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RESEARCH ARTICLE

Problem-Based Jobsheets for PLC Practicum with a Pick and Place Trainer Kit and FPWIN Pro 7

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This article contributes to:

4 QUALITY EDUCATION

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SUSTAINABLE DEVELOPMENT GOALS

ABSTRACT

Vocational secondary schools (SMK) tasked with producing industry-ready graduates frequently lack structured, validated instructional materials for complex automation equipment. This study reports the design, development, and validation of a Problem-Based Learning (PBL) Jobsheet Module for the Panasonic PLC-based Pick and Place Trainer Kit, programmed through FPWIN Pro 7. Following a Research and Development (R&D) approach using the Four-D (4D) model, limited to the Develop phase, five progressive jobsheets were constructed and evaluated for validity by subject-matter and instructional media experts, and for practicality by one vocational teacher and ten Grade XI Industrial Automation students at *SMK Pembangunan Teknologi Robotik UNP*, Padang, Indonesia. Expert validation yielded a composite score of 91.67% (Very Valid), comprising 89.58% for content validity and 93.75% for media validity. Practicality testing returned an overall mean of 93.6% (Very Practical), with teacher and student ratings of 93.8% and 93.5%, respectively. Qualitative feedback indicated that the PBL problem scenarios reduced cognitive load, enhanced procedural independence, and improved learners' confidence in troubleshooting electro-pneumatic systems. These findings confirm that integrating authentic industrial problem scenarios into structured jobsheet modules produces highly valid and practical teaching materials aligned with Industry 4.0 competency demands, while also providing a replicable design framework for vocational automation educators.

KEYWORDS

PBL-based jobsheet module; FPWIN Pro 7; Pick and Place trainer kit; PLC vocational education; Instructional material validity; Practicality; 4D development model

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1. INTRODUCTION

The global ascent of Industry 4.0, characterized by cyber-physical integration, intelligent manufacturing, and pervasive automation, has profoundly reoriented the competency requirements expected of vocational secondary school (Sekolah Menengah Kejuruan, SMK) graduates in Indonesia. Among the core technical competencies mandated by the national curriculum for the Industrial

Automation Engineering concentration, proficiency in Programmable Logic Controller (PLC) programming is among the most critical, given its direct applicability across manufacturing, logistics, and energy sectors [1], [2]. Despite this strategic importance, empirical evidence from SMK practitioners consistently documents a persistent gap between intended and attained learning outcomes in PLC practicum sessions, attributable in large part to the absence of validated, sequentially structured instructional materials that bridge the cognitive demands of theoretical PLC logic and the psychomotor demands of operating physical automation trainers [3], [4].

Practicum learning in vocational contexts is fundamentally mediated by instructional materials that serve simultaneously as procedural guides, conceptual scaffolds, and formative assessment tools [5]. Within electronics and automation programmes, the *jobsheet* (practical work sheet) occupies a pivotal role: it encodes Standard Operating Procedures, delineates safety protocols, and structures observation tasks so that learners can engage equipment independently and reproducibly [6]. However, when a novel piece of equipment, such as the Panasonic FP0-E32T-based Pick and Place Trainer Kit paired with the FPWIN Pro 7 programming environment, is introduced into a laboratory, its pedagogical potential is seldom realized without an accompanying module that has been formally validated for content accuracy, curricular alignment, and usability [7], [8].

The Problem-Based Learning (PBL) model offers a theoretically robust framework for embedding authentic industrial challenges into jobsheet design. Originating in medical education and subsequently generalized across professional preparation programmes [9], PBL situates learners as active investigators who must identify knowledge gaps, formulate hypotheses, conduct structured experiments, and present evidence-based solutions [10]. In the automation engineering context, PBL problem scenarios can be drawn directly from common industry faults, such as actuator timing failures, counter mis-sequencing, or pneumatic pressure anomalies, thereby ensuring that practicum activities develop not merely procedural competence but also the diagnostic reasoning skills demanded by modern smart factories [11], [12].

