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Strategic Human Capital Development for Maritime Infrastructure through Enhanced CAD Competency in Vocational Education

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ABSTRACT – The Indonesian maritime industry faces a critical human capital paradox, where a surplus of vocational graduates exists alongside persistent difficulty among shipyards in recruiting personnel capable of executing modern Product-Oriented Work Breakdown Structure and digital drafting workflows. This study investigates this disconnect through the pilot implementation of an Applied CAD for Maritime Engineering curriculum at a partner vocational high school, SMKN 5. Using a Guided Replication methodology, the intervention bridged the gap between theoretical software knowledge and industrial application by emphasizing parametric modeling and design-for-production logic. The results show that student aptitude is high, as evidenced by the rapid acquisition of three-dimensional modeling skills, while the national vocational infrastructure remains critically unprepared. The study identified a significant technological readiness gap in which existing school hardware was unable to support industry-standard software, requiring external technical intervention. These findings indicate that closing the maritime skills gap requires more than curriculum reform alone, but also necessitates fundamental improvements in school computing infrastructure and a pedagogical shift from software-centric instruction toward production-centric learning. This research proposes a scalable framework for integrating industrial competencies into vocational education to support the long-term development of Indonesia’s maritime workforce.

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INTRODUCTION

The global maritime engineering market is currently defined as "candidate-led." According to the Faststream Naval Architecture Employment Report 2025, 64% of early-career professionals planned to change jobs in 2025, driven by a global shortage of talent capable of managing decarbonization projects [1]. However, in Indonesia, this global shortage is exacerbated by local economic policies. While the global industry struggles with an aging workforce, Indonesia struggles with retention. As reported by IPERINDO (Indonesian Shipbuilding and Offshore Association) during their 2025 National Working Meeting (Rakernas), the domestic industry faces a critical inability to staff the projected construction of 3,000 new fishing vessels and 1,684 commercial renewals required by the government [2].

The primary variable making recruitment difficult in Indonesia is the asymmetric competition from the extractive industries. Recent findings indicate a massive "brain drain" of engineering talent toward the downstreaming agenda. Recruitment data suggests that mining site engineers in Sulawesi or Kalimantan command salary premiums of 30–50% over shipyard project engineers in Batam or Java [3]. Shipyards, often operating on thinner margins due to competitive state tenders, cannot match these packages. Consequently, many Naval Architecture graduates pivot to other field immediately upon graduation instead of direct shipyard project as shown in Figure 1 [1].

For the talent that remains in the maritime sector, a significant quality Study by Isbah et al [4] highlights that while the quantity of vocational graduates is sufficient, their specific technical competencies are lagging. Furthermore, study by Barasa et al., [5] utilized semi-structured interviews with industry professionals. It found notable deficiencies in applied digital skills as in proficiency in modeling software, and green propulsion. Furthermore, IPERINDO members report that fresh graduates effectively require 6 to 12 months of on-the-job

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retraining before they are operationally profitable, discouraging shipyards from hiring junior engineers and intensifying the war for the few available Senior engineers [6].

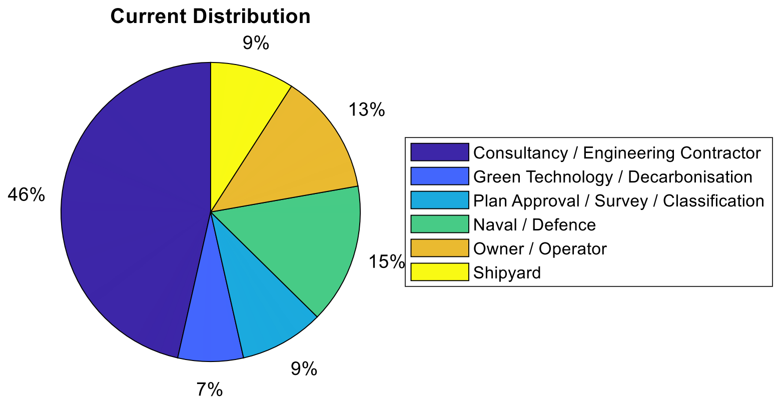

Figure 1. Work distribution of naval architects' employment 2025

A critical failure in the current Indonesian education pipeline is the confusion between general drafting and specialized marine design. Study by Saputra et al., [7] indicate that while Vocational Schools (SMK) and universities successfully teach 2D drawing plan, the teaching of drafting process, Parametric 3D, and Digital Twin software used by modern shipyards were almost entirely fail. According ILO reports [8], Indonesia's national curriculum suffers from a 3–5 year update lag. The report notes that while the industry has moved toward Digital Twin manufacturing (where the ship is built virtually before physically), many vocational curricula still focus on manual drafting techniques or outdated 2D license-free software due to the high cost of enterprise licenses (often >$20,000/seat) which schools cannot afford. Moreover study by Anisah et al., [9] stating that vocational graduates in construction and engineering often face a shock upon entering the workforce because the software they mastered in school was obsolete by the time they graduated. A deeper structural issue state that the lecturers and teachers themselves often lack exposure to modern shipyard workflows [4]. Because senior engineers intend to work in mining, the teachers remaining in the academic sector often have little to no recent industrial experience. Consequently, students are taught "theoretical CAD" drawing shapes without understanding the production logic (e.g., weld allowances, nesting optimization) that the software is supposed to solve.

