



LMS-Based Problem-Based E-Worksheets for Mechatronics Vocational Education: Development, Validation, and Effectiveness in Problem-Solving Skills

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ABSTRACT

Problem-solving skills are essential competencies in vocational education, particularly in technical fields that require students to connect theoretical knowledge with practical workplace applications. This study developed and evaluated LMS-based Problem-Based e-Worksheets (PBeWs) designed to enhance the problem-solving skills of eleventh-grade Mechatronics Engineering students in vocational pneumatics learning on logic gates. The developed PBeWs integrated problem-based learning scenarios, contextual pneumatic system tasks, multimedia materials, collaborative activities, and automatic feedback within a Moodle-based Learning Management System. Expert validation was conducted by subject matter and media experts to assess content accuracy, instructional design quality, media quality, and LMS integration before classroom implementation. The effectiveness of the PBeWs was examined using a quasi-experimental pre-test–post-test control group design involving 80 students from two vocational high schools, divided into experimental and control groups. Students in the experimental group learned using LMS-based PBeWs, whereas students in the control group used conventional worksheets. The results showed that students using LMS-based PBeWs achieved greater improvement in problem-solving skills than those using conventional worksheets. These findings indicate that LMS-based PBeWs represent a feasible and promising instructional tool for supporting analytical, contextual, and vocationally relevant problem-solving skill development in technical education.

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1. INTRODUCTION

Vocational education is increasingly expected to equip students not only with domain-specific technical competencies but also with the capacity to engage in complex problem-solving within technology-rich professional environments (Savaengkan & Chaijaroen, 2025). Vocational High Schools (VHS) occupy a strategic position in preparing students with competencies relevant to contemporary industrial and workplace demands, consistent with the Technical and Vocational Education and Training (TVET) framework advocated by UNESCO and ILO (Suharno et al., 2020). The vocational curriculum is characterised by a strong practical orientation, with applied activities accounting for approximately 60% of instructional time compared with 40% for theoretical content (Papadakis et al., 2021). This emphasis on practice-based learning highlights the critical need for instructional materials that foster authentic, problem-oriented engagement rather than procedural drills and routine task completion.

Effective participation in vocational and professional contexts requires competencies that extend beyond technical proficiency (Chans et al., 2024). Problem-solving ability represents one of the most essential cognitive competencies needed for students to navigate complex occupational tasks and respond adaptively to evolving industrial demands (Sampeallo, 2022). Successive curriculum reforms, including the 2013 Curriculum and the more recent Kurikulum Merdeka, have emphasised the importance of higher-order thinking skills (HOTS); however, their integration into vocational instructional practice remains constrained. Empirical evidence suggests that classroom learning in many vocational settings continues to be teacher-centred and cognitively undemanding, prioritising low-level tasks such as recall and memorisation over analytical reasoning, evaluation, and knowledge construction (López et al., 2023).

Problem-Based Learning (PBL) has been widely recognised as a pedagogically effective approach to cultivating problem-solving competencies in vocational education (Wagino et al., 2025). PBL positions students

as active agents in the learning process and encourages analytical inquiry, collaborative reasoning, and reflective engagement with authentic real-world problems. A substantial body of empirical research confirms that PBL can produce significant gains in critical thinking, analytical reasoning, and problem-solving performance (Hastuti et al., 2024). The pedagogical effectiveness of PBL, however, depends substantially on the quality of instructional media and scaffolding structures available within the learning environment. Worksheets, which serve a central scaffolding function in guiding students through practical activities, remain predominantly conventional, static, and oriented toward procedural exercises (Rahmawati et al., 2025). Such materials tend to assess only lower-order cognitive skills and fail to engage students with contextualised, industry-relevant problems that reflect authentic vocational practice (Prianto et al., 2022).

Digital e-Worksheets have been introduced as learning tools capable of supporting more interactive, flexible, and cognitively demanding learning experiences (Putri et al., 2025). Unlike conventional worksheets, e-Worksheets can incorporate multimedia components, including instructional videos, simulations, and real-time automated feedback, thereby aligning more effectively with the demands of problem-solving-oriented pedagogy in contemporary educational settings (Nenggala et al., 2024). Well-designed e-Worksheets within a PBL framework can scaffold students through structured problem-solving processes while simultaneously supporting the development of higher-order thinking capacities.

Integration of e-Worksheets within a Learning Management System (LMS), such as Moodle, can further strengthen their pedagogical value by providing a structured digital environment for content delivery, formative assessment, learner monitoring, and collaborative knowledge construction (Yamani et al., 2022). LMS-based platforms in TVET contexts have demonstrated the capacity to support both cognitive and psychomotor learning dimensions, thereby facilitating learning experiences that are interactive and vocationally situated (Suriaman et al., 2023). Empirical research examining LMS-based e-Worksheets in vocational technical education, particularly in specialised subject domains such as pneumatics and logic gate systems, remains notably limited.

The present study addresses this gap by developing LMS-based Problem-Based e-Worksheets (PBeWs) and systematically evaluating their effectiveness in enhancing vocational students' problem-solving skills. The study is further distinguished by its contextual integration of logic gate principles within pneumatic systems, which establishes a meaningful connection between abstract theoretical constructs and real-world industrial applications. Unlike prior studies conducted in general educational or non-technical settings, this investigation situates LMS-based PBeWs within the specific context of vocational pneumatic logic gate learning. This focus contributes a contextually grounded and methodologically rigorous perspective to the broader discourse on technology-enhanced vocational instruction.

The following research questions guided this study:

RQ1. What are the characteristics of LMS-based PBeWs developed to enhance vocational problem-solving skills?

RQ2. How feasible are the developed PBeWs based on expert validation?

RQ3. How effective are LMS-based PBeWs in improving students' problem-solving skills compared with conventional worksheets?

2. MATERIAL AND METHOD

Research Design

This study employed a quasi-experimental pre-test–post-test control group design (Dimitrov & Rumrill, 2003) to evaluate the development and effectiveness of LMS-based Problem-Based e-Worksheets (PBeWs) in enhancing vocational students' problem-solving skills. Participants were assigned to two groups: an experimental group that received LMS-based PBeWs and a control group that received conventional worksheets and classroom instruction. Baseline equivalence in problem-solving skills was established through a pre-test administered to both groups prior to the intervention.