Despite growing research on PLC-based trainers in vocational settings [13], [14], and a parallel body of work on PBL-integrated instructional materials in technical subjects [15], [16], a significant methodological gap remains: studies rarely combine (a) a formally validated PBL-structured jobsheet module, (b) a specific commercial PLC trainer (the Pick and Place kit), and (c) a dedicated industrial-grade programming interface (FPWIN Pro 7) within a single coherent development study. Furthermore, the majority of existing validation studies either report expert validity alone without practicality data from actual students, or employ small-scale field trials without systematically connecting practicum outcomes to PBL phase adherence [17], [18]. This study directly addresses these gaps by reporting the complete development and dual-stage validation, including expert validity and end-user practicality, of a five-jobsheet PBL module designed for Grade XI Industrial Automation students.

The research objectives are threefold: (1) to document the systematic design and development process of the PBL Jobsheet Module using the Four-D (4D) R&D model; (2) to determine the level of expert-assessed validity of the module across content and media dimensions; and (3) to evaluate the module's practicality as perceived by the teacher and students who used it in simulated practicum conditions. The outcomes of this study are expected to contribute a replicable instructional design template for vocational automation educators and to strengthen the evidence base for PBL-mediated practicum learning in the context of PLC-driven industrial systems.

2. Literature Review

2.1. Instructional Materials in Vocational PLC Education

Vocational education pedagogy assigns a central role to purposefully designed learning materials that can guide learners through complex procedural tasks while simultaneously fostering conceptual understanding [5]. Within PLC practicum contexts, structured jobsheets and modules serve as the primary interface between the learner and the equipment, providing a standardized scaffold that reduces cognitive overload and supports self-regulated practice [19]. Nieveen's [20] widely cited quality framework for instructional materials identifies *validity* (alignment with intended outcomes and subject-matter correctness) and *practicality* (usability under realistic field conditions) as two non-negotiable quality criteria that must be empirically verified before a material can be recommended for broad implementation. Validity is typically assessed through structured expert appraisal, while practicality is ascertained via end-user response questionnaires administered after simulated or real classroom use [21], [22].

The Panasonic FP0-E32T PLC, a 32-point digital I/O expansion module operating on 24 VDC, has been adopted in several SMK laboratories owing to its compact form factor, multi-axis pulse output support, and compatibility with the FPWIN Pro 7 programming suite [23]. FPWIN Pro 7 complies with the IEC 61131-3 international standard, supporting Ladder Diagram (LD), Structured Text (ST), Function Block Diagram (FBD), and Sequential Function Chart (SFC) languages, and incorporates an integrated simulator for pre-deployment programme validation [24]. Despite their industrial relevance, no prior published study has reported the development and validation of a structured jobsheet module specifically integrating these tools with a PBL pedagogical framework.

2.2. Problem-Based Learning in Technical and Vocational Education

Problem-Based Learning (PBL) was formally conceptualized by Barrows and Tamblyn [9] as an instructional strategy in which learning is triggered by engagement with an ill-structured, authentic problem rather than preceded by formal instruction. Epistemologically grounded in constructivist theory, PBL holds that durable knowledge is built through cycles of problem identification, hypothesis formation, self-directed investigation, and reflective evaluation [25], [26]. In vocational and technical education, PBL has demonstrated consistent efficacy across multiple meta-analyses: Hung et al. [27] found significant improvements in problem-solving skills relative to conventional instruction; similarly, Walker and Leary [28] reported positive effects on knowledge application and motivation across STEM-related disciplines.

The five canonical PBL phases, problem orientation, student organization, collaborative investigation, result presentation, and reflective evaluation [29], map naturally onto the sequential, task-oriented structure of automation practicum activities. When embedded in a jobsheet format, each PBL phase can be operationalized as a structured section: the orientation section presents the industrial fault scenario; the organization section assigns group investigation roles; the investigation section guides FPWIN Pro 7 simulation tasks; the presentation section documents ladder diagram solutions; and the evaluation section involves physical execution on the trainer kit followed by peer and instructor assessment [12], [15]. This nested structure distinguishes a PBL jobsheet from a conventional step-by-step procedure sheet, because the former requires learners first to diagnose a problem before they can access procedural guidance, thereby activating higher-order reasoning [30].

