic credits, intrinsic motivations related to global experience and personal growth were more prominent.

Overall, the pre-program survey indicates that students entered the program with balanced expectations, encompassing both engineering knowledge acquisition and broader professional development aligned with the WA11GAP.

5.1.2 Analysis of Actual Learning Outcomes (Post-program Survey)

The post-program survey results indicate that many of the initial expectations were largely fulfilled or exceeded, particularly in areas related to collaborative learning and personal development.

Students reported substantial learning gains in:

- Applying robotics knowledge to realistic, socially relevant problems (e.g., disaster prevention),
- Communicating ideas and progress within multicultural teams,
- Collaboratively designing and implementing solutions under time and resource constraints.

Notably, while some students initially prioritized improving their English proficiency, post-program responses suggest that confidence in communication and willingness to express opinions improved more strongly than linguistic accuracy itself. This indicates that the program successfully reduced psychological barriers to participation, a key factor in effective teamwork and learning.

In summary, RQ1 analysis shows that students' motivations for participating in the PBL program were closely aligned with the learning outcomes they ultimately perceived, particularly with respect to global collaboration, applied engineering practice, and personal growth.

5.1.3 Pre-Post Score Comparison

Regarding students' initial motivations of the PBL1, the highest-rated items in the Pre-Program survey were "To improve communication and presentation skills" and "To develop teamwork skills" (both M = 3.74), followed by "To make new and international friends" and "To practice English" (both M = 3.66). In the Post-Program survey, however, "To develop teamwork skills" and "To make new and international friends" received the highest mean scores (both M = 3.83), exceeding their respective Pre-Program values. This suggests that the effectiveness of this face-to-face program may lie particularly in its ability to enhance interpersonal skills. "To practice English" also remained highly rated in the Post-Program survey (M = 3.75). For students in an EFL (English as a Foreign Language) context, improving English proficiency is a critical issue, and it may be inferred that a practice-oriented PBL program is well suited to supporting such improvement. The largest Pre–Post increases were observed for "To receive a certificate and credits" (+0.36) and "To understand social problems" (+0.35). The former may reflect an increased sense of accomplishment after students actually received a certificate, which may not have been strongly anticipated at the outset. The latter increase may be attributed to the program's thematic focus on disaster prevention and response as a real-world social issue.

The results of PBL2 was quite similar. "To have international experience" was the highest for both Pre (M = 3.76) and Post (M = 3.81), followed by "To develop teamwork skills" (both M = 3.62), "To make new and international friends" (M = 3.62 and 3.57), and "To improve communication and presentation skills" (M = 3.52 and 3.57).

5.2 RQ2: Intended and Actual Acquisition of WA11GAP Competencies

Table 3 represents the comparison of WA11GAP acquisition for the PBL1. In the pre-program survey, students were asked which competencies aligned with the Washington Accord [1] 11 Graduate Attribute Profile (WA11GAP) they aimed to develop through participating in this robotics workshop.

Table 3: Pre-post comparison of WA11GAP acquisition for the PBL 1 in Thailand

No.	J: Japanese student T: Thai student	Pre (N=35)			Post (N=36)		
		All	J: 10	T: 25	All	J: 10	T: 26
1	Engineering knowledge	3.31	2.73	3.84	3.61	3.10	3.81
2	Problem analysis	3.37	2.93	3.84	3.67	3.20	3.85
3	Design/development of solutions	3.46	3.13	3.84	3.50	3.00	3.69
4	Investigation	3.29	2.93	3.63	3.33	2.70	3.58
5	Tool usage	3.20	2.67	3.68	3.42	3.10	3.54
6	The Engineer and the World	3.31	2.80	3.79	3.56	3.20	3.69
7	Ethics	3.11	2.73	3.53	3.33	2.70	3.58
8	Individual and collaborative teamwork	3.69	3.53	3.89	3.81	3.70	3.85
9	Communication	3.77	3.60	3.95	3.89	4.00	3.85
10	Project management and finance	3.17	2.40	3.84	3.39	2.60	3.69
11	Lifelong learning	3.31	2.87	3.74	3.75	3.50	3.85
	Average	3.36	2.94	3.78	3.57	3.16	3.73

Table 4 describes the comparison of WA11GAP acquisition for the PBL2. Once again, Thai students put higher scores than Japanese.