In response to these structural gaps between industry demand and educational supply, this study presents a targeted capacity-building program aimed at improving marine CAD competency among vocational students through the redesign of drafting and planning subject content. The program was implemented as a case study at a vocational school in Balikpapan, East Kalimantan which is a strategic hub for Indonesia's naval engineering and offshore activities, yet one where educational resources, software access, and industry-aligned competencies remain limited. The study adopts a participatory approach, combining structured discussions with teacher teams to align learning outcomes with contemporary shipyard workflows, alongside hands-on CAD practices conducted directly with students. Qualitative insights were further strengthened through interviews with teachers and students to evaluate existing competency gaps, learning barriers, and program effectiveness.

STUDY LITERATURE

2.1 Ship Industry and Human Resources Requirement

Modern ship production has fundamentally shifted away from system-oriented construction (building a ship room-by-room) to Product-Oriented Work Breakdown Structure (PWBS). As defined in the foundational texts of ship production, PWBS applies the principles of Group Technology to subdivide a vessel into manageable interim products (blocks and modules) that can be manufactured in parallel, independent of the ship's final erection site [10].

Effective PWBS execution requires a rigorous breakdown of work (Work Breakdown Structure) aligned with the physical breakdown of the ship (Product Breakdown Structure). Research highlights that shipyards utilizing a well-defined PWBS can significantly reduce man-hours by optimizing the Hull Block Construction Method (HBCM). A comparative analysis of shipyard practices demonstrates that best practice involves a specific logic in defining interim products such as double-bottom blocks to maximize standardized work and minimize unique, labor-intensive tasks [11].

While global leaders in shipbuilding have fully integrated PWBS, the Indonesian maritime sector is currently in a transitional phase. A 2024 study on medium-sized Indonesian shipyards indicates that the industry is striving to adopt these methods to meet the demand for complex vessels, such as Mini LNG carriers [12]. However, the implementation of PWBS in Indonesia is hindered by gaps in "Orgaware" (organizational structure) and "Inforware" (information systems). While basic block erection sequences are generally understood, the sophisticated integration of design, engineering, and manufacturing facilities often lags. The capability to execute PWBS is not just about having cranes and docks ("Technoware"); it requires a systemic synchronization where engineering designs are assigned specifically to manufacturing system levels, which is a practice that is still being refined in domestic yards.

The most critical bottleneck identified in the literature is not merely equipment, but "Humanware" is the competence and skills of the workforce. The transition to PWBS and Industry 4.0 requires professionals far more specialized than traditional manual laborers. Complex Planning & Engineering: The industry does not just need welders; it needs engineers capable of "non-routine decisions with low physical effort" but high intellectual output. These professionals must understand the intricate logic of block assembly and creating "interim products" rather than just interpreting a general arrangement drawing [12]. Digital & AI Proficiency: As shipyards evolve into "Smart Shipyards," the human resource requirement shifts toward digital literacy. Recent studies discuss the integration of AIoT (Artificial Intelligence of Things) for real-time dispatching of shipyard transporters. This implies a desperate need for a new breed of shipbuilders: those who can operate within a digital twin environment, manage data-driven logistics, and maintain complex automated systems [13].

Drafting in naval architecture is hierarchical. It begins with the definition of the hull form and cascades down to the cutting instructions for a single steel plate. According to Eyres & Bruce [14], the foundational document is the Lines Plan, which defines the 3D curvature of the hull in 2D projections (Profile, Body Plan, and Half-Breadth Plan). Without an accurate Lines Plan, no other drafting can occur. This is followed by the General Arrangement (GA), which allocates space for cargo, machinery, and accommodation. These are referred to as "Key Plans" and are primarily used for Classification Society approval and owner verification.

Once the form is defined, the drafting focus shifts to structural integrity. The Midship Section and Construction Profile drawings detail the "scantlings" the dimensions of frames, girders, and plating thickness. Molland [15] notes that traditional drafting focuses on the "System View" (e.g., a drawing of the Fire Main system running through the whole ship). However, modern drafting for production requires a "Zonal View" (e.g., a drawing of just the Fire Main pipe segments that exist inside Block 101). This requires the drafter to understand not just the system, but the physical boundaries of the production blocks.