Students in the experimental group engaged in learning activities using PBeWs delivered through a Moodle-based LMS, whereas students in the control group received equivalent instructional content through conventional printed worksheets and teacher-directed classroom instruction. Both groups were taught by the same teachers, covered identical subject matter on pneumatic logic gates, and received the same number of instructional sessions across six meetings over three weeks. Students completed a post-test using the same instrument at the end of the intervention period. Effectiveness was determined through gain score analysis, statistical significance testing, and effect size comparison between the two groups.

Participants and Sampling

The study involved 80 eleventh-grade students majoring in Mechatronics Engineering from two vocational high schools, consisting of one public school and one private school, in Cimahi, Indonesia. A purposive sampling technique was employed because both schools had active and accredited Mechatronics Engineering programmes and implemented the Teaching Factory (TEFA) learning model, which emphasises applied and industry-oriented problem-solving. This orientation was directly aligned with the intervention design of the present study. Eleventh-grade students were selected because they had acquired foundational competencies in the preceding semester and were at an appropriate stage of core competency consolidation.

Class A in each school was assigned as the experimental group ($n = 20$ per school; total $n = 40$), whereas Class B was assigned as the control group ($n = 20$ per school; total $n = 40$). Intact class assignment was employed rather than individual randomisation, consistent with the quasi-experimental nature of the study and the practical constraints of the vocational school context. This sequential class assignment was adopted to minimise the risk of treatment contamination between groups. School type, namely public and private school, was treated as a contextual grouping variable rather than a formal independent variable in the analysis. The study was conducted during the even semester of the 2024/2025 academic year.

Instrument

The primary instructional intervention in this study was the Problem-Based e-Worksheets (PBeWs), which consisted of seven structured learning modules delivered through the Moodle LMS. Each module incorporated problem-based learning scenarios contextualised within pneumatic logic gate applications and was supported by instructional videos, circuit simulations, step-by-step problem-solving guides, collaborative discussion forums, and integrated automatic feedback mechanisms. To assess students' problem-solving skills, a seven-item essay-based test was developed covering four dimensions: problem identification, solution planning, solution implementation, and evaluation of results. The instrument was validated by two subject matter experts and one assessment expert. Content validity was established through expert judgment, and reliability analysis using Cronbach's alpha yielded a coefficient of $\alpha = .87$, indicating high internal consistency. In addition, the feasibility of the PBeWs was evaluated using a structured validation instrument completed by two subject matter experts and two media experts. This instrument assessed content accuracy, instructional design quality, media quality, and LMS integration using a five-point Likert scale. Finally, a user response questionnaire was administered to students in the experimental group to examine their perceptions of the PBeWs in terms of usability, content relevance, and learning support.

Intervention Procedure

The intervention was implemented across six instructional meetings over three weeks during regular school hours. Students in the experimental group accessed the PBeWs through individual LMS accounts on school-provided devices. Each session followed a structured PBL sequence consisting of problem orientation, collaborative inquiry, solution development, presentation, and reflection. Teachers in the experimental group acted as facilitators rather than direct instructors by guiding students through the problem-solving process embedded in the PBeWs. Automatic feedback within the LMS provided immediate formative responses after each task was completed. Students in the control group received equivalent content through conventional printed worksheets and teacher-directed instruction based on the school's standard lesson plans. Both groups received the same total instructional time to ensure content equivalence across conditions.

Data Analysis

Data were analysed following a sequential analytical strategy: descriptive statistics, assumption testing, gain analysis, within-group comparison, between-group comparison, and effect size. Descriptive statistics were computed to summarise the distribution of pre-test and post-test scores for both groups, including mean, median, and standard deviation. Normalised Gain (N-Gain) was calculated using the formula proposed by (Hake, 1998):

$$N - Gain = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}}$$

*Gain scores were interpreted using the following criteria: high ($g > 0.70$), medium ($0.30 \leq g \leq 0.70$), and low ($g < 0.30$). Assumption testing was conducted using the Shapiro–Wilk test ($p < .05$) to assess the normality of score distributions, given the sample size of 40 per group. Within-group comparisons of pre-test and post-test scores were conducted using the Wilcoxon Signed-Rank Test, applied when data did not meet normality assumptions. Between-group comparisons of post-test and N-Gain scores were conducted using the Mann–Whitney U Test to determine whether differences between the experimental and control groups were statistically significant. Effect size was calculated using Cohen's d to determine the practical magnitude of the intervention's impact, interpreted as small ($d < 0.50$), medium ($0.50 \leq d < 0.80$), or large ($d \geq 0.80$) following Cohen's (1988) criteria.

Ethical Consideration

This study received ethical approval from the Ethics Committee of Universitas Pendidikan Indonesia (No. 110/UN40.K/PT.01.01/2025). Informed consent was obtained from all students, parents or guardians, and participating schools before data collection. Participant confidentiality and anonymity were strictly maintained throughout the study, with all identifying information replaced by numerical codes. Students were informed that participation was entirely voluntary and that withdrawal at any time would carry no academic consequences.

3. RESULTS

Characteristics of LMS-Based PBeWs

The LMS-based PBeWs were characterised by two main design components: the integration of PBL syntax into structured learning activities and the embedding of these activities within the Moodle LMS platform. The first component involved the systematic incorporation of PBL stages into each learning activity, as illustrated in Figure 1. Contextual problems drawn from pneumatic systems were used as entry points to guide students sequentially through five PBL stages: problem orientation, organising students for study and investigation, guiding group investigation, developing and presenting results, and analysing and evaluating.

Each PBL stage was mapped onto specific worksheet activities designed to address the targeted problem-solving dimensions. The Problem Orientation stage corresponded to the activity of explaining the problem statement, in which students were presented with a contextual pneumatic system problem to initiate inquiry. The Organising Students for Study and Investigation stage was linked to the activity of identifying logic gates, in which students analysed the relevant theoretical components underlying the problem. The Guiding Group Investigation stage corresponded to the activity of justifying the selection of logic gates, requiring students to reason analytically and defend their component choices. The Developing and Presenting Results stage encompassed two parallel activities: constructing input-output truth tables and designing pneumatic system circuits, both of which required applied reasoning and systematic solution planning. The Analysing and Evaluating stage was mapped onto two culminating activities: testing pneumatic system circuits and formulating strategies for handling pneumatic system failures, both of which required evaluative judgement and reflective problem-solving.