Table 4: Pre-post comparison of WA11GAP acquisition for the PBL 2 in Japan

No.	J: Japanese student T: Thai student	Pre (N=21)			Post (N=21)		
		All	T: 10	J: 11	All	J: 11	T: 10
1	Engineering knowledge	3.10	2.75	3.56	3.43	3.33	3.56
2	Problem analysis	3.19	3.00	3.44	3.57	3.42	3.78
3	Design/development of solutions	3.29	3.00	3.67	3.43	3.25	3.67
4	Investigation	3.24	3.00	3.56	3.24	3.00	3.56
5	Tool usage	3.24	3.00	3.56	3.43	3.50	3.33

6	The Engineer and the World	3.19	2.92	3.56	3.14	2.92	3.44
7	Ethics	3.00	2.58	3.56	2.95	2.75	3.22
8	Individual and collaborative teamwork	3.62	3.58	3.67	3.81	3.75	3.89
9	Communication	3.76	3.67	3.89	3.86	3.75	4.00
10	Project management and finance	3.19	2.83	3.67	3.33	3.08	3.67
11	Lifelong learning	3.14	2.67	3.78	3.38	3.25	3.56
	Average	3.27	3.00	3.63	3.42	3.27	3.61

5.2.1 Intended WA11GAP Competencies (Pre-program Survey)

The both results indicate that students initially placed strong emphasis on the following competencies:

- [No. 9] “Communication”, particularly in an international and EFL context.
- [No. 8] “Individual and collaborative teamwork”, highlighting awareness of the importance of team-based engineering practice.
- [No. 2] “Problem analysis” and [No. 3] “design/development of solutions”, indicating interest in applying engineering knowledge to real-world problems.
- [No. 1] “Engineering knowledge” and [No. 5] “tool usage”, reflecting expectations of learning new robotics technologies.

In contrast, competencies such as [No. 7] “ethics”, [No. 10] “project management and finance’, and [No. 11] “lifelong learning” were initially rated as relatively less prominent. This suggests that, at the outset, students tended to prioritize tangible and immediately applicable skills over more abstract or long-term professional attributes.

5.2.2 Acquired WA11GAP Competencies (Post-program Survey)

Post-program survey responses indicate a shift in students’ perceived competency acquisition, both in terms of breadth and depth.

Students reported strong gains in:

- [No. 9] “Communication”, particularly in expressing ideas, negotiating roles, and resolving misunderstandings,
- [No. 8] “Individual and collaborative teamwork”, as a result of sustained interaction within multinational teams,
- [No. 3] “Design and development of solutions”, through iterative prototyping and problem-solving activities,
- [No. 9] “Tool usage”, including both robotics platforms and AI-based support tools.

Importantly, competencies that were initially less emphasized—such as "[No.11] lifelong learning" and "[No. 6] the engineer and society/world"—showed increased recognition in post-program responses of PBL1. Through engagement with disaster-prevention themes and reflection on societal impact such as seeing historic legacies in ancient capital of Thailand, students appeared to develop a broader understanding of engineering as a socially embedded profession. [11 lifelong learning] awareness was also enhanced at the PBL2. Hence, this shift suggests that participation in the PBL program not only strengthened initially targeted competencies but also expanded students' awareness of the full WA11GAP spectrum.

5.3 Synthesis: Relationship Between Expectations and Outcomes

Regarding the PBL1, the top three competencies at the pre-program stage were "Communication" (M = 3.77), "Individual and collaborative teamwork" (M = 3.69), and "Design/development of solutions" (M = 3.46). In the post-program results, the top competencies were "Communication" (M = 3.89), "Individual and collaborative teamwork" (M = 3.81), and, interestingly, "Lifelong learning" (M = 3.75). In terms of the PBL2, the top three competencies at the pre-program stage were "Communication" (M = 3.76), "Individual and collaborative teamwork" (M = 3.62), and "Design/development of solutions" (M = 3.29). In the post-program results, the top competencies were "Communication" (M = 3.86), "Individual and collaborative teamwork" (M = 3.81), and "Problem solving" (M = 3.53).