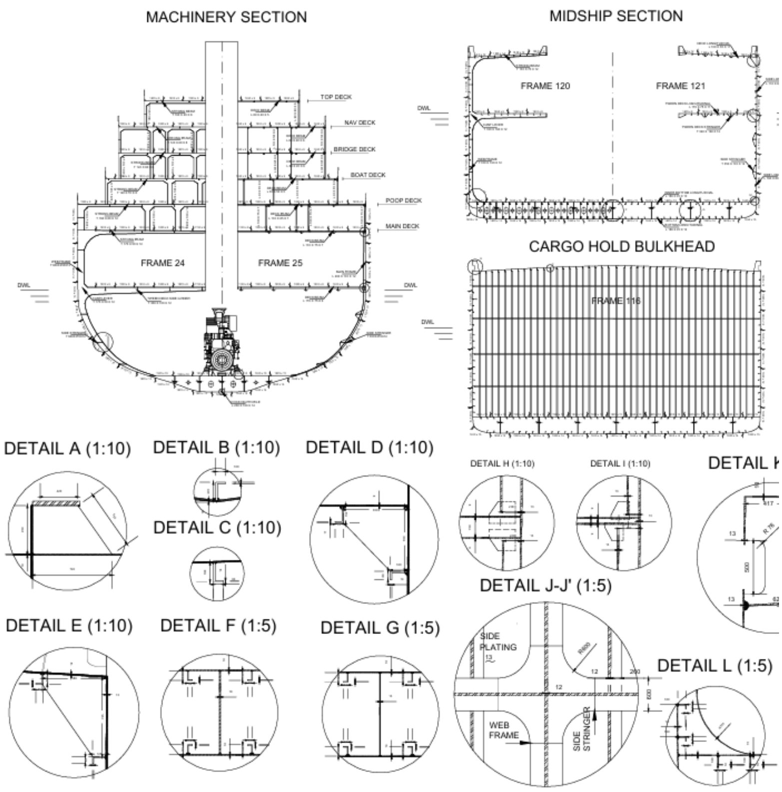

Figure 2. Ship drafting illustration (construction plan)

A critical evolution in this field is the transition from Computer-Aided Drafting (CAD) to Computer-Aided Manufacturing (CAM). Traditional Drafting (2D) Uses software like AutoCAD to draw lines that represent steel. The output is a printed paper drawing. Modern Modeling (3D) Uses software like Aveva Marine, ShipConstructor, or Cadmatic. Here, the engineer does not "draw" a plate; they "model" a 3D object with attributes (weight, material grade, center of gravity). As described in the SNAME Ship Design and Construction guide, modern drawings are merely 2D "views" generated from a live 3D database. If the 3D model changes, the drawings update automatically. This reduces interference errors (e.g., a pipe running through a steel beam) which are common in manual 2D drafting [16]. The ultimate goal of the drafting process is the Nesting Plan. This is where the specific shapes of brackets, floors, and webs defined in the engineering drawings are arranged onto a raw steel plate sheet to minimize waste. Effective nesting requires a drafter to understand CNC (Computer Numerical Control) logic specifically burning margins (allowance for material lost to the cutting torch) and thermal distortion prevention. A drawing plan that does not account for these production realities will result in parts that do not fit during assembly [17].

2.2 Vocational High School and Engineering Education Curilcullum

A primary challenge in current Engineering Education is the misconception that access to hardware equals competency. A 2025 study on technology literacy in Indonesian Vocational Schools (SMK) reveals that while many institutions have invested in computer labs, students' actual Technology Literacy specifically in Computer-Aided Design (CAD) remains uneven. Saputra et al., [7] identify that technology literacy consists of three dimensions: technological knowledge, critical thinking/decision making, and technical skills. Their findings indicate that while students may score high in basic operation (technical skills), they often struggle with the critical thinking aspect required to troubleshoot design errors or adapt to new software interfaces. This suggests that the current curriculum focuses too heavily on "tool usage" (clicking buttons) rather than engineering logic.

The rigidity of the traditional vocational curriculum exacerbates the skills gap. While the industry moves toward Industry 4.0 technologies like Digital Twins and AIoT, the academic curriculum often remains static. Obsolescence of Tools as noted in parallel research by Anisah et al. [9], there is a phenomenon of "technological shock" where graduates enter the workforce only to find the software they mastered is no longer the industry standard. The curriculum often fails to update quickly enough to include parametric modeling or cloud-based collaboration tools. The "Merdeka" Curriculum Opportunity as state by Saputra et al. [7] highlight that the Merdeka Belajar (Freedom to Learn) curriculum offers a pathway to fix this by allowing more flexible, project-based learning. However, the success of this is heavily dependent on the Self-Directed Learning capability of the student, which the study found to be a weak point in many private vocational schools. Effective engineering education requires a transition from theoretical knowledge to applied competence. In the specific context of maritime and construction engineering, the curriculum often teaches CAD as an art form rather than a production instruction. Students are taught to draw lines that "look like a ship," but are rarely taught the production constraints (such as material nesting or welding access) that dictate how those lines should be drawn . The bottleneck is often the educators themselves. If teachers lack recent industrial exposure, they cannot impart the "tacit knowledge" of the industry. This results in graduates who possess "certified skills" but lack "job readiness".

