

IMPACTS OF CDIO FRAMEWORK IMPLEMENTATION ON OUTPUT PRODUCTIVITY AND INTERPERSONAL SKILLS DEVELOPMENT

Muhammad Arifin, Iman Fahruzi, Hendawan Soebhakti

Electrical Engineering Department, Politeknik Negeri Batam

Siti Noor Chayati

Informatic Engineering Department, Politeknik Negeri Batam

ABSTRACT

Universities and polytechnics under the Ministry of Higher Education, Science, and Technology in Indonesia are encouraged to generate tangible impacts for industry and society. This policy has been positively adopted by Politeknik Negeri Batam (Polibatam), which has implemented Project-Based Learning (PBL) within the Conceive–Design–Implement–Operate (CDIO) framework since 2021. Through this approach, students are actively involved in project work throughout all stages of their academic programs, from introductory to advanced levels. The implementation of PBL and the CDIO framework at Polibatam is expected to enhance both internal and external institutional impacts. Institutional records indicate that the adoption of PBL and CDIO has led to a substantial increase in output productivity, particularly in the number of registered intellectual property rights and published academic articles. In 2023, Polibatam recorded its highest outputs, with 196 intellectual property registrations and 110 academic publications. Since the initial implementation of PBL in 2018, these outputs have been expected to generate significant benefits for stakeholders and society. Several project themes directly engage external stakeholders, particularly through collaborative industry-based projects, which have produced measurable impacts for partners. Moreover, the integration of the CDIO framework with a strong emphasis on PBL has contributed to the development of students' interpersonal competencies, including communication and teamwork skills. Feedback from 52 industries employing Polibatam graduates indicates that graduates' communication and teamwork skills are predominantly rated as excellent or good, with a notable improvement observed following the implementation of PBL and CDIO.

KEYWORDS

Project-Based Learning, CDIO Framework, Tangible Impacts, Interpersonal Skills, Standards: 1-5, 7, 8, 12.

INTRODUCTION

Higher education in Indonesia, including both academic and vocational institutions, plays a crucial role in developing human resources to support national strategic goals, such as the Golden Indonesia 2045 vision (Sasrawan, 2025). Indonesian higher education institutions are mandated to fulfill three core functions—education, research, and community service—known as the Tri Dharma of Higher Education (Std.1). In line with national policy, the Ministry of Higher Education, Science, and Technology emphasized in 2025 that universities and polytechnics must generate measurable impacts for industry and society, advancing educational quality, producing competent graduates (Std.2), and delivering applied outputs that benefit external stakeholders.

Politeknik Negeri Batam (Polibatam), as a public higher education institution, actively supports government-led strategic programs while contributing to industry and community development. With four departments and 25 study programs, Polibatam has strengthened its impact through Project-Based Learning (PBL) (Std.5, 8) with the Conceive–Design–Implement–Operate (CDIO) framework. PBL is one of learning methods having been implemented at several study programs at Polibatam. Other applied learning methods are case methods, problem-based learning, and competency-based learning. Nonetheless, PBL is as a major learning method at Polibatam. PBL was first introduced in 2018 in the Robotics Engineering program with 14 projects and expanded to 10 programs with 293 projects by 2020. Since then, Polibatam has positioned itself as a “Kampus PBL,” reflecting the broad adoption of project-based initiatives across programs.

In 2020, the Robotics Engineering program formally adopted the CDIO framework to systematically guide PBL, align projects with curriculum outcomes (Std.2), and enhance learning effectiveness. By 2022, 17 study programs implemented PBL, comprising 271 internal and 87 external collaborative projects. The PBL Expo, first held in 2021 and repeated in 2022, provides a platform for students to showcase products and services developed through project activities, fostering innovation and professional skills.

Polibatam became an official CDIO member following the 2022 Asian Regional Meeting hosted by Singapore Polytechnic. The integration of PBL and CDIO has enabled more structured and effective learning processes (Std.7) (Pee & Leong, 2005), optimizing educational outcomes and generating tangible benefits for both the institution and its stakeholders. Moreover, this approach has strengthened students' interpersonal skills (CDIO Syllabus 3), particularly teamwork and communication, through systematic engagement in collaborative, project-based learning (Säisä et al., 2017). Collectively, these initiatives demonstrate Polibatam's commitment to producing highly competent graduates, fostering innovation, and delivering measurable impacts to industry and society.