3. METHODS

3.1. Research Design

This study adopted a Research and Development (R&D) methodology using the Four-D (4D) model [31], truncated to three stages (*Define, Design, Develop*) due to the study's scope of producing and validating a laboratory-ready instructional product rather than conducting a broad institutional dissemination. A quantitative descriptive approach was used to analyze Likert-scale data from validation sheets and practicality questionnaires, supplemented by qualitative analysis of open-ended expert comments that informed product revision.

The Four-D model, introduced by Thiagarajan, Semmel, and Semmel [31], provides a systematic, recursive framework for instructional material development comprising four stages: *Define*, *Design*, *Develop*, and *Disseminate*. The model is widely employed in Indonesian vocational education research because of its explicit provision for iterative expert validation and field-testing prior to broad dissemination [32], [33]. In the *Define* stage, front-end analysis, learner analysis, task analysis, concept analysis, and specification of instructional objectives establish the design parameters. The *Design* stage produces an initial prototype, selecting media format and layout conventions consistent with the principles of self-instructional modules. The *Develop* stage refines the prototype through expert appraisal and developmental testing, producing a field-ready artefact. When time or resources preclude full dissemination, limiting the study to the first three stages, as implemented in the present research, is an accepted methodological practice endorsed by Sugiyono [34] and Akker et al. [35].

3.2. Development Procedure

This study adopted a Research and Development (R&D) methodology using the Four-D (4D) model [31], truncated to three stages (*Define, Design, Develop*) due to the study's scope of producing and validating a laboratory-ready instructional product rather than conducting a broad institutional dissemination. A quantitative descriptive approach was used to analyze Likert-scale data from validation sheets and practicality questionnaires, supplemented by qualitative analysis of open-ended expert comments that informed product revision.

3.2.1 Define Stage

Front-end analysis confirmed that the Pick and Place Trainer Kit in the *SMK Pembangunan Teknologi Robotik UNP* laboratory lacked any accompanying written practical guide; instruction was delivered verbally by the teacher. Learner analysis of eleven Grade XI Industrial Automation Engineering students revealed basic prior knowledge of electro-pneumatic components but no prior experience with FPWIN Pro 7. Task analysis decomposed the curriculum element *Sistem Kontrol Elektro Pneumatik dan Hidrolik* (Electro-Pneumatic and Hydraulic Control Systems, Phase F) into five hierarchically sequenced competency clusters, each addressed by one jobsheet. Instructional objectives were formulated using Bloom's revised taxonomy verbs at the Apply and Analyse levels, consistent with the complexity demands of the competency [36].

3.2.2 Design Stage

An A4 print format was selected based on laboratory readability requirements. Each of the five jobsheets was structured with the following standardized sections: (1) practicum title and learning objectives, (2) time allocation, (3) equipment and materials list, (4) brief theoretical background, (5) occupational health and safety (K3) procedures, (6) PBL-oriented problem scenario, (7) step-by-step work procedure including FPWIN Pro 7 screenshots, (8) observation/data recording table, and (9) post-practicum evaluation tasks. The visual design followed Daryanto's [37] instructional module characteristics—*self-instructional, self-contained, stand-alone, adaptive*, and *user-friendly*—with sans-serif section headings, annotated screenshots for each FPWIN Pro 7 programming step, and coloured K3 alert boxes. Five jobsheets were designed as presented in Table 1.

Table 1. Structure of the Five PBL Jobsheets and Integrated Problem Scenarios

Jobsheet	Topic	PBL Phase/Problem Scenario	Learning Outcome
JS-01	Basic PLC Programming (Ladder Diagram)	**Phase 1: Orientation** Students identify why manual control is inefficient for the Pick and Place sequence	Understand PLC I/O and construct basic ladder rungs
JS-02	Timer Instructions (TON)	**Phase 2: Organization** Groups analyze a timed conveyor stoppage fault and assign investigation roles	Program TON timers for delay-dependent actuator control
JS-03	Counter Instructions (CTU)	**Phase 3: Investigation** Students simulate a cycle-count limit switch fault in FPWIN Pro 7	Implement CTU counters to trigger end-of-batch outputs
JS-04	Internal Memory and Self-Holding Circuits	**Phase 4: Result Presentation** Groups demonstrate corrected self-holding logic to prevent actuator bounce	Design latching circuits for pneumatic gripper lock control
JS-05	Sequential Control of the Pick and Place System	**Phase 5: Evaluation** Full-system commissioning test against an industry checklist on the physical trainer kit	Integrate all instructions into a complete PLC programme for the Pick and Place trainer kit

3.2.3 Develop Stage

The development stage comprised two sequential sub-phases: expert appraisal (validity testing) followed by developmental testing (practicality testing).