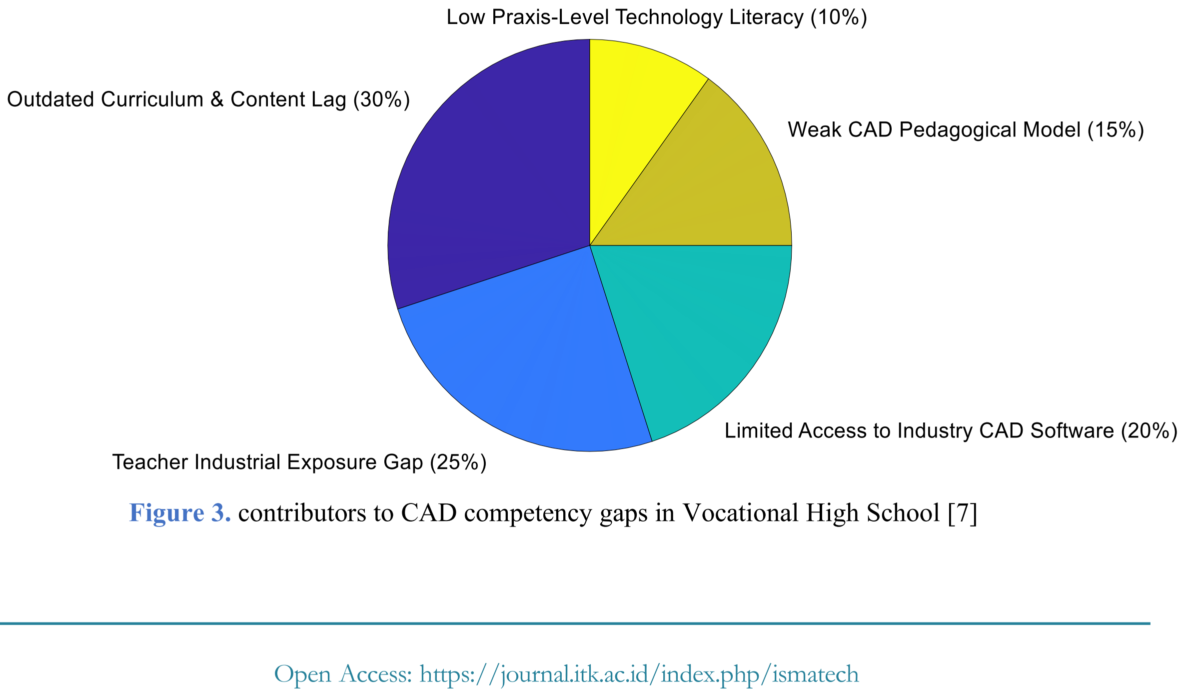

Figure 3. contributors to CAD competency gaps in Vocational High School [7]

The literature suggests that for Indonesia to meet its human resource requirements for the shipbuilding and engineering sectors, the SMK curriculum must pivot from a "Software-Centric" approach (teaching how to use CAD software) to a "Problem-Centric" approach (teaching how to solve engineering problems using CAD). This requires not only infrastructure upgrades but a fundamental shift in instructional models to foster the "critical thinking" dimension. As shown in Figure 3, The dominant contributors to CAD competency gaps in SMK are structural rather than motivational. Curriculum obsolescence and limited teacher exposure to modern industrial workflows account for more than half of the total impact. Infrastructure and software access further compound the issue, while student motivation and facilities play a comparatively minor role. This indicates that improving CAD outcomes in vocational schools requires curriculum redesign, teacher upskilling, and workflow-oriented CAD instruction, rather than merely increasing facilities or student motivation [7].

2.3 Computer Aided Design in Naval Architecture and Engineering

Despite the rise of 3D modeling, 2D drafting remains the backbone of schematic design (P&ID, electrical diagrams) and General Arrangement (GA) plans. However, professional naval drafting requires adherence to strict data management standards often overlooked in education. The efficiency of a drawing is determined by "Layer Management" and "Block Attribute" discipline [18]. In shipbuilding, this is critical because a single vessel contains millions of parts. Unlike architectural CAD (which may use arbitrary origins), Naval CAD must strictly utilize the World Coordinate System (WCS) where the origin (0,0,0) is typically defined at the intersection of the After Perpendicular (AP) and the Baseline (BL) . Moreover, Autodesk guidelines emphasize using Xrefs to allow multiple engineers to work on different deck levels simultaneously while referencing a master hull outline. This "Collaborative Design" workflow is a specific competency often missing in vocational training, where students typically draw "static" files in isolation.

Modern shipyards have moved beyond "drawing lines" to "modeling objects." In this workflow, a structural member (e.g., a longitudinal stiffener) is not defined by drawn lines, but by parameters (profile type, material grade, start/end coordinates). This shift changes the definition of "drafting." The drafter is no longer responsible for the visual representation but for the database integrity. The 2D drawings (cutting plans, assembly drawings) are merely "reports" generated automatically from this 3D database. If the model is modified, all associated drawings update instantly, eliminating the "interference errors" common in manual 2D drafting.

The cutting edge of Naval CAD is the Digital Twin. Thw modern CAD environment could be described as an ecosystem where the design model feeds directly into Computer Aided Engineering (CAE) for Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD). In this context, "drafting" includes assigning Metadata to CAD objects. For example, a pipe in a CAD model is not just a cylinder; it contains data on pressure ratings, flow rates, and maintenance schedules. This allows the CAD model to be used not just for construction, but for the vessel's entire lifecycle maintenance, aligning with the "Smart Shipyard" concept (Industry 4.0) [19].

A significant disconnect exists between academic instruction and industrial necessity. Strljic et al. (2024) note that while education focuses on Geometry (how to draw the shape), the industry requires Information (how to manage the data behind the shape). Vocational graduates often master the "Command Line" of software like AutoCAD but fail to understand Design for Production (DfP) logic such as adding shrinkage allowances to CAD data to account for welding heat distortion, a standard practice in shipyard CAD offices [20].