POLIBATAM EDUCATIONAL MODEL

As a vocational higher education institution, Politeknik Negeri Batam (Polibatam) has institutional vision and mission as shown in Table 1.

Table 1. Polibatam's Vision and Mission

Vision	Mission
Become A New Generation Polytechnic That Is Excellent, Adaptive, Innovative, And Globally Competitive, With A Strong Connection to Industry and Society to Support a Progressive and Prosperous Indonesia	Active in the Process of Creating, Disseminating, and Applying Science and Technology Through High-Quality Vocational Higher Education Services and Applied Research That Is Open, Relevant, and Closely Collaborates with Society and Industry, with the Implementation of Good Institutional Governance for a Better National Life

Polibatam's educational model centers on professional training and certification, supported by an integrated curriculum (Std.3) that develops disciplinary, personal, professional, and interpersonal skills alongside product and service creation. This curriculum is built on four pillars: a business and industrial mindset, social and community engagement, sustainable development, and innovative pedagogy, the latter reinforcing Polibatam's identity as a "Kampus PBL." These pillars are guided by the institutional motto, "Double Action." Together, this model underpins Polibatam's strategic objectives of good governance, strong industry partnerships, applied research, and creative innovation (Figure 1).

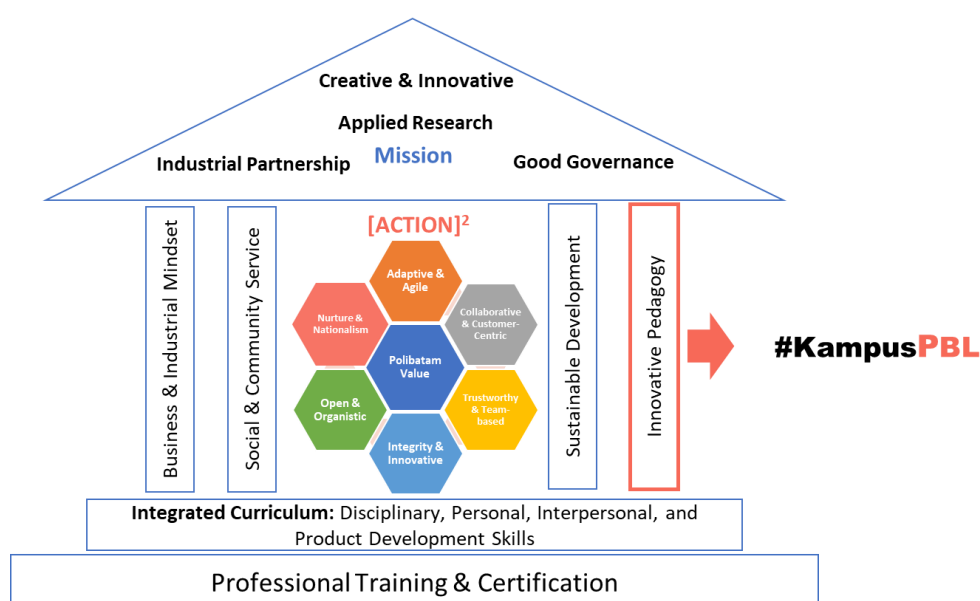


Figure 1. Polibatam Educational Model.

Politeknik Negeri Batam (Polibatam), as one of Indonesia's Institutions of Higher Learning (IHLs), fulfills three core mandates known as the Tri Dharma. These mandates are supported by established good practices at Polibatam and by key actors in PBL implementation, including lecturers, students, and industry partners. Such collaboration has fostered innovation at Polibatam, leading to the development of its identity as a "Kampus PBL." At Polibatam, PBL is interpreted not only as Project-Based Learning but also as a broader

concept encompassing projects, problems, and other contextually relevant meanings. These innovations are expected to generate substantial impacts for industry and society, as illustrated in Figure 2.