Expert Appraisal: The draft module was submitted to two domain experts: a subject-matter expert with a doctoral qualification in Electrical Engineering and more than ten years of PLC teaching experience, and an instructional media expert specializing in vocational instructional design. Each expert completed a structured Likert-scale validation sheet (1 = Very Poor to 5 = Very Good) covering the domains listed in Table 2. Experts also provided written qualitative comments that guided targeted product revisions.

Developmental Testing: Following expert-driven revision, the finalized module was used by one vocational teacher and ten Grade XI TOI students during a two-session simulated practicum. The teacher used the module independently to facilitate the practicum, while students followed the module to program the FPWIN Pro 7 simulator and subsequently execute their verified programmes on the physical Pick and Place Trainer Kit. Immediately after completion, participants filled in the practicality questionnaire. A brief pre-trial questionnaire gauging students' initial perceptions of the module was also administered before the practicum session to capture expectation-versus-experience comparisons.

3.3. Research Setting and Participants

The study was conducted at *SMK Pembangunan Teknologi Robotik UNP*, Padang, West Sumatra, Indonesia, a vocational school established under the auspices of the Universitas Negeri Padang, specializing in robotics and industrial automation. The practicum laboratory houses six Pick and Place Trainer Kits, each equipped with a Panasonic FP0 5.0K PLC unit and a workstation computer running FPWIN Pro 7. All eleven Grade XI Teknik Otomasi Industri (TOI) students enrolled in the Electro-Pneumatic Control Systems course participated. One teacher holding a master's degree in Electrical Engineering Education and responsible for the automation practicum also participated.

3.4. Instruments and Data Analysis

Validity Instrument: Two expert validation sheets were developed, each operationalizing Nieveen's [20] quality criteria. The content validity sheet (28 items) assessed curriculum alignment, the conceptual accuracy of PLC and electro-pneumatic content, the appropriateness of K3 procedures, and the quality of PBL scenario integration. The media validity sheet (24 items) assessed layout aesthetics, typographic legibility, image proportion, visual hierarchy, and language clarity.

Practicality Instrument: The practicality questionnaire (20 items for students; 22 items for teachers) measured ease of module use, instructional clarity, time efficiency, learner engagement, and alignment with the trainer kit hardware. Both instruments were validated for content by two independent reviewers and pilot-tested for internal consistency; Cronbach's alpha values exceeded 0.80 for all scales, confirming adequate reliability.

Data Analysis: Validity and practicality scores were computed as a percentage of the maximum possible score using the formula (1) recommended by Riduwan [38]:

$$\text{Score } (\%) = (\text{Obtained score} / \text{Maximum ideal score}) \times 100\% \quad (1)$$

The five-tier interpretive scale used was: 81–100% = Very Valid/Very Practical; 61–80% = Valid/Practical; 41–60% = Moderately Valid/Practical; 21–40% = Less Valid/Practical; 0–20% = Not Valid/Not Practical. A minimum threshold of 61% ("Valid" and "Practical") was set as the acceptance criterion, consistent with established practice in Indonesian R&D educational studies [32], [33].

4. Results

4.1. Product Description: PBL Jobsheet Module

The final product is a 98-page printed module comprising five sequentially organized jobsheets, a foreword, a table of contents, and a consolidated reference list. Each jobsheet opens with a one-paragraph authentic industrial fault scenario printed in a shaded box, designed to activate prior knowledge and orient the learner to the PBL investigation task before procedural instructions are revealed. FPWIN Pro 7 screenshots—enlarged to occupy at least one-third of the page width—illustrate each programming step, minimizing ambiguity during independent use. K3 alert boxes, printed in amber, identify hazardous steps involving pressurized pneumatic components and highvoltage solenoid drivers. The final jobsheet (JS-05) integrates all preceding skills into a full-sequence control programme for the five-stage Pick and Place cycle, constituting a capstone problem-solving task that mirrors commissioning activities in manufacturing environments.