PROGRAM IMPLEMENTATION

3.1 Practice Program Preparation

The partner in this community service program is SMK Negeri 5 located Balikpapan as shown in Figure 4. which is a vocational high school with a strong institutional focus on the maritime and shipping sector, aligning its educational programs with the needs of Indonesia's marine and offshore industries. The school offers specialized competencies in areas such as marine engineering (ship machinery), ship construction and hull fabrication, nautical studies, and supporting maritime technologies, preparing students for direct entry into shipyards, offshore facilities, and marine service companies. Located in Balikpapan, a strategic maritime and energy hub in East Kalimantan, the school plays an important role in supplying technically skilled human resources for the regional shipbuilding, repair, and offshore ecosystem. This maritime-oriented profile makes SMK Negeri 5 Balikpapan a highly relevant and appropriate partner for programs aimed at strengthening applied CAD competencies in ship design and production contexts.

In the implementation program, the partner plays a strategic role in supporting the successful execution and sustainability of the activities. First, the partner provides essential learning facilities by making available an adequately equipped computer laboratory for the training sessions. This includes the provision of computer units for all participants, as well as technical support from the school's laboratory technicians to ensure that all hardware and software systems are properly prepared and functioning prior to the commencement of the program. Second, the partner is responsible for selecting and mobilizing the target participants of the program, namely students from Grade XI and/or Grade XII. These students serve as the primary beneficiaries and are required to participate in the full sequence of activities, including the pre-test, intensive training workshops on parametric 3D CAD, and the completion of project assignments implemented through a Project-Based Learning (PjBL) approach. Third, teachers from the partner institution actively participate in the program as recipients of knowledge transfer to ensure long-term impact and program continuity. They are involved in learning and adopting the shipbuilding-oriented 3D CAD training modules developed by the community service team, enabling them to integrate the materials into future teaching practices and sustain the outcomes of the program beyond its formal implementation period.

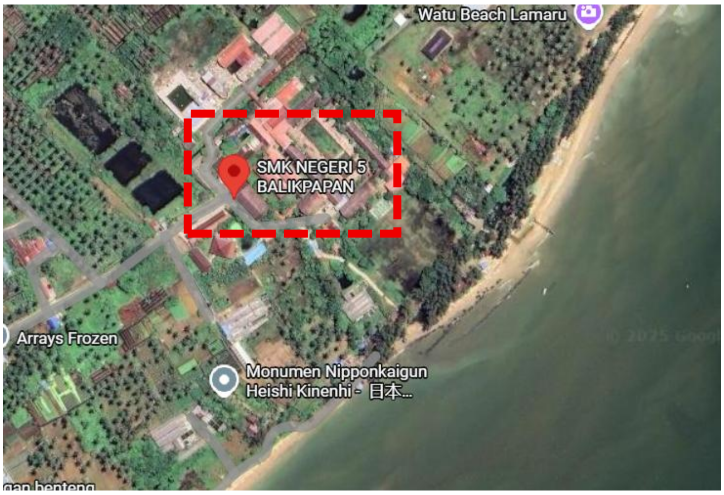

Figure 4. SMK 5 Balikpapan location from geographical perspective

The implementation of the program was carried out through a structured, multi-stage approach designed to ensure relevance, effectiveness, and sustainability, which described in Figure 5. The process began with Phase 1 Preparation and Needs Analysis, which focused on establishing formal collaboration with the partner school through coordination meetings, obtaining institutional permissions, and signing a Memorandum of Understanding. This phase also included a field needs analysis conducted through Focus Group Discussions with teachers to identify existing gaps in CAD competency and instructional practices. In addition, an initial competency assessment was administered in the form of pre-tests for both students and teachers to map baseline skill levels.

The program then proceeded to Phase 2 Development and Training of Trainers, during which the community service team developed a Project-Based Learning oriented 3D CAD training module specifically tailored to shipbuilding and maritime applications. To support effective implementation, CAD software was installed and configured in the school's computer laboratory. At the same time, a Training of Trainers program was conducted for teachers to facilitate knowledge transfer, strengthen instructional capacity, and ensure the sustainability of the program beyond the intervention period. Next, Phase 3 Student Implementation was carried out as the core activity of the program. This phase involved intensive CAD workshops for students, focusing on parametric 3D modeling aligned with maritime and shipbuilding contexts. The learning process applied a Project-Based Learning approach, enabling students to use CAD skills to solve realistic design problems. Throughout this phase, continuous mentoring and technical assistance were provided to guide students in developing their projects and addressing practical challenges. The final stage, Phase 4 Evaluation and Reporting, focused on assessing both learning outcomes and overall program effectiveness. Student performance was evaluated through final project presentations produced through the Project-Based Learning activities. Program effectiveness was further assessed using post-tests and participant satisfaction questionnaires to measure competency improvement and stakeholder responses. This phase concluded with the preparation of a comprehensive final report and the dissemination of results to document outcomes and support future replication of the program. Building upon the previously outlined multi-phase implementation framework, the execution of the program commenced with a preliminary coordination stage aimed at assessing the technological readiness of the partner vocational high school. This initial stage involved direct consultations with the teaching staff to understand existing instructional practices, followed by an on-site audit of the computer laboratory facilities to evaluate their suitability for advanced CAD-based learning activities. The infrastructure assessment revealed a hardware–software gap that is commonly encountered in vocational education institutions. While the school was able to provide adequate physical computer terminals for student use, the audit identified a critical lack of industry-standard engineering software required for parametric 3D CAD instruction. To address this constraint without violating software licensing regulations, the implementation team prepared and deployed student version licenses of the required CAD software, enabling lawful and immediate access for instructional purposes.