The anticipated impacts, outputs, or outcomes include tangible products and services directly beneficial to industry and the community, scholarly publications, and intellectual property outputs such as copyrights, patents, and industrial designs. Additionally, students experience direct benefits through the enhancement of interpersonal competencies, particularly teamwork and communication skills (CDIO Syllabus 3).

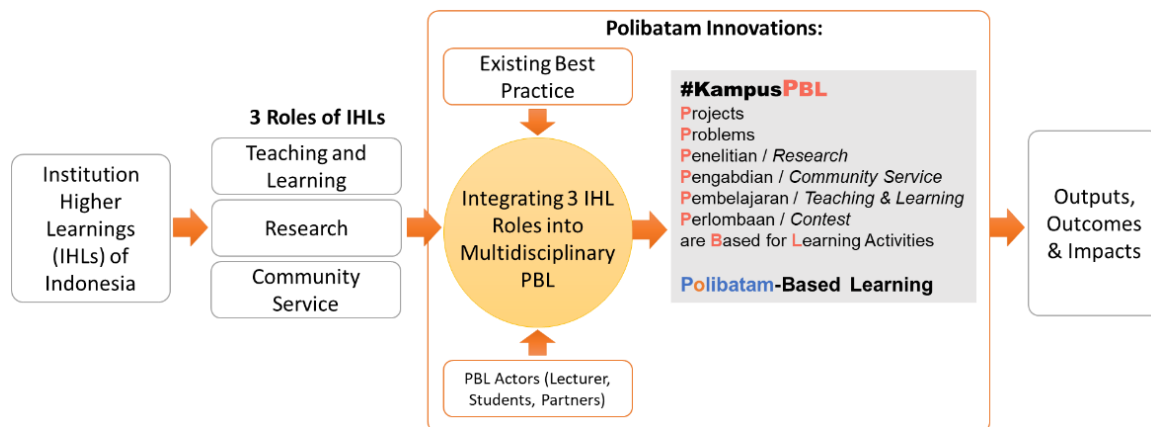


Figure 2. Integration of the Three Core Roles of Higher Education Institutions into PBL.

IMPACT ANALYSIS OF CDIO FRAMEWORK IMPLEMENTATION

Polibatam has pursued initiatives to enhance graduate quality and institutional contributions to society since its establishment in 2000. However, evaluations conducted prior to 2017 indicated that Polibatam's outputs remained limited, as many lecturers and students demonstrated low awareness of scholarly and innovation outputs, including journal publications, patents, copyrights, and industrial designs. This condition was largely attributed to the predominance of conventional, lecturer-centered teaching methods. In 2017, the Robotics Engineering study program initiated the implementation of PBL as a student-centered learning approach. Since then, learning activities across Polibatam have increasingly adopted PBL, with targeted outputs encompassing products, services, scientific publications, patents, copyrights, and industrial designs.

In the implementation of PBL, each project team is assigned responsibility for completing projects aligned with the disciplinary focus of its respective study program, with interdisciplinary collaboration applied depending on project complexity (Std.5). Project team sizes vary, typically comprising two to more than four students. Throughout the project process, students are encouraged to generate ideas and propose solutions to the assigned problems. Project topics are derived from both internal and external sources (Takemata *et al.*, 2013). Internal projects generally originate from lecturers' research activities, study programs, and Polibatam's Centers of Excellence (CoE), whereas external project topics are proposed by industry and community partners. In some cases, Polibatam teams engage directly with industry and community stakeholders to identify real-world problems, which are subsequently addressed through PBL activities. Between 2023 and 2025, approximately 16 partners participated in PBL implementation, representing industrial, governmental, academic, and

technology sectors. Moreover, student projects were not limited to industry-based initiatives but also addressed internal institutional needs, competitions, student activities, lecturers' research, community service programs, and entrepreneurial endeavors. The distribution of project topics across these categories is presented in Table 2.

Table 2. Distribution of Project Numbers by Category.