4.2 Expert Validation Results

Table 2 presents the scores awarded by the two domain experts across the content and media validity dimensions.

Table 2. Expert Validation Results

Validation Aspect	Validator	Score (%)	Category
Content Validity (Curriculum alignment, PLC/pneumatic concepts, PBL syntax integration)	Subject-Matter Expert	89.58	Very Valid
Media Validity (Layout, typography, image proportion, visual appeal)	Instructional Media Expert	93.75	Very Valid
Overall Mean		91.67	Very Valid

The overall expert validity score of 91.67% places the module firmly within the "Very Valid" category (81–100%), exceeding the minimum acceptance threshold by more than 30 percentage points. The content validity score (89.58%) reflects positive expert judgement on five sub-dimensions: (i) accuracy of PLC programming concepts, (ii) correctness of electro-pneumatic system descriptions, (iii) alignment with Phase F curriculum learning outcomes, (iv) appropriateness of K3 safety content, and (v) quality of PBL phase integration within each jobsheet. The media validity score (93.75%) indicates strong endorsement of the module's visual design, with particular commendation for the clarity of FPWIN Pro 7 screenshots' annotations and for the use of differential typography to distinguish procedural instructions from PBL scenario text.

The subject-matter expert's written comments focused on two areas requiring revision: (a) several FPWIN Pro 7 screenshots were too small to distinguish individual ladder rungs and required enlargement, and (b) the K3 section of each jobsheet needed more precise specification of the emergency stop button (X0) location and its role in the control circuit. The media expert recommended separating large screenshot figures from surrounding instructional text using explicit figure captions and adjusting the observation table columns to accommodate separate recording of pneumatic actuator stroke direction (extend/retract) and gripper state (open/closed). All recommended revisions were implemented prior to the practicality trial.

4.3 Practicality Testing Results

As illustrated in Figure 1, students worked in small groups at laboratory workstations equipped with laptops running FPWIN Pro 7, with the physical Pick and Place Trainer Kit positioned at the end of the bench for hardware execution. Printed copies of the jobsheet module — visible on the table — were used independently by each group throughout the session, while the teacher assumed a facilitative coaching role rather than delivering direct verbal instruction. This observable shift in teacher behaviour corroborates the module's self-instructional design intent and aligns with PBL facilitation principles in which the instructor serves as a guide rather than a knowledge transmitter [29]. Upon session completion, participants completed the practicality questionnaire. Table 3 summarises the results.