The worksheet activities were also mapped onto the four stages of Polya's problem-solving framework, as shown in Figure 2. The Understanding the Problem stage was addressed through the activity of explaining the problem statement, in which students identified and interpreted the core pneumatic problem presented. The Devising a Plan stage corresponded to the activities of identifying logic gates and justifying their selection, in which students engaged in analytical reasoning to determine an appropriate solution pathway. The Carrying Out the Plan stage encompassed the activities of constructing input-output truth tables and designing pneumatic system circuits, requiring students to implement their planned solutions systematically. The Looking Back stage was addressed through the activities of testing pneumatic system circuits and formulating strategies for handling pneumatic system failures, in which students evaluated the outcomes of their solutions and reflected on alternative approaches. This dual alignment with PBL stages and Polya's problem-solving framework indicated that each worksheet activity was deliberately situated within an integrated instructional sequence designed to elicit specific problem-solving behaviours. These behaviours included analytical reasoning, logical inference, solution planning, implementation, and evaluative judgement.

The second design component involved the integration of these PBL-based activities into the Moodle LMS platform, as illustrated in Figure 3. The PBeWs were implemented using two primary Moodle plugins: the Assignment plugin, which facilitated the submission of worksheet tasks, pre-tests, and post-tests, and the Forum

plugin, which supported collaborative discussions and peer interaction among students. The overall LMS structure followed a systematic instructional flow comprising six sequential phases: introduction, pre-learning reflection, pre-test, PBeWs activities, post-test, and user response collection. This structured digital architecture ensured consistent accessibility, coherent learning sequences, collaborative interaction, and systematic documentation of student performance throughout the intervention.

Worksheet activities within the LMS environment were further supported by instructional videos, embedded circuit simulations, step-by-step problem-solving guides, and an integrated automatic feedback system that provided immediate formative responses after task completion. Unlike conventional worksheets, which generally present tasks in isolation, the LMS-based PBeWs situated each activity within real-world pneumatic contexts. This design required students to analyse, synthesise, and evaluate information across the full problem-solving sequence. Collectively, these characteristics establish that the LMS-based PBeWs function not merely as digital content delivery tools but as structured pedagogical scaffolds specifically designed to cultivate vocational students' problem-solving competencies in a systematic, contextualised, and technology-enhanced learning environment. This dual design foundation, structured PBL, and problem-solving scaffolding embedded within an LMS platform defined the distinctive characteristics of the developed PBeWs and provided the instructional basis for the feasibility and effectiveness evaluations reported in the subsequent sections.

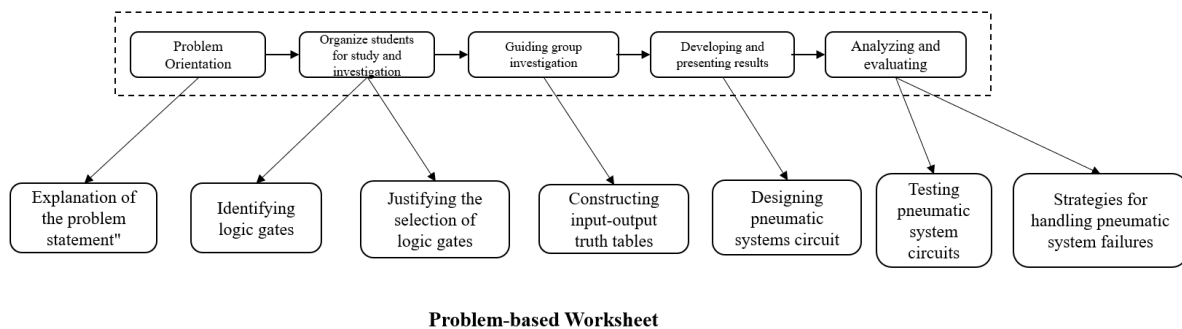


Figure 1. Stages of PBeWs Based on PBL Syntax

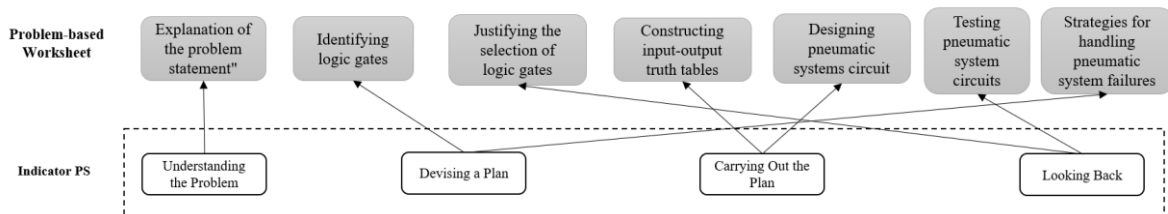


Figure 2. Stages of PBeWs Based on Problem-Solving Skills

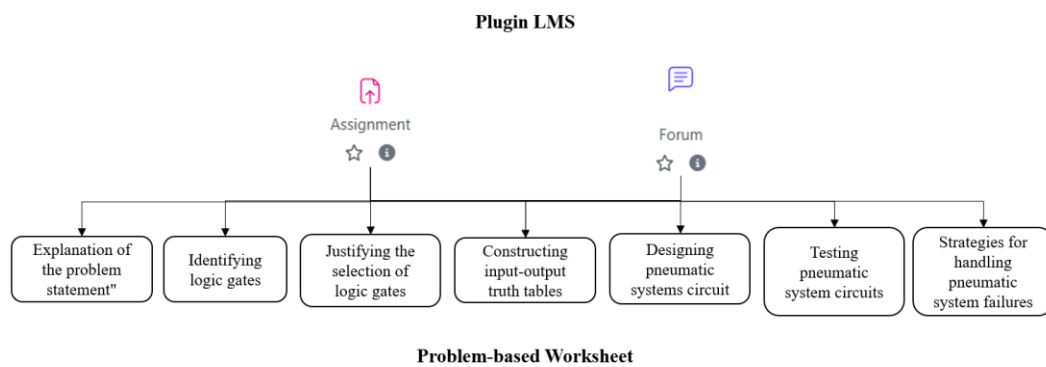


Figure 3. Stages of PBeWs Based on LMS

Feasibility of LMS-Based PBeWs (Expert Validation)

The feasibility of the developed PBeWs was assessed through expert validation encompassing three components: the PBeWs content and design, the problem-solving test instruments, and the user response questionnaires.