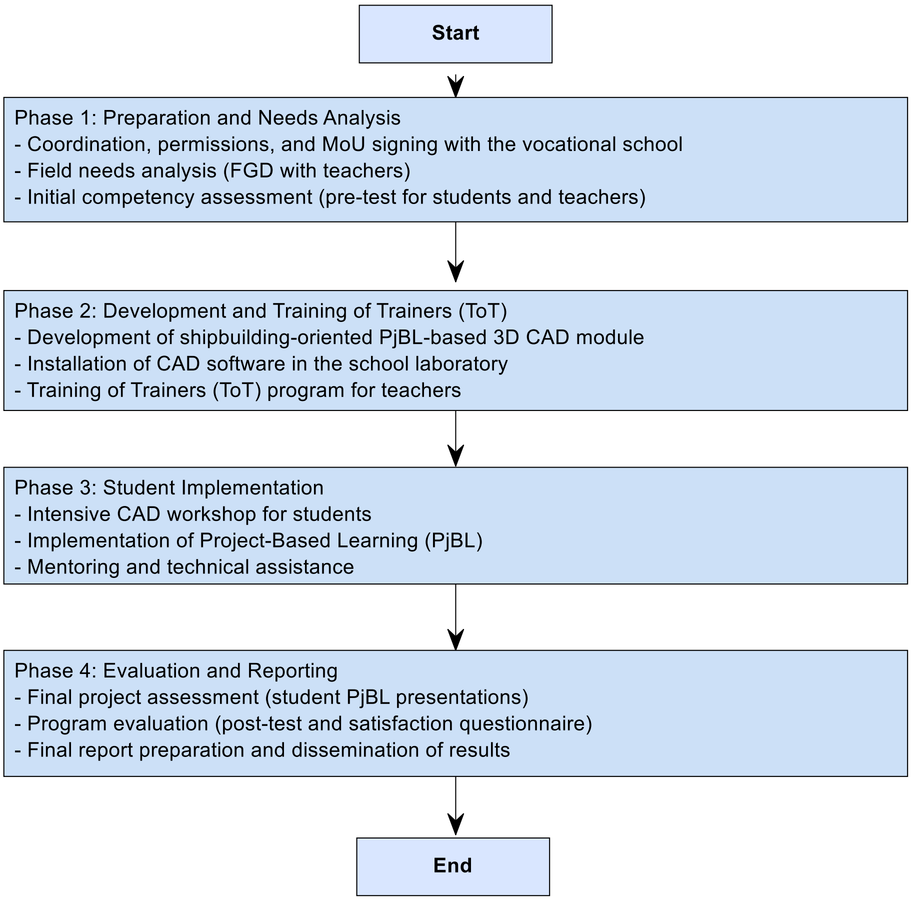

Figure 5. School-based implementation for school-based practice of CAD lesson

During the subsequent installation and testing process, several technical challenges became apparent. A portion of the existing hardware inventory was unable to support modern parametric modeling software due to system instability and insufficient hardware specifications, particularly in terms of memory capacity and graphics processing capabilities. To ensure the effectiveness of the training sessions and to guarantee that each student could participate in individual hands-on practice, the team supplemented the existing facilities by deploying additional high-specification personal computers and laptops to the training site. This intervention ensured continuity of learning activities and maintained the integrity of the Project-Based Learning approach adopted in the program. The experience gained from this phase underscored an important consideration for future scalability and replication of the program. It became evident that the successful adoption of advanced CAD curricula in vocational schools requires a minimum level of technological infrastructure readiness. This readiness extends beyond the mere availability of computer units and includes adequate processing specifications, compatible hardware, and access to valid software licenses capable of supporting industrial-grade applications.

In parallel with the infrastructure preparation, the program team developed a specialized learning module that can be seen in Figure 6. Unlike generic CAD manuals, this module was intentionally designed to bridge the gap between software operation and real industrial application within the maritime and shipbuilding context. The instructional content emphasized mastery of CAD features directly relevant to naval architecture, such as spline control, coordinate system management, and standardized layering practices. These technical elements were integrated into practical exercises derived from actual shipyard workflows, including the development of lines plans and basic structural detailing.