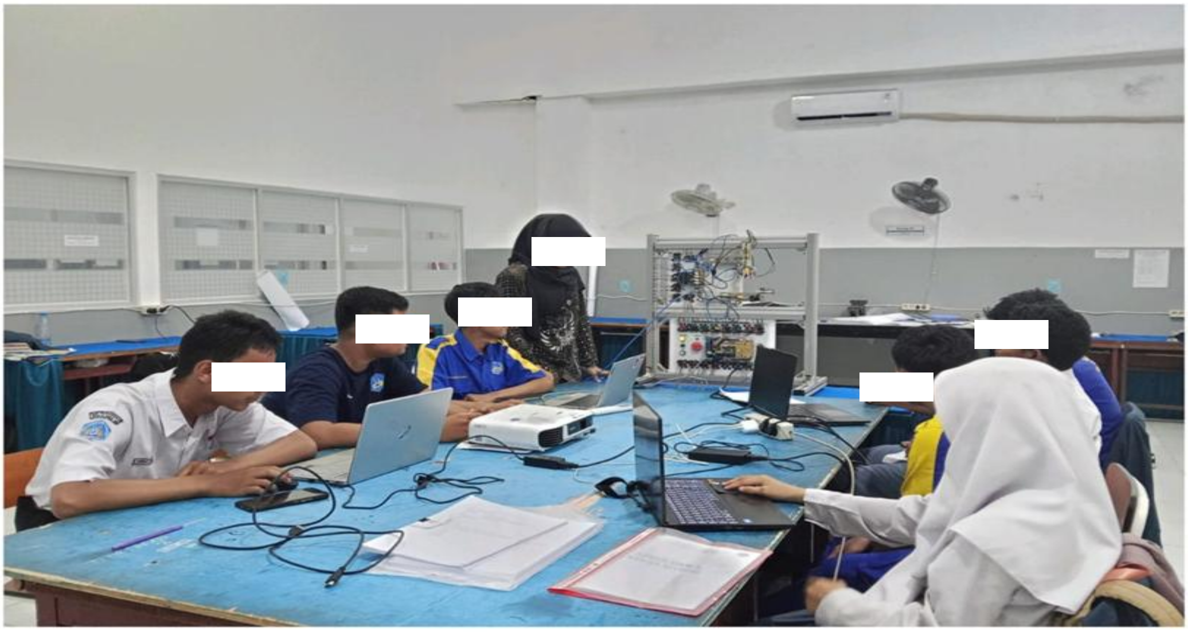

Figure 1. Practicality trial session at the Industrial Automation laboratory of *SMK Pembangunan Teknologi Robotik UNP*: students using the PBL Jobsheet Module with laptops running FPWIN Pro 7, with the Pick and Place Trainer Kit visible in the background (right), supervised by the vocational teacher.

Table 3. Practicality Testing Results

Respondent	n	Mean Score (%)	Std. Dev.	Category
Vocational Teacher	1	93.8	–	Very Practical
Students (pre-trial response)	10	92.0	3.12	Very Practical
Students (post-trial response)	10	95.0	2.85	Very Practical
Overall Mean		93.6		Very Practical

All respondent groups returned scores in the "Very Practical" range (81–100%). The overall mean of 93.6% indicates consistent end-user satisfaction across both teacher and student respondents. Notably, student post-trial scores (95.0%) exceeded pre-trial scores (92.0%), suggesting that initial module perceptions were slightly conservative and that actual use experience exceeded learner expectations—a pattern consistent with disconfirmation of expectations theory in user satisfaction research [39].

Qualitative comments from the teacher emphasized that the module's self-contained structure substantially reduced the need for verbal instructions during the practicum, enabling the teacher to fulfil a coaching rather than directing role. Students' open-ended responses most frequently cited the "step-by-step FPWIN Pro 7 screenshots" and "the initial problem scenario" as the most helpful module features, while the most commonly requested improvement was the addition of colour-coded wiring diagrams for the pneumatic solenoid connections.

5. Discussion

5.1 Validity of the PBL Jobsheet Module

The composite validity score of 91.67% is consistent with the upper end of the range reported in comparable R&D studies in vocational automation education. Wisnu Tri Harjianto and Zamtinah [15] achieved expert validity scores of 88.97% (content) and 85.42% (media) for a PBL-based handout/jobsheet targeting electrical installation; the present study's scores are marginally higher on both dimensions, attributable to the more systematic integration of PBL phase markers within the jobsheet structure and the deliberate visual treatment of FPWIN Pro 7 procedural screenshots. The high content validity score (89.58%) specifically affirms that embedding authentic problem scenarios drawn from real electro-pneumatic faults does not compromise instructional accuracy—a concern occasionally raised against contextualized problem-based materials [40].

The expert revision process underscores the iterative importance of the Develop stage in the 4D model. Both rounds of revisions, screenshot enlargement, and K3 specification enrichment, followed by figure captioning and table restructuring, directly addressed the gap between intended self-instructional characteristics and observed usability. This iterative refinement process is consistent with design-based research principles emphasizing continuous alignment between instructional design and authentic learning environments [20], [41].