PBeWs Validation

Expert validation of the LMS-based PBeWs was conducted by four validators comprising two subject matter experts and two media experts, who evaluated the PBeWs across four dimensions: content accuracy, PBL instructional design, media quality, and LMS integration. The Aiken's V coefficients ranged between 0.67 and 1.00, with most items scoring above 0.78, and an overall Content Validity Index (CVI) of 0.86, categorised as "very good." These values indicate acceptable to strong content validity across the evaluated items. Validators confirmed that the PBeWs fulfilled the pedagogical requirements of PBL syntax, were aligned with vocational curriculum competencies, and incorporated contextual industrial problems appropriate to pneumatic logic gate learning. Minor revisions were recommended, particularly concerning the clarification of technical terminology, the enrichment of problem complexity, and the enhancement of visual representations. Following these revisions, the PBeWs were judged as feasible and ready for implementation.

Test Instrument Validation

The problem-solving test instruments were validated by three experts and demonstrated acceptable content validity, with Aiken's V coefficients ranging from 0.78 to 1.00 across all items. Construct validity was further examined using Rasch modelling, which indicated that most items demonstrated satisfactory fit to the measurement model, as evidenced by Mean Square (MNSQ) infit and outfit values within the acceptable range of 0.5 to 1.5, and ZSTD values not exceeding ± 2.0 . These fit statistics confirmed that the items functioned as intended and contributed coherently to the measurement of problem-solving skills. Reliability analysis yielded a Cronbach's alpha of .87, indicating good internal consistency and supporting the overall feasibility of the test instruments for use in the intervention study.

Improvement of Problem-Solving Skills (PSS)

Table 1. Mean scores, median values, and standard deviations of students' PSS

	N	Class												
		Experiment						Control						
		Logic Gate AND		Logic Gate OR		Logic Gate NOT		Logic Gate AND		Logic Gate OR		Logic Gate NOT		
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Mean														
PC	23	58.4	80.9	60.7	78.7	62.7	80.6	28	57.6	62	50.1	54.6	53.7	57.3
PE	17	42.3	66.2	39.9	62.4	46.4	68	12	34.5	39.6	35.7	39.9	38.1	42.3
Median														
PC	23	57.1	82.1	60.7	78.6	64.3	78.6	28	57.1	62.5	50	53.6	53.6	57.1
PE	17	42.9	67.9	39.3	60.7	46.4	67.9	12	33.9	39.3	35.7	39.3	39.3	42.9
SD														
PC	23	5.86	3.49	5.17	3.79	5.38	3.18	28	6.20	6.01	7.36	6.86	8.55	8.39
PE	17	6.47	4.21	7.29	4.75	3.98	6.49	12	4.66	4.16	5.49	5.25	4.43	4.52

*PC = Public, PE= Private

Descriptive statistics in Table 1 show the mean scores, median values, and standard deviations of students' problem-solving skills across the pre-test and post-test for both the experimental and control groups in public and private schools. The descriptive results provided an initial overview of students' performance before and after the intervention. These results were important because they showed the direction and magnitude of score changes across different logic gate topics. The presentation of mean, median, and standard deviation also allowed the results to be interpreted in relation to both central tendency and score variability.

Mean scores showed a clear improvement in post-test performance among the experimental groups across all three logic gate topics, namely AND, OR, and NOT, in both public and private schools. The public school experimental group showed increases from 58.4 to 80.9 for AND, from 60.7 to 78.7 for OR, and from 62.7 to 80.6 for NOT. The private school experimental group showed corresponding increases from 42.3 to 66.2 for AND, from 39.9 to 62.4 for OR, and from 46.4 to 68.0 for NOT. The control groups showed comparatively modest increases across the same topics, indicating that the experimental intervention was associated with greater mean score gains than conventional worksheet instruction.

Median values were reported alongside mean scores because subsequent inferential analyses employed non-parametric tests, for which the median provides an appropriate measure of central tendency. The experimental groups showed consistent increases in median scores across all logic gate topics in both school types. The public school experimental group showed median score increases from 57.1 to 82.1 for AND, from 60.7 to 78.6 for OR, and from 64.3 to 78.6 for NOT. The private school experimental group showed increases from 42.9 to 67.9 for AND, from 39.3 to 60.7 for OR, and from 46.4 to 67.9 for NOT. Standard deviations generally decreased from pre-test to post-test in the experimental groups across the three logic gate topics. The lower post-test SD values suggested that the intervention may have supported more homogeneous and consistent skill development among students.

Normalised Gain Analysis

N-Gain values in Table 2 show the improvement of problem-solving skills across the AND, OR, and NOT logic gate topics for both experimental and control groups in public and private schools. N-Gain scores were interpreted using Hake's classification criteria: high ($g > 0.70$), medium ($0.30 \leq g \leq 0.70$), and low ($g < 0.30$). The use of N-Gain was intended to account for differences in students' baseline performance before the intervention. This analysis therefore provided a standardised measure of learning improvement across groups and school contexts.

Table 2. N-Gain of PSS

	Class							
	N	Experiment			N	Control		
		Logic Gate AND	Logic Gate OR	Logic Gate NOT		Logic Gate AND	Logic Gate OR	Logic Gate NOT
PC	23	0.53	0.46	0.48	28	0.10	0.09	0.08
PE	17	0.41	0.36	0.40	12	0.08	0.06	0.07

*PC = Public, PE= Private

Public school results showed that the experimental group achieved medium-category gains across all three logic gate topics, with N-Gain values of 0.53 for AND, 0.46 for OR, and 0.48 for NOT. The public school control group recorded substantially lower gains of 0.10 for AND, 0.09 for OR, and 0.08 for NOT, all of which fell within the low category. Private school results showed a comparable pattern, with the experimental group achieving medium-category N-Gain values of 0.41 for AND, 0.36 for OR, and 0.40 for NOT. The private school control group recorded low-category gains of 0.08 for AND, 0.06 for OR, and 0.07 for NOT. These findings indicated that students who learned using LMS-based PBeWs experienced greater standardised improvement than students who learned using conventional worksheets.