No.	Project Category	2023/2024 Academic Year		2024/2025 Academic Year	
		Fall	Spring	Fall	Spring
1	External Needs	92	65	51	90
2	Internal Needs	292	460	337	566
3	Competition	97	125	80	213
4	Student Activity	5	6	13	23
5	Research	103	110	88	147
6	Community Service	50	49	36	57
7	Entrepreneurship	13	9	13	6

The CDIO framework provided structured guidance for study programs in managing teaching and learning processes and PBL activities. Subsequently, other study programs were encouraged to implement the CDIO framework. The integration of PBL within the CDIO framework has produced significant impacts on lecturers, students, the institution, and external partners (Std.3, 5, 7). One of the impacts is intellectual property outputs, which have been generated by Polibatam lecturers and students as illustrated in Figure 3.

Figure 3(a) shows that in 2017 and 2018, the number of registered intellectual property rights was relatively low. This condition can be attributed to several factors, including a smaller student population, lower levels of lecturer motivation, and the predominance of traditional teaching approaches that did not actively involve external stakeholders in the learning process.

However, from 2019 to 2025, the number of registered intellectual property rights increased significantly, reaching a peak in 2023 with 196 submissions. This upward trend is closely associated with the implementation and expansion of project-based learning (PBL) at Polibatam. The increase in intellectual property outputs can therefore be partially attributed to PBL activities, consistent with findings reported by Guo et al., which highlight the role of PBL in generating tangible learning outputs.

Nevertheless, the increase in intellectual property registrations cannot be attributed solely to the implementation of project-based learning (PBL). Several additional factors have likely contributed to this trend, including the expansion in the number of faculty members and students, as well as institutional incentive schemes provided by the management, particularly for those who successfully secure granted intellectual property rights. The student population

at Polibatam grew substantially from approximately 4,911 in 2019 to 13,374 in 2025, accompanied by a corresponding increase in the number of lecturers. This expansion likely facilitated greater engagement in PBL activities and, consequently, a higher volume of outputs. Furthermore, incentive mechanisms may have encouraged faculty members to more actively prepare and submit intellectual property applications. Collectively, these factors have played a significant role in the observed increase in intellectual property registrations affiliated with Polibatam. The detailed distribution of intellectual property authorship is further disaggregated into copyrights, patents (including utility patents), and industrial designs, as presented in Figure 3(b). In the Indonesian context, intellectual property rights are of considerable importance for lecturers, students, and institutions, as they support lecturers' career advancement, serve as recognized artefacts for students in specific courses, and contribute to enhancing institutional reputation.

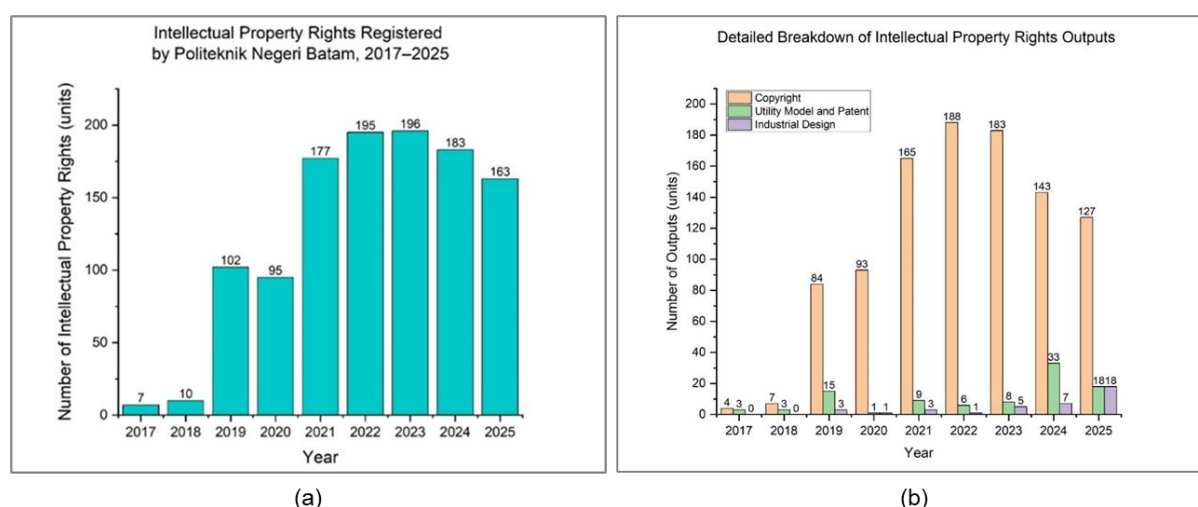


Figure 3. (a) Distribution of Intellectual Property Rights Generated by Lecturers and Students, and (2) the detailed breakdown of intellectual property rights outputs