5.2 Practicality and Learner Experience

The overall practicality mean of 93.6% surpasses the 77.01% reported by Wisnu Tri Harjianto and Zamtinah [15] for a comparable PBL jobsheet at a different SMK. It aligns with Haryudo et al.'s [7] finding that integrating a project-based trainer kit substantially elevates student motivation and procedural competency relative to a conventional worksheet-guided practicum. Several design features of the present module plausibly account for the high practicality rating:

Software-first simulation: Requiring students to verify their ladder diagram in the FPWIN Pro 7 software simulator before connecting to the physical trainer kit effectively decoupled programme logic debugging from hardware risk management. This two-phase workflow reduced equipment-damage incidents during the trial to zero and allowed students to iterate on their solutions at low cost, consistent with Suyetno and Elmunsyah's [3] argument for simulation-based PLC learning media. Module self-containedness, operationalized through the inclusion of concise technical explanations, annotated diagrams, and integrated K3 reminders, supported independent learning and reduced unnecessary cognitive burden during practicum activities. This finding is consistent with multimedia learning principles emphasizing structured visual-verbal integration to improve comprehension and retention [42].

PBL problem orientation: The opening problem scenario in each jobsheet served as a cognitive activator, producing measurable engagement, as evidenced by the observation that all 10 student groups initiated peer discussion before accessing the procedural steps, a hallmark of successful PBL initiation [29]. The teacher confirmed that this self-directing behaviour meaningfully reduced instructional interruptions during the practicum session. This finding aligns with Jonassen et al. [43], who argued that engineering education should emphasize authentic, ill-structured problem-solving experiences that resemble real industrial contexts.

Self-contained structure: Module self-containedness, operationalized through the inclusion of condensed but accurate technical background, full equipment lists with annotated diagrams, and integrated K3 reminders at safety-critical steps, permitted students to proceed independently for extended intervals. This finding reinforces Daryanto's [37] characteristic of a quality instructional module and corroborates Sukiman's [6] observation that self-directed instructional materials standardize delivery quality regardless of within-cohort variation in prior experience.

The pre-to-post improvement in student practicality ratings (92.0% to 95.0%) is theoretically significant because it suggests that the affective resistance sometimes associated with unfamiliar PBL structures [44] was overcome through actual engagement with the authentic problem scenario, ultimately enhancing perceived utility. This trajectory is consistent with Hmelo-Silver's [10] observation that PBL benefits compound across the learning sequence as students internalize the investigation framework.

5.3 Contextualization within the Literature and Industry Relevance

Table 4 positions this study's outcomes alongside related prior research to illustrate the contribution and generalisability of the findings.

Table 4. Comparative Summary of Validity and Practicality Across Related Studies

Study	Validity (%)	Practicality (%)	Context
This study	91.67 (Very Valid)	93.6 (Very Practical)	***PBL Jobsheet Module*** Pick and Place PLC, FPWIN Pro 7, Grade XI TOI
Wisnu Tri Harjianto & Zamtinah [15]	88.97–85.42 (Very Valid)	77.01 (Feasible)	***PBL Handout / Jobsheet*** Electrical Lighting Installation, Grade XI TITL
Oka et al. [13]	Valid (>80%)	Not measured	***PLC Trainer*** Traffic light control, vocational context
Rindaryati et al. [12]	Not reported	Effective (Practical)	***PLC Trainer*** Pneumatic relay control, SMK Batam

This comparison highlights two consistent patterns across the literature. First, PBL-integrated vocational instructional materials consistently achieve high expert validity scores when developed through iterative R&D processes. Second, practicality scores tend to be more heterogeneous and are often slightly lower than validity scores because they are sensitive to contextual factors, including laboratory infrastructure quality, student prior knowledge, and teacher facilitation skills. The high, internally consistent practicality scores obtained from both teacher and student groups in the present study therefore reflect not only the quality of the module design but also the supportive laboratory infrastructure available at *SMK Pembangunan Teknologi Robotik UNP*.

From an industry-readiness perspective, the five-jobsheet progression from basic I/O logic to full-sequence Pick and Place control mirrors the task complexity hierarchy encountered in industrial PLC commissioning workflows. Embedding this progression within PBL scenarios that reference realistic fault conditions, such as actuator bounce, missed counts, and gripper timing errors, directly prepares students for troubleshooting responsibilities in automated manufacturing cells, consistent with the competency demands articulated in Indonesia's Making Indonesia 4.0 roadmap [2] and the IEC 61131-3 programming standard adopted by FPWIN Pro 7 [24].