The overall N-Gain pattern indicated that students in the experimental groups demonstrated meaningfully greater learning improvement than those in the control groups across both school types and all logic gate topics. The consistently medium-category gains in the experimental groups contrasted with the uniformly low-category gains in the control groups. This contrast provided preliminary evidence that LMS-based PBeWs were associated with more substantial improvement in problem-solving skills than conventional worksheet instruction. The pattern also suggested that the intervention was beneficial across different school contexts, although the gains in the private school experimental group were slightly lower than those in the public school experimental group.

Improvement by Class**Table 3.** Wilcoxon Signed-Rank Test of PSS

Logic Gate	Class	N	Z	Sig. (2-tailed)	Conclusion	
PC	AND	Experiment	23	-4.214	0.000	A significant increase was observed
		Control	28	-4.256	0.002	A significant increase was observed
	OR	Experiment	23	-4.212	0.000	A significant increase was observed
		Control	28	-4.734	0.002	A significant increase was observed
	NOT	Experiment	23	-4.207	0.000	A significant increase was observed
		Control	28	-4.585	0.002	A significant increase was observed
PE	AND	Experiment	17	-3.626	0.000	A significant increase was observed
		Control	12	-3.090	0.002	A significant increase was observed
	OR	Experiment	17	-3.630	0.000	A significant increase was observed
		Control	12	-3.165	0.002	A significant increase was observed
	NOT	Experiment	17	-3.625	0.000	A significant increase was observed
		Control	12	-3.133	0.002	A significant increase was observed

*PC = Public, PE= Private

The Wilcoxon Signed-Rank Test was conducted to examine pre-test to post-test differences in problem-solving skills within each group, given that normality assumptions were not fully met. The results are presented in Table 3. Public school data showed statistically significant pre-test to post-test improvements in both the experimental and control groups across all three logic gate topics. The experimental group yielded Z values of -4.214 for AND, -4.212 for OR, and -4.207 for NOT, all significant at $p < .001$. The control group also showed significant results, with Z values of -4.256 for AND, -4.734 for OR, and -4.585 for NOT, all significant at $p = .002$. Private school data showed a comparable pattern, with the experimental group producing Z values of -3.626 for AND, -3.630 for OR, and -3.625 for NOT, all significant at $p < .001$. The control group yielded Z values of -3.090 for AND, -3.165 for OR, and -3.133 for NOT, all significant at $p = .002$. All groups therefore demonstrated statistically significant within-group improvement from pre-test to post-test. The experimental groups, however, showed substantially greater descriptive gains and higher N-Gain values than the control groups, indicating stronger improvement after the implementation of LMS-based PBeWs.

Improvement by School Type**Table 4.** Mann-Whitney U Test of PSS

Logic Gate	Class	Mean N-Gain/ Rank	Sig. (2-tailed)
PC	AND	Experiment	40
		Control	14.50
	OR	Experiment	40
		Control	14.50
	NOT	Experiment	40
		Control	14.50
PE	AND	Experiment	21
		Control	6.50
	OR	Experiment	21
		Control	6.50
	NOT	Experiment	21
		Control	6.50

*PC = Public, PE= Private

The Mann-Whitney U Test was conducted to examine differences in N-Gain scores between the experimental and control groups within each school type. The results are presented in Table 4. The results indicate statistically significant differences in N-Gain scores between the experimental and control groups across all three logic gate topics, namely AND, OR, and NOT, in both public and private schools ($p < .001$). The public school experimental group achieved a mean rank of 40.00, compared with 14.50 for the control group. The private school experimental group recorded a mean rank of 21.00, compared with 6.50 for the control group. These results indicated that students in the experimental groups demonstrated significantly greater improvement in problem-solving skills than those in the control groups across both school types. The consistency of this pattern strengthened the evidence that LMS-based PBeWs provided stronger instructional support for improving vocational problem-solving skills than conventional worksheets.

Improvement of Item Indicators in Public Schools

Item-level comparisons in Figures 4, 5, and 6 show the pre-test and post-test mean scores across the seven problem-solving skill indicators for the AND, OR, and NOT logic gate topics in the public school setting. The indicators consisted of MM (Understanding the Problem), MS (Devising a Plan), MR (Carrying Out the Plan), and MNR (Looking Back). Scores were measured on a 1–4 rating scale and interpreted using four categories: Very Low (1.00–1.75), Low (1.76–2.50), High (2.51–3.25), and Very High (3.26–4.00). This item-level analysis was used to examine whether the improvement occurred broadly across problem-solving dimensions or was concentrated only in certain indicators.