Journal articles constitute another important output of the teaching and learning process. In this study, the total number of academic publications is treated as an artefact of problem-based learning (PBL) activities, given that PBL is integrated not only into teaching and learning but also into research. As shown in Figure 4, journal publications recorded in the SINTA database of the Ministry of Higher Education, Science, and Technology display a fluctuating trend. The number of publications peaked in 2019 with 110 articles, declined to 20 in 2022, rose again to 78 in 2023, and decreased to 34 in 2025. Despite these fluctuations, the overall average remains higher than in the pre-2018 period.

A notable decline occurred between 2020 and 2022, with publications reaching their lowest point in 2022. This decrease may be attributed to the COVID-19 pandemic, during which teaching and learning processes were significantly disrupted. Following the easing of the pandemic, publication output increased to 78 articles in 2023, although this upward trend was not sustained in the subsequent two years, with output declining to 34 articles in 2025.

Similar to the trend observed in intellectual property rights, the annual number of academic publications is influenced by multiple factors. The primary driver is the integration of PBL into the curriculum and instructional practices, which requires students to develop innovative solutions to real-world problems derived from PBL topics. Furthermore, the submission of journal manuscripts has been incorporated as a component of student assessment,

encouraging students to prepare article drafts during the completion of PBL projects. In addition, institutional factors play a significant role. Polibatam, through its Center of Research and Community Service, has implemented a policy providing incentives for lecturers who publish in nationally and internationally reputable journals. This policy has encouraged collaborative publication efforts between lecturers and students during and following PBL activities.

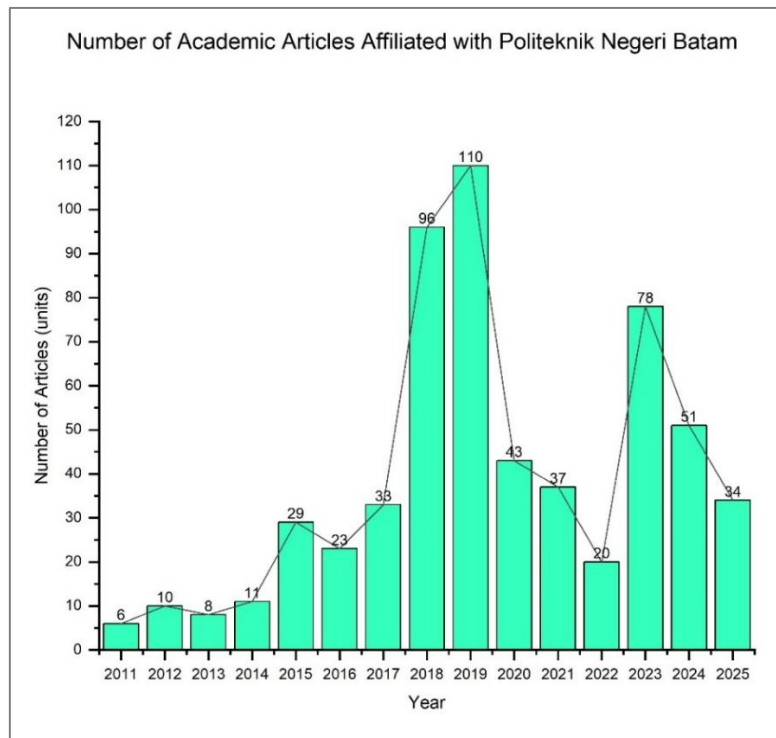


Figure 4. Total number of academic publications affiliated with Politeknik Negeri Batam.