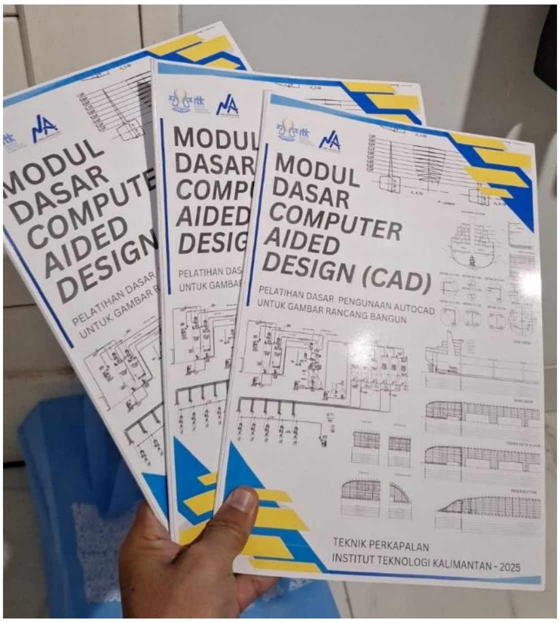

Figure 6. CAD learning module for trainers (Teachers) and students

The learning module was also designed with a sustainability-oriented strategy. It functioned as the core instructional material for the Train-the-Trainer component, enabling teachers to acquire the necessary competencies to continue delivering the curriculum independently after the conclusion of the program. Additionally, the module was formally deposited in the school library as a permanent learning resource, allowing students to access the material for independent study and ongoing skill development.

3.2 Implementation of school-based practice

Building on the infrastructure preparation and module development stages, the implementation phase placed strong emphasis on stakeholder engagement and the readiness of teaching staff. The program began with a series of semi-structured interviews and coordination meetings involving school administrators and vocational teachers. The qualitative insights gathered from these interactions revealed a high level of institutional openness toward the program. Although the school acknowledged that it was not yet fully equipped particularly in terms of software licensing availability and the depth of CAD-related curriculum the intervention was received with considerable enthusiasm and support.

Importantly, the vocational teachers perceived the program not merely as a short-term student workshop, but as a valuable professional development opportunity. During the discussions, teachers expressed a strong motivation to upgrade their own competencies, recognizing that mastery of modern CAD workflows directly influences the quality and relevance of the graduates they produce. The training was viewed as a strategic opportunity that positioned teachers as dual beneficiaries of the program, acting both as facilitators of student learning and as professionals striving to maintain their relevance within the evolving maritime and naval engineering education landscape.

Following the establishment of teacher readiness and infrastructure support, the training modules were implemented through hands-on sessions conducted in the school's computer laboratories, supplemented by additional hardware provided by the implementation team when required. The instructional approach adopted a guided replication method, in which students learned by closely following and replicating the procedures demonstrated by the mentor. This method was intentionally selected to bridge the gap between conceptual understanding and practical execution.

Figure 7. Documentation session with the teaching staff

The learning activities were structured to simulate a simplified industrial workflow. Before engaging with the CAD software, students were required to interpret and analyze a given technical drawing. This step emphasized comprehension of engineering logic, including dimensions, symbols, scales, and spatial relationships, rather than rote memorization of software commands. Only after this interpretative phase did students proceed to the drafting stage, where they digitally recreated the drawings by mirroring the mentor's step-by-step guidance. This transition from analytical reading to active drafting proved essential in strengthening students' understanding of coordinate systems, geometric constraints, and parametric relationships.

Figure 8. CAD practices by the students is school's computer lab

The response from students throughout the implementation phase was notably positive. Direct observations during the sessions showed high levels of engagement and enthusiasm, as students experienced the immediate visual feedback of their command inputs transforming into precise engineering geometries on the screen. The commonly reported apprehension toward complex technology was quickly replaced by curiosity and confidence, accompanied by a rapid assimilation of drafting logic and workflows.

Insights from post-implementation interviews with students further highlighted the program's impact. Many students reported a fundamental shift from passive to active learning, expressing satisfaction at finally being able to practice drafting independently. Prior to the program, their exposure to technical drawings had largely been limited to observing static images or diagrams, without the opportunity to actively produce them. Through hands-on CAD practice, students gained a sense of ownership over the learning process.

Students also demonstrated an improved understanding of the industrial relevance of CAD skills. They recognized that CAD is not an isolated drawing activity, but a foundational competence that supports downstream processes such as CNC machining, ship systems integration, and construction planning. Perhaps most significantly, the program contributed to broadening students' career perspectives. The practical exposure encouraged them to envision professional pathways beyond general labor roles, with increased interest in specialized positions such as CAD drafters or field engineers. Several students also expressed renewed motivation to pursue higher education, indicating that the intervention had a meaningful influence on both their technical competencies and long-term career aspirations.