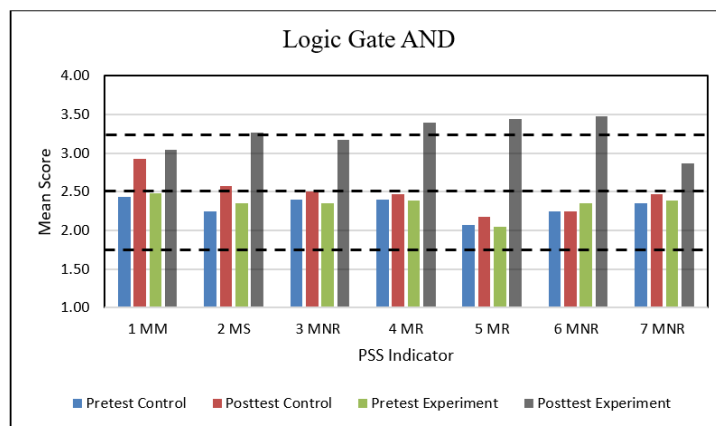


Figure 4. Comparison of Pretest and Post-test Results by Item logic gate AND

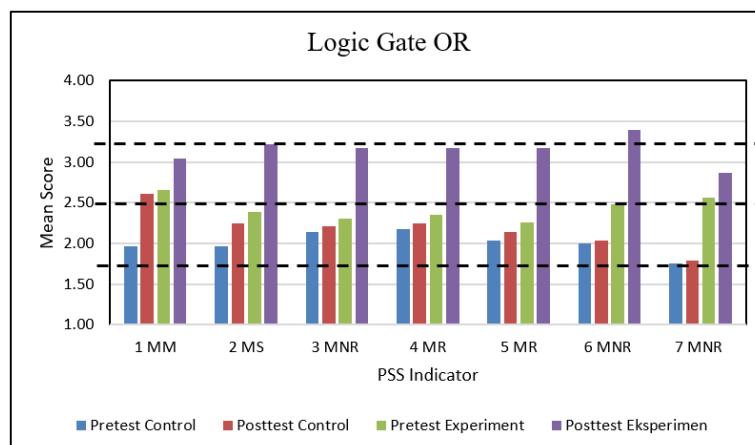


Figure 5. Comparison of Pretest and Post-test Results by Item logic gate OR

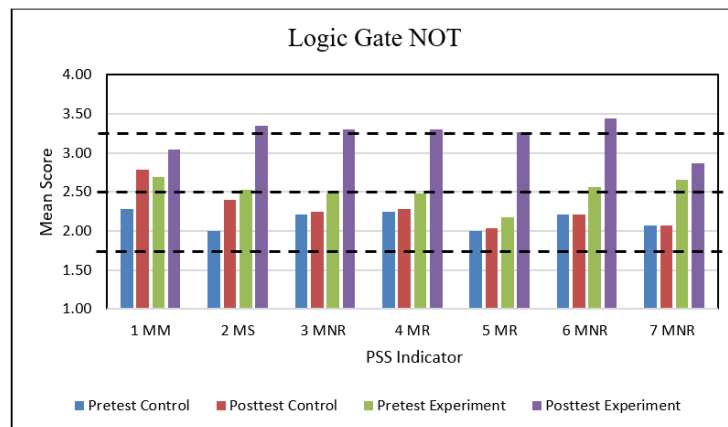


Figure 6. Comparison of Pretest and Post-test Results by Item logic gate NOT

*Description: MM = Understanding the Problem, MS = Devising a Plan, MR = Carrying Out the Plan, MNR = Looking Back

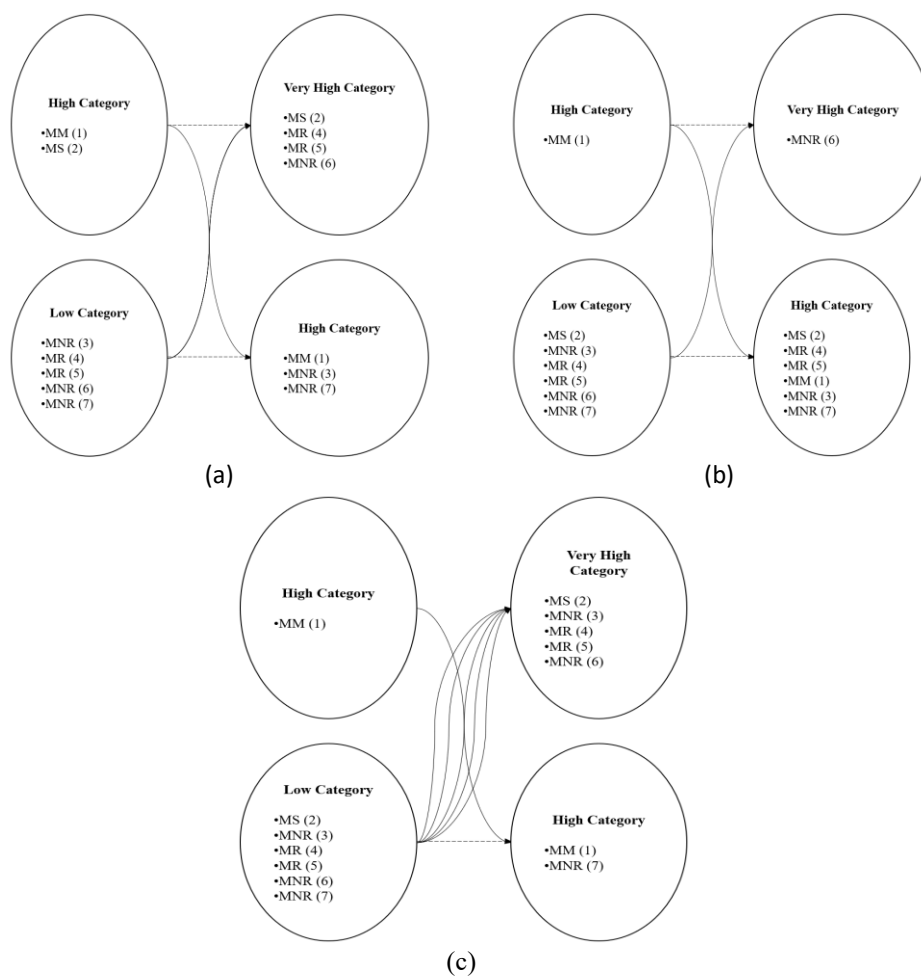


Figure 7. PSS Category for (a) AND Logic Gate in Public School (b) OR Logic Gate in Public School (c) NOT Logic Gate in Public School

A consistent pattern was observed across all three logic gate topics in the public school setting. The experimental group demonstrated substantially greater post-test improvement than the control group across nearly all indicators. Post-test scores in the experimental group approached or exceeded 3.00 across most items, placing the majority of indicators within the High to Very High categories. The most pronounced gains were observed in MM, MS, and MNR, which reflected the dimensions of problem understanding, planning, and evaluation. The control group generally remained within the Low category at post-test, indicating comparatively limited improvement after conventional worksheet instruction. Categorical distributions shown in Figures 7 further indicated that most indicators in the experimental group shifted from the Low or High pre-test category to the High or Very High post-test category across AND, OR, and NOT logic gate topics.