Another observable impact of CDIO implementation is the improvement of students' interpersonal skills, particularly teamwork and communication (Deveci & Ayish, 2018). Through the widespread adoption of project-based learning within the CDIO framework, most students at Polibatam participate in project teams with assigned roles, such as team leaders and members. In addition to achieving project objectives, students implicitly develop teamwork and communication skills through continuous interaction, discussion, and collaborative problem-solving within their projects (Crespi et al., 2022).

Communication skills are developed not only through spontaneous interactions during project work but also through frequent opportunities to present project progress to peers and faculty serving as facilitators or project managers. Additionally, students are required to prepare project plans, periodic progress reports, and final reports using the "SIAP PBL" application. As students engage in projects almost every semester, these interpersonal skills are expected to be reinforced and internalized, providing lasting benefits for their future professional work.

Input and evaluations from industry stakeholders and users

Interpersonal skills, particularly teamwork and communication, are critical competencies for Polibatam graduates in the workplace. Through the implementation of project-based learning (PBL) and the Conceive–Design–Implement–Operate (CDIO) framework, Polibatam

systematically fosters the development of these skills, including proficiency in both Indonesian and English. This approach is consistent with findings reported by Dampierre et al. (2024) in their review study.

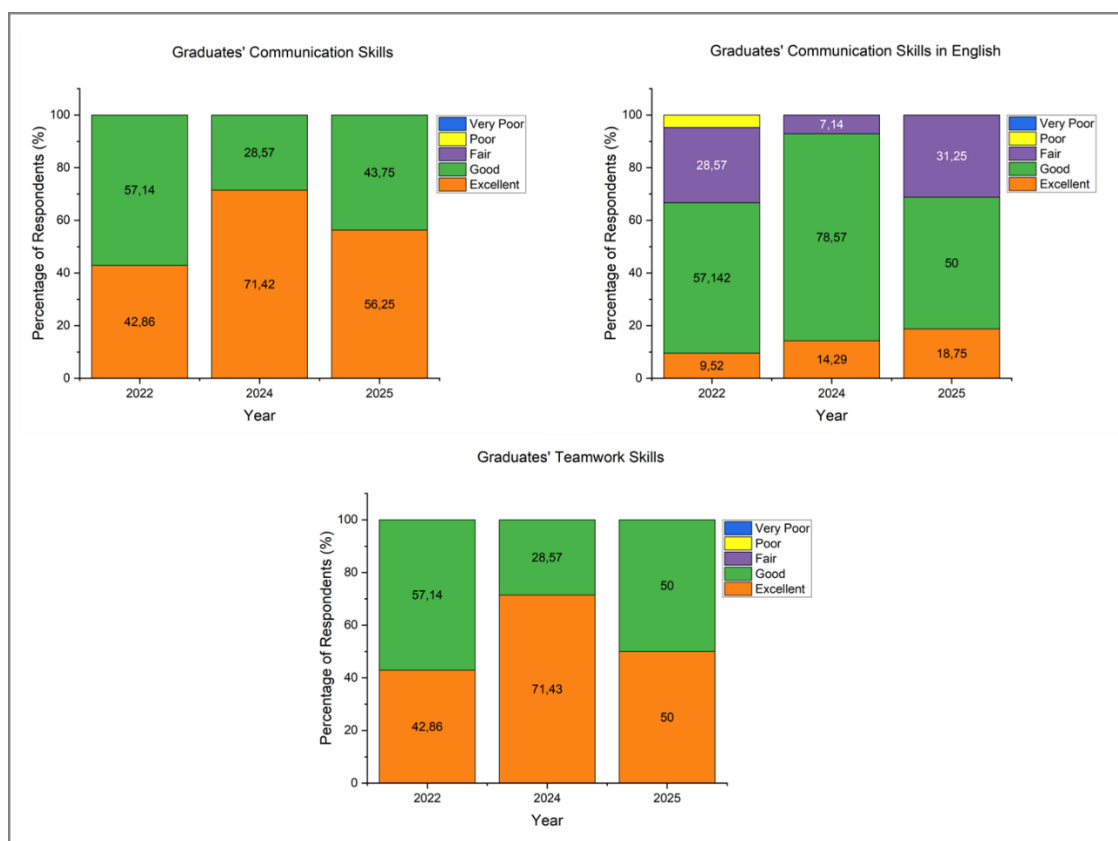


Figure 5. The communication, English communication, and teamwork skills of graduates, as evaluated through surveys conducted with industry stakeholders.