Figure 9. Documentation with the students of SMKN 5 Balikpapan

CONCLUSION

The pilot implementation of the Applied CAD for Maritime Engineering program at the partner Vocational High School (SMKN 5) serves as both a validation of student potential and a critical diagnostic of the national vocational infrastructure. First, the program validated that the "competency gap" is not a result of student aptitude, but of opportunity. Through the Guided Replication method, students demonstrated a rapid acquisition of drafting logic, moving successfully from passive interpretation of diagrams to active parametric modeling. The immediate shift in student perception from viewing CAD as abstract coursework to recognizing it as a gateway to high-value careers in CNC machining and ship construction confirms that early exposure to industrial workflows is a potent driver for workforce regeneration. However, the execution highlighted a severe Infrastructure-Competency Mismatch that threatens the scalability of such programs. The study identified that the mere presence of computer laboratories is insufficient. The inability of existing school hardware to support industry-standard parametric software, coupled with the reliance on the research team's external workstations and student licenses, exposes a critical vulnerability. For vocational schools to genuinely act as a supply chain for the modern maritime industry, a fundamental upgrade in Technological Readiness is mandatory. This entails not just the procurement of hardware with adequate processing power for modeling, but also the institutionalization of valid software licensing to prevent legal and technical bottlenecks. Ultimately, bridging the human capital gap in Indonesia's shipbuilding sector requires a dual-investment strategy. It necessitates the tangible investment in industrial-grade computing infrastructure and the intangible investment in continuous "Train-the-Trainer" programs. Without empowering teachers with recent industrial experience and the tools to teach "Design for Production," vocational graduates will continue to face a technological shock upon entry into the workforce. The learning modules developed and deposited during this study provide a foundational step, but sustained integration requires a permanent realignment of school facilities with shipyard realities.

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REFERENCES

[1] Faststream, "The Naval Architecture Employment Report," 2025.

[2] A. Mabrori, "Iperindo Gelar Rakernas, Ada Potensi Pembangunan Kapal Baru 5.564 Unit," Logistiknews.id.

[3] M. Page, "Indonesia Salary Guide 2025," Jakarta, 2025.

[4] M. F. Isbah *et al.*, "Vocational education and skills development for new economies in Indonesia: uneasy parallel challenges," *Asian Education and Development Studies*, pp. 1–14, Nov. 2025, doi: 10.1108/AEDS-09-2025-0461.

[5] L. Barasa, B. Kurniadi, and I. Fahcruddin, "Bridging skills gaps in maritime engineering: Aligning education with industry and sustainability demands," *Research and Development in Education (RaDEn)*, vol. 5, no. 1, pp. 378–387, May 2025, doi: 10.22219/raden.v5i1.39400.

[6] T. Mahadi, "IPERINDO Masih Hadapi Tantangan SDM di Industri Perkapalan," Kontan.co.id.

[7] N. A. Saputra, I. Hamidah, A. Setiawan, L. S. Riza, I. Rachman, and T. Matsumoto, "Technology Literacy of Vocational Students in CAD Learning Materials: A Study at Private and Public Mechanical Engineering Vocational Schools," *Journal of Technical Education and Training*, vol. 17, no. 2, pp. 1–21, 2025.

[8] ILO, "Sectoral skills priorities for the shipbuilding industry," Jakarta, 2025.

[9] A. Anisah, T. Iriani, M. A. Ramadhan, and Y. Yusrina, "The Relevance of the Merdeka Curriculum Vocational School to the Competency Needs in the Construction Field in the Industry," *INVOTEK: Jurnal Inovasi Vokasional dan Teknologi*, vol. 23, no. 3, pp. 199–206, Jun. 2024, doi: 10.24036/invotek.v23i3.1161.

[10] R. L. Storch, *Ship production*. Cornell Maritime Press, 1995.

[11] V. Brandić and D. Kolić, "PWBS Best Practice Analysis of Two Shipyards," *Pomorski zbornik*, pp. 47–57, 2017.

[12] B. Ma'ruf *et al.*, "Technology capability of Indonesian medium-sized shipyards for ship production using Product-oriented Work Breakdown Structure method (case study on shipbuilding of Mini LNG vessel)," *Cogent Eng*, vol. 11, no. 1, Dec. 2024, doi: 10.1080/23311916.2023.2284534.

[13] Y. Choo *et al.*, "AIoT image analysis for real-time dispatching of shipyard transport devices: A focus on trailers," *Expert Syst Appl*, vol. 296, p. 128947, Jan. 2026, doi: 10.1016/j.eswa.2025.128947.

[14] D. J. Eyres and G. J. Bruce, "Basic design of the ship," in *Ship Construction*, Elsevier, 2012, pp. 3–9. doi: 10.1016/b978-0-08-097239-8.00001-5.

[15] A. F. Molland, *The Maritime Engineering Reference Book: A Guide to Ship Design, Construction and Operation*. Burlington: Elsevier, 2011.

[16] T. Lamb, *Ship Design and Construction*. United States: The Society of Naval Architecture and Marine Engineers, 2003.

[17] S. W. Rulita, Gunawan, and M. D. A. Fakhri, "Optimization of Nesting Systems in Shipbuilding: A Review," *Journal of Marine Science and Application*, vol. 24, no. 1, pp. 152–175, Feb. 2025, doi: 10.1007/s11804-025-00644-1.

[18] Autodesk, "The Hitchhiker's Guide to AutoCAD Basics: Precision and Coordinates for Engineering," *Autodesk Official Knowledge Network*, 2024.

[19] H. Syahab *et al.*, "Structural Design Evaluation For Underwater Remotely Operated Vehicle (ROV), Case Study: Madura Straits," in *10th International Seminar on Ocean, Coastal Engineering, Environmental and Natural Disaster Management*, Surabaya: IOP Publishing, 2023.

[20] N. S. Madusanka, Y. Fan, S. Yang, and X. Xiang, "Digital Twin in the Maritime Domain: A Review and Emerging Trends," *J Mar Sci Eng*, vol. 11, no. 5, p. 1021, May 2023, doi: 10.3390/jmse11051021.