Improvement of Item Indicators in Private Schools

Item-level comparisons in Figures 8, 9, and 10 show the pre-test and post-test mean scores across the seven problem-solving skill indicators for the AND, OR, and NOT logic gate topics in the private school setting. Scores were measured using the same 1–4 rating scale as that applied in the public school analysis. The analysis was conducted to determine whether similar patterns of improvement were also evident in the private school context. This comparison was important because the descriptive and N-Gain results suggested that improvement occurred in both school types, although with different magnitudes. A consistent pattern was also observed in the private school setting. The experimental group demonstrated substantially greater post-test improvement than the control group across nearly all indicators. Post-test scores in the experimental group generally reached the High category, particularly for MS (Devising a Plan), MNR (Looking Back), and MR (Carrying Out the Plan). The control group showed only marginal improvement and remained predominantly within the Low category at post-test across all three logic gate topics. Categorical shifts shown in Figures 11 indicated that most indicators in the experimental group transitioned from the Very Low or Low pre-test category to the Low or High post-test category across AND, OR, and NOT topics. This upward shift suggested that LMS-based PBeWs were associated with meaningful gains in problem-solving skill development in the private school context, although the level of improvement was somewhat lower than that observed in the public school setting.

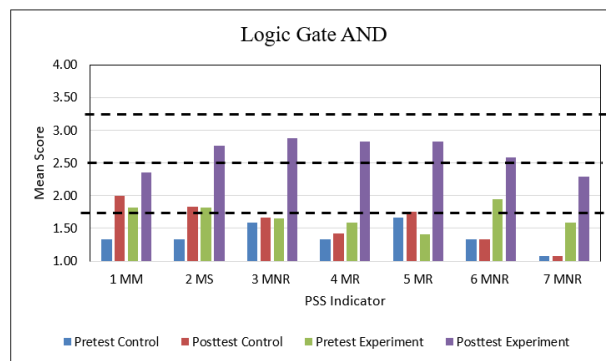


Figure 8. Comparison of Pretest and Post-test Results by Item logic gate AND

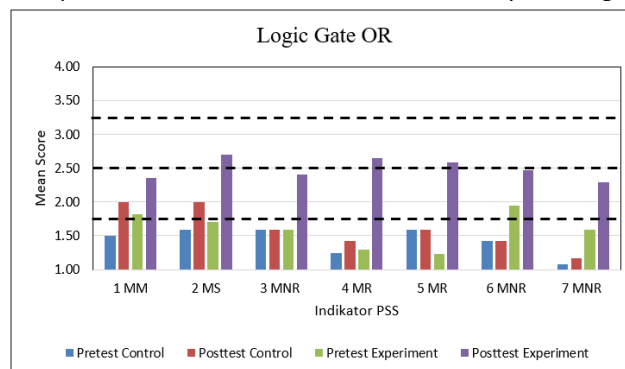


Figure 9. Comparison of Pretest and Post-test Results by Item logic gate OR

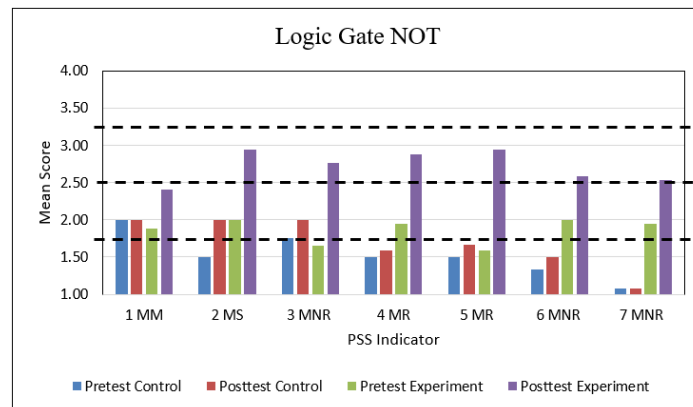


Figure 10. Comparison of Pretest and Post-test Results by Item logic gate NOT

*Description: MM = Understanding the Problem, MS = Devising a Plan, MR = Carrying Out the Plan, MNR = Looking Back