5.4 Limitations and Future Research Directions

Several limitations of this study should be acknowledged. First, the study was deliberately limited to the Develop stage of the 4D model. The Disseminate stage, involving wider deployment across multiple schools and student cohorts, was not conducted, thereby constraining the generalisability of the practicality findings. Second, the practicality sample comprised only eleven participants from a single school. Although this scale is consistent with the developmental testing procedures recommended in the 4D model [31], it does not permit statistical generalization to the broader population of vocational automation students. Third, the study evaluated validity and practicality, but not effectiveness. The module's impact on measurable learning outcomes, including knowledge acquisition, psychomotor skill development, and problem-solving ability, was not examined using experimental or quasi-experimental research designs.

Future research should: (1) extend the study to the Disseminate stage, deploying the module across multiple SMK institutions with comparable trainer kit infrastructure to establish cross-site validity and practicality consistency; (2) conduct a controlled effectiveness trial comparing PBL jobsheet-guided practicum against conventional instruction on pre-/post-test PLC competency measures; (3) expand the module to higher-complexity topics, including HMI integration and SCADA supervisory programming, consistent with the Industry 4.0 curriculum trajectory; and (4) explore digital adaptations, such as a tablet-optimized e-jobsheet incorporating embedded simulation links to FPWIN Pro 7 and augmented reality overlays for hardware component identification.

6. Conclusion

This study developed and validated a five-jobsheet Problem-Based Learning module for the Pick and Place PLC Trainer Kit with FPWIN Pro 7, targeting Grade XI Industrial Automation Engineering students at an Indonesian vocational secondary school. The development followed the Four-D (4D) R&D model through the Develop stage, producing an instructional artefact that integrates authentic industrial fault scenarios with sequential procedural guidance, FPWIN Pro 7 simulation steps, and formalized K3 safety protocols within a self-instructional module format.

Expert validation returned a composite validity score of 91.67% ("Very Valid"), with content validity at 89.58% and media validity at 93.75%, confirming that the module meets curriculum alignment, conceptual accuracy, and instructional design quality standards. Practicality testing with one teacher and ten students yielded an overall mean of 93.6% ("Very Practical"), with all respondent groups placing the module in the highest practicality tier. Post-trial student scores exceeded pre-trial scores, indicating that actual PBL-structured practicum experience exceeded initial learner expectations.

These findings have three principal implications for vocational education practice. First, they demonstrate that embedding authentic industrial problem scenarios within a formally structured module format is both feasible and valued by vocational learners and educators, countering assumptions that problem-based approaches are incompatible with equipment-intensive practicum environments. Second, the software-before-hardware simulation strategy, using FPWIN Pro 7 as a risk-free verification environment before physical trainer kit execution, constitutes a transferable instructional design principle applicable to any PLC-based practicum. Third, the strong validity and practicality outcomes justify recommending the module for adoption as the official practicum guide for the Electro-Pneumatic Control Systems element at the developing institution, with the expectation that similar outcomes could also be achieved in equivalent vocational laboratories.

Declarations

Author Contributions

Elfitra Rahma Fionandes: Conceptualization; Methodology; Investigation; Data Curation; Writing – Original Draft. **Zulwisli:** Supervision; Validation; Formal Analysis; Writing – Review & Editing. **Ilmiyati Rahmy Jasril:** Methodology; Validation; Writing – Review & Editing. **Winda Agustiarmi:** Resources; Visualization; Writing – Review & Editing. All authors have read and approved the final version of the manuscript.

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Ethical Approval

The study involves the design, development, and classroom-level testing of an instructional material. Institutional permission for data collection was obtained from *SMK Pembangunan Teknologi Robotik UNP*. Participation was voluntary. No sensitive personal data was collected.

Informed Consent

All participants involved in the validation and practicality testing stages provided informed consent before participation. The collected data were used solely for academic research purposes and reported in anonymized form.

Funding

This study was conducted without external funding.

Data Availability Statement

The developed Jobsheet Module and anonymized validation/practicality data are available upon reasonable request from the corresponding author.

Competing Interests

The authors declare no conflicts of interest.

Generative AI and AI-Assisted Technologies Statement

During the preparation of this manuscript, generative AI tools were used solely to assist with language editing and proofreading. All outputs were critically reviewed, revised, and validated by the authors to ensure academic integrity, originality, and accuracy.

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