During these PBL programs, Japanese and Thai students were organized into joint teams. In addition to robotics learning and problem-solving activities, group activities such as visits to historical sites were incorporated, which appears to have contributed positively to these outcomes. Regarding "Lifelong learning," it showed the largest increase in the pre–post comparison in the PBL1 (+0.44) and PBL2 (+0.24). In other words, although this competency was not strongly recognized at the outset, students gained significant awareness of its importance through participation in the PBL program. This shift may also be related to the fact that WA11GAP was explained during the program orientation, and the importance of continuous learning was emphasized again during the closing ceremony.

Taken together, the analysis of pre- and post-program surveys indicates that:

1. Students entered the program with strong expectations of competency acquisitions regarding communication, teamwork, and technical learning.
2. These expectations were largely met, particularly in collaborative competencies and applied engineering skills.
3. Participation in the program led to unexpected or initially undervalued gains, especially in self-efficacy [3], communication confidence, and awareness of societal and lifelong learning dimensions of engineering.

These findings support the effectiveness of global PBL as a pedagogical approach for fostering WA11GAP-aligned competencies and suggest that structured reflection and intercultural collaboration play a key role in broadening students' competency development beyond their initial expectations.

5.4 RQ3: What learning experiences did participating students perceive as irreplaceable by AI?

In the both PBL programs described above, participating students were actively encouraged to make use of AI tools throughout the learning process. The rationale for this approach was that students from both countries are EFL speakers. In particular, many Japanese students lack confidence in spoken English and may hesitate to contribute verbally, which can lead to stalled communication and, ultimately, lost learning opportunities. To address this issue, students were first encouraged to articulate their ideas in their native language, then use AI tools to translate the content into English and read it aloud. The pedagogical intention was to reduce anxiety about speaking while simultaneously providing opportunities to learn accurate and context-appropriate expressions. In addition, students were encouraged to use AI proactively for technical and contextual support, including searching for information on Arduino applications, programming methods, unfamiliar tool usage, and the realities of disaster scenarios in Thailand. As a result, it was observed that students frequently used AI for translating into English, troubleshooting issues encountered during their first experiences with Arduino and robot programming, and preparing slides for the final presentation.

5.4.1 Analysis of the Latest AI Usage amongst Students

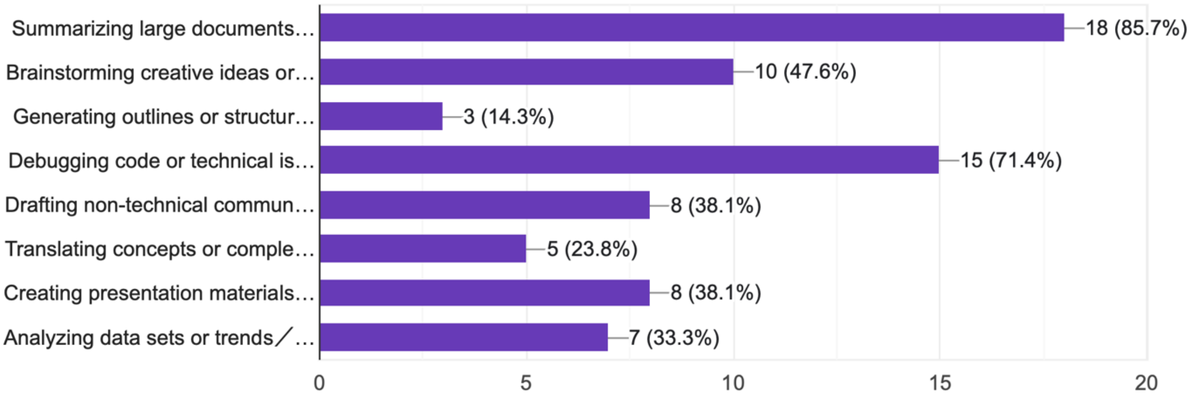
After the PBL2, a survey was administered to investigate how AI had been used. The qualitative survey items were structured to identify, within each category, the specific situations in which AI was used, the tools or outputs that were created, and the nature of the resulting products. These categories were designed with explicit reference to alignment with the (WA11GAP).

The survey categories are as follows:

1. Searching for technical information, such as Arduino-related knowledge and tool applications
2. Conducting problem analysis and deeper investigation, including understanding the realities of disaster scenarios
3. Designing solutions, such as exploring applications of disaster response robots
4. Supporting English communication and facilitating group work
5. Resolving difficulties encountered during intercultural exchange

As shown in the Figure 3, amongst 21 participants, they frequently used AI for “Summarizing large documents or research papers, translation” (85.7%), “Debugging code or technical issues” (71.4%), and “Brainstorming creative ideas” (47.6%). This also proved that they were utilizing AIs in multiple situations.

Figure 3. Uses of AI tools among participants (multiple responses allowed)



Here is a summary of the responses from participants.

- AI Tools for Coding & Debugging: ChatGPT, Claude, and Gemini were frequently used for coding, checking programming, and debugging, particularly with Arduino IDE.
- AI for Research, Information, and Language: ChatGPT and Gemini were commonly used for research, finding information, reasoning/logic discussions, and for both Japanese and English translation/sentence creation. DeepL and Google Translate were also used for translation.
- Design and Presentation Tools: Canva was a primary tool for presentation design. Gemini was also used for presentation design and image creation.
- Specialized Software and Hardware: Tools for mechanical design included SolidWorks and Fusion360 for 3D modeling, and 3D printers for fabrication. Arduino IDE was used specifically for server motor control and creating programs.
- General Assistance: ChatGPT and Gemini were utilized for generating ideas (e.g., robot ideas), improving reports, organizing ideas clearly, and simplifying text.

5.4.2 Discussion for RQ3: AI-Irreplaceable Learning Experiences

This study investigated what learning experiences students perceived as irreplaceable by AI in an international robotics-focused PBL program conducted in an EFL environment. The findings suggest that, while AI tools effectively supported translation and rapid access to technical information, students identified several learning experiences that remained fundamentally human-centered and could not be substituted by AI. These experiences are closely related to self-efficacy development, experiential learning processes, and social constructivist mechanisms of learning within multicultural teams.

1) Socially Negotiated Collaboration and Team Dynamics Beyond “Communication Skill”

In these PBLs, participants had initial motivation to improve [No. 9 communication] and [

No. 8 Individual and collaborative teamwork] from the beginning, and successfully improved through active learning program. In the PBL1, a notable result in the WA11GAP pre–post comparison was that the highest was [No.11 lifelong learning] (+0.44) while perceived gains were also large in [No.1 engineering knowledge (+0.30)] and [No.2 problem analysis

(+0.30)], and [No.6 The Engineer and the World]. The result of PBL2 also showed the similar characteristics that [No.2 problem analysis (+0.38)], [No.1 engineering knowledge (+0.33)], and [No.11 lifelong learning]. While it cannot be directly determined whether active AI usages have affected these results or not, at least it can be analyzed that the active AI usage did not negatively affect their communication ant teamwork acquisition. It can be also considered that the awareness of lifelong learning could be facilitated in combination with the interactive communication and teamwork activities, since AI may have negative influence on humans' curiosity.

Students' perceived "AI-irreplaceable" learning therefore appears to lie in the human dynamics of collaboration: building trust, assigning roles, negotiating constraints, and sustaining motivation under time pressure. These experiences align with Social Constructivism and Communities of Practice, where learning emerges through participation in shared practice rather than individual knowledge acquisition alone.

2) Development of Self-Efficacy Through Emotional and Behavioral Change

The program intentionally emphasized reducing anxiety and encouraging students to express opinions without hesitation. This design choice is consistent with Social Cognitive Theory, in which self-efficacy grows through mastery experiences, reflective processing, and social persuasion. AI translation tools may reduce language barriers, but they do not directly produce the emotional shift required for students to move from passive participation to proactive engagement.

Students' "AI-irreplaceable" experiences were likely associated with moments such as: presenting ideas despite fear of making mistakes, receiving feedback from peers, and recognizing that their contributions mattered in team progress. These experiences are intrinsically relational and context-dependent. Importantly, the program's daily activity reports likely amplified this effect by enabling students to externalize their experience, observe their progress over time, and enter discussions with prepared ideas—thereby lowering the threshold for participation as a mental hurdle. In this sense, AI may have supported communication, but the psychological transformation into a more confident participant was achieved through embodied practice and social interaction.

3) Authentic Engineering Judgment and Contextualization of Societal Problems

The substantial post-program increase in [No.6 The Engineer and the World (+0.25)] in the PBL1 suggests that students gained a stronger awareness of how engineering is embedded in societal contexts. In this program, disaster prevention served as an authentic theme requiring students to connect technical design decisions to realistic constraints, stakeholder needs, and contextual differences between Japan and Thailand.

AI can provide information about disaster risks or technical options; however, students perceived irreplaceable learning in making engineering judgments under ambiguity, such as determining which problems matter most, what trade-offs are acceptable, and how a design should be adapted to local realities. These competencies are not simply knowledge-based but involve values, responsibility, and situational awareness, which are central to WA11GAP and aligned accreditation criteria.

4) Experiential Learning: From Doing to Reflecting to Re-designing

Kolb's Experiential Learning Theory suggests that learning occurs through iterative cycles of experience, reflection, conceptualization, and experimentation. The program's structure—hands-on robotics work, daily reflective reporting, and discussion based on written records—enabled students to convert "activities" into "lessons learned" and "long-term learning."

From an AI perspective, tools can accelerate information retrieval and support drafting or translation. However, students perceived irreplaceable learning in the embodied and iterative nature of making: debugging hardware/software, coping with unexpected failures, negotiating team decisions, and iterating designs based on constraints. These processes generate tacit knowledge and practical wisdom that are difficult to replicate through AI-mediated simulation alone. Additionally, the hypothesis can be developed that the reduction of the time-consuming workload such as "summarizing large amount of documents" in English and "debugging code or technical issues" by AI assistance contributed to more time allocation to interactive communication and team works.

5) Implications: AI as Scaffold, Not Substitute, in Future Active Learning

Overall, the findings suggest a clear boundary between what AI can support and what it cannot replace. AI tools served as effective scaffolds for language mediation and knowledge supplementation, which likely contributed to the observed increase in Tool usage. However, students' irreplaceable experiences were centered on human factors: relational collaboration, self-efficacy development, and contextual engineering judgment.

This implies that effective active learning in the AI era should not treat AI as a threat to learning, but rather as a resource that reduces extraneous barriers so that students can engage more deeply in human-centered competencies. In international PBL contexts, this means intentionally designing learning activities where AI assists with translation or technical lookup while preserving—and even amplifying—situations requiring negotiation, responsibility, and interpersonal leadership.

6) Negative effect of the smartphone usage

Although not collected as quantitative data, an important concern observed during the study should be noted. In apparent parallel with the increasing use of AI, there has been a rapid rise in the number of students who, during group presentations, do not memorize and orally explain their assigned content but instead simply read text displayed on their smartphones. In many cases, this text appears to be AI-generated translations used by students who are less confident in English. This raises concerns that students are only reading text superficially without fully understanding the content, and that little of it is retained after the presentation. Therefore, it may be appropriate to prohibit the use of smartphones during presentations in the future.

7) Necessity of Dos and Don't's for AI usage in learning activities

It is obvious that we cannot avoid AI usage anymore. Students are more actively utilizing it much faster than teachers, who are also adopting AIs for their own research and teaching activities. Meanwhile, everybody is aware that AI is a double-edge sword that can enhance human capability and weaken the basic functions. This research indicated that the participants feel that they could improve communication and team work skills through self-evaluation. On the other hand, the observation of the final presentation revealed that too much dependence on smart phone deteriorated their performance as they tend to see a device screen and read the translation, which deterred them from eye-to-eye interaction with audience. Too much reliance on technology would degrade human essentials.

Thus, Dos and Don't's for AI usage in learning activities would be necessary. This could be our next research theme.

5.3 Limitation

A limitation of this study is that the findings rely primarily on self-reported survey responses and reflections, which may be influenced by social desirability bias and differences in students' interpretation of Likert-scale categories, particularly in an EFL and intercultural context. In addition, the sample size was limited to participants from a single program cycle, which may constrain generalizability across institutions, disciplines, or cohorts. The post-program group interviews were conducted with students who provided especially detailed survey responses, which may introduce a selection bias toward more reflective or highly engaged participants. Furthermore, some competencies may have been difficult for students to judge immediately after a short program, and missing responses in specific items (e.g., lifelong learning) limited direct pre–post comparison. Future work will address these limitations by expanding data collection across multiple cohorts, strengthening measurement validity through scale refinement and reliability checks, incorporating external or performance-based indicators (e.g., peer assessment, rubric-based evaluation of team outputs, observation logs), and systematically analyzing daily activity reports and interview transcripts to triangulate mechanisms of competency development.

6. Conclusion

This study examined learning outcomes in a Japan–Thailand bidirectional global PBL program focused on robotics for disaster-prevention applications. Using a mixed-methods approach, the study analyzed (i) students' initial motivations and expected outcomes (RQ1), (ii) intended and perceived acquisition of competencies aligned with the WA11GAP (RQ2), and (iii) learning experiences students perceived as irreplaceable by AI (RQ3). The program design intentionally emphasized intercultural teamwork in EFL setting, structured reflection through daily activity reports, and strategic use of AI tools to support translation and knowledge supplementation.

This study reinforces the value of PBL as an essential approach in engineering education in the AI era. While AI tools can effectively support translation and rapid access to technical information, they cannot replace the human-centered learning processes through which students develop teamwork, communication competencies, and lifelong learning awareness. Participation in the program provided students with first-hand experiences of coordinating tasks, negotiating meaning, and collaboratively solving problems in multicultural teams. These authentic interactions also enabled students to recognize—more deeply than before—why such competencies are indispensable for engineering practice.

Accordingly, a key implication is that educators should explicitly position teamwork and communication as central intended learning outcomes from the start of the program. By intentionally "making these outcomes visible" to participants at the outset—through clear framing, guidance on team roles, and expectations for active contribution—supervisors can further enhance students' engagement and strengthen the resulting competency development. In other words, the educational impact of PBL is maximized when instructors not only provide project tasks but also deliberately scaffold the social and psychological conditions that enable effective collaboration.

Moreover, adopting PBL as a form of problem-based learning around realistic societal challenges—such as disaster prevention—offers benefits beyond technical learning. Working on authentic problems requires students to confront constraints, uncertainties, and stakeholder considerations, thereby fostering engineering judgment that differs fundamentally from rote memorization of knowledge. Through this process, students can develop stronger awareness of broader professional attributes, including ethical responsibility and lifelong learning, as they come to appreciate that engineering solutions must be continuously refined in response to evolving real-world conditions.

Finally, interdisciplinary experiential learning environments such as this PBL program can strengthen students' self-efficacy by helping them overcome anxiety, contribute actively to teams, and experience success through iterative problem-solving. Increased self-efficacy, in turn, can motivate students to pursue further learning and to sustain engagement with real-world engineering challenges—supporting the development of lifelong learning orientations. Therefore, as AI becomes increasingly embedded in engineering practice, providing practical, collaborative, and context-rich PBL opportunities will become even more critical. By leveraging PBL more strategically, engineering educators can enhance not only learning effectiveness but also students' acquisition of accreditation-aligned competencies required for future engineers.

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