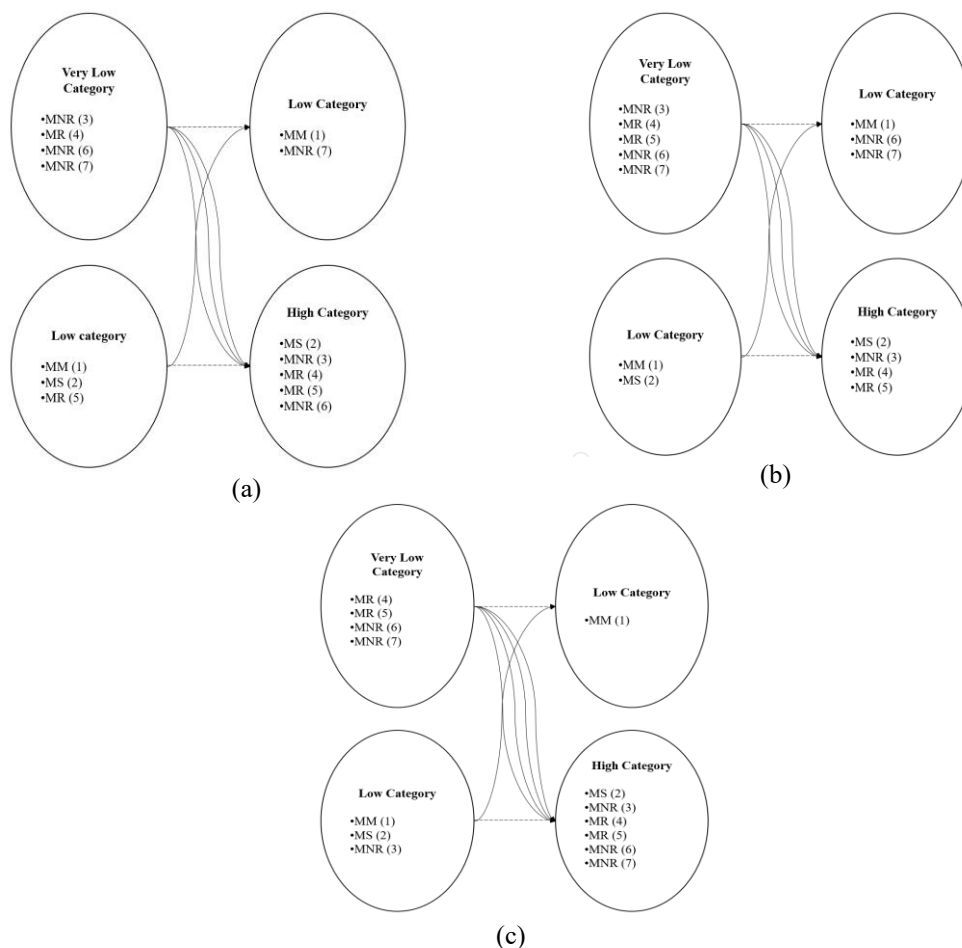


Figure 11. PSS Category for (a) AND Logic Gate in Private Schools (b) OR Logic Gate in Private Schools (c) NOT Logic Gate in Private Schools

Effective Test of PSS**Table 5. Effective Test PSS**

	Logic Gate	Z	N	r	Category
PC	AND	-4.214	23	-0.879	High
	OR	-4.212	23	-0.878	High
	NOT	-4.207	23	-0.877	High
PE	AND	-3.626	17	-0.879	High
	OR	-3.63	17	-0.880	High
	NOT	-3.625	17	-0.879	High

*PC = Public, PE= Private

Effect size was calculated using the r statistic derived from the Wilcoxon Signed-Rank Test Z values, where the absolute value of r was interpreted following Cohen's (1988) criteria: small ($r < .30$), medium ($.30 \leq r < .50$), and large ($r \geq .50$). The negative sign of the r values reflects the direction of the Z statistic rather than the magnitude of the effect and was therefore disregarded in the interpretation. The results presented in Table 5 indicate that the LMS-based PBeWs produced a large effect on students' problem-solving skill improvement across all three logic gate topics in both school types. In the public school setting, effect size values were $r = -0.879$ (AND), $r = -0.878$ (OR), and $r = -0.877$ (NOT), all categorised as large. A comparable pattern was observed in the private school setting, where effect size values of $r = -0.879$ (AND), $r = -0.880$ (OR), and $r = -0.879$ (NOT) were similarly categorised as large. These findings indicate that the magnitude of improvement associated with LMS-based PBeWs was practically substantial across both public and private school contexts.

4. DISCUSSION

Effectiveness of LMS-Based PBeWs in Improving Problem-Solving Skills

The findings suggest that LMS-based Problem-Based e-Worksheets (PBeWs) were associated with stronger gains in vocational students' problem-solving skills than conventional worksheets, as evidenced by medium-category N-Gain values in the experimental groups and large effect sizes ($r \geq 0.877$) across all logic gate topics in both school types. These results are consistent with the view advanced by (Lu & Xie, 2024), who emphasised how technology can serve as an effective scaffold for guiding students to solve problems. In the present study, this scaffolding function was operationalised through structured PBL tasks, multimedia support, and integrated automatic feedback within the Moodle LMS, providing students with a systematic pathway through the problem-solving process in vocational pneumatic logic gate learning.

The improvement observed in the experimental groups also suggests a shift in students' responses from descriptive recognition toward more analytical problem-solving. Pre-test responses tended to focus on observable symptoms in pneumatic systems without sufficient conceptual explanation or technical reasoning. Post-test responses demonstrated greater analytical depth, including the ability to identify technical problems, apply relevant logic gate concepts, and formulate more precise problem statements. This shift indicates that LMS-based PBeWs supported not only score improvement but also qualitative development in the way students approached technical problems. The pattern reflected a broader improvement across the experimental group rather than an isolated change in individual student responses.

The findings extend previous evidence on the value of combining PBL and digital learning environments. Chang et al. (2022) showed that the integration of PBL and LMS can enhance higher-order thinking skills. The present study adds a more specific contribution by showing that LMS-based PBeWs can support the documentation, structuring, and monitoring of students' problem-solving processes in vocational technical education. This contribution is relevant because higher-order thinking requires not only exposure to complex tasks but also guided opportunities to analyse, plan, implement, and evaluate solutions systematically. Similar support for problem-solving and higher-order thinking has been reported in studies on active learning, digital argumentation, and creative pedagogy (Mintzes & Walter, 2020; Affandy et al., 2024).

The results also align with studies that highlight the role of digital platforms in strengthening problem-solving competence in vocational education. Yang et al. (2025) and Ramdani et al. (2025) reported that digital problem-based learning can support vocational students' competence development. Tan and Shen (2023) also

emphasised the instructional potential of hybrid problem-based learning models. Hossain and Tatulian (2025) further showed that LMS-integrated digital systems can help students document and reflect on their learning processes. The present study reinforces these findings by demonstrating that LMS-based PBeWs can serve as a technology-supported instructional model for improving problem-solving skills in vocational pneumatic learning.

Vocational Relevance and Contextual Value of LMS-Based PBeWs

One important contribution of this study lies in its relevance to vocational education, particularly in linking problem-solving tasks to authentic technical learning contexts. The PBeWs design incorporated authentic scenarios reflecting real workplace challenges in pneumatic systems, bridging the gap between theoretical knowledge and practical application. In vocational education, problem-solving skills are not only about understanding concepts but also about the ability to apply analytical reasoning in real-world situations (Savaengkan & Chaijaroen, 2025). This is concretely illustrated in the study through the integration of logic gate concepts AND, OR, and NOT within pneumatic system contexts, requiring students to apply abstract theoretical knowledge to technically grounded, industry-relevant problems. While (Chang & Hwang, 2025) have explored enhancing problem-solving competence in vocational schools using digital platforms, the present study provides contextually specific evidence of how learning materials deliberately designed around authentic vocational scenarios can produce measurable improvements in problem-solving performance.

The emphasis on authentic scenarios aligns with evidence suggesting that contextualised tasks in vocational e-learning are important for increasing student engagement and preparing students for industry demands (Chang et al., 2024; Pimblett et al., 2025). Furthermore, the findings are responsive to evolving workplace expectations