Survey data collected by the Career Development Center (CDC) in 2022, 2024, and 2025, involving approximately 52 company respondents, indicate that alumni demonstrate strong capabilities in teamwork and communication. These competencies show a consistent upward trend over the observed period, as illustrated in Figure 5. The surveyed alumni had graduated at least one year prior to participation, implying that the 2024 and 2025 data reflect graduates from 2023 and 2024, respectively. Notably, nearly all respondents had been engaged in PBL activities during their studies, particularly between 2019 and 2024.

Overall, the survey results classify alumni interpersonal skills predominantly within the “good” to “excellent” categories. These outcomes suggest that the integration of PBL into the curriculum has contributed positively to the development of interpersonal competencies prior to graduation from Polibatam.

CONCLUSION

The implementation of Project-Based Learning (PBL) in conjunction with the CDIO framework at Polibatam has had a substantial impact on both internal stakeholders and external partners, including industry and the broader community. PBL activities are integrated across nearly all study programs, beginning in the first year (Std. 4) and continuing through to final-year

capstone projects (Std. 5). This approach has contributed to a notable increase in academic outputs, particularly in intellectual property (IP), including copyrights, utility models, patents, and industrial designs, as well as scholarly publications. The number of registered IP outputs at Polibatam rose significantly, reaching a peak of 196 in 2023. Although the number of academic publications also increased overall, a slight decline was observed after 2020, followed by a recovery in 2023, potentially reflecting the impact of the COVID-19 pandemic. In addition, PBL has played a key role in enhancing students' interpersonal competencies. Feedback from industry partners indicates that Polibatam graduates exhibit strong interpersonal skills, with 71.42% rated as excellent in communication and 71.43% in teamwork in 2024.

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GPT-5.2 was employed in the review process of this paper, particularly for the Areas for Improvement section. The model was used to assist in synthesizing selected literature identified through the author's independent, manual keyword searches conducted via Google. Based on this input, the author composed the relevant sections using their own original wording and critical interpretation. The prompts submitted to the model and the corresponding responses are provided in this link: <https://bit.ly/4n19hXE>.

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BIOGRAPHICAL INFORMATION

Muhammad Arifin is the Coordinator of the Electronics Manufacturing Engineering Study Program at Politeknik Negeri Batam. He leads the curriculum development team and the institutional CDIO Taskforce, guiding multidisciplinary departments in the adoption of CDIO and Outcome-Based Education. His work focuses on aligning engineering education with institutional strategy and industrial standards.

Iman Fahrudi is the Head of the Research and Community Services Center at Politeknik Negeri Batam. In this role, he oversees and coordinates research and community service activities conducted by faculty members and students, and administers internal competitive funding schemes for research and community engagement at Polibatam. He is also a lecturer in the Department of Electrical Engineering, with research interests in electrical engineering, biomedical devices, sensors, and signal processing.

Siti Noor Chayati is the Head of the Career Development Center (CDC) at Politeknik Negeri Batam. In this capacity, she leads the management of student internships, oversees internship activities in industry, initiates collaborations with external stakeholders, and conducts surveys of alumni and industry partners. She also serves as a lecturer in the Geomatics Engineering Study Program, with research interests in geomatics engineering and surveying.

Hendawan Soebhakti is an Assistant Professor in Robotics Engineering Technology and Expert Staff to the Vice Director for Academic Affairs at Politeknik Negeri Batam. He is a lead driver of Project-Based Learning (PBL) and the CDIO framework, overseeing the institutional CDIO Taskforce. His pedagogical interests include robotics for STEM education, while his research focuses on autonomous mobile robots and industrial automation.

Corresponding author

Hendawan Soebhakti
Politeknik Negeri Batam.
Electrical Engineering Department.
Ahmad Yani Street, Batam City, Riau
Islands, Indonesia 29461
hendawan@polibatam.ac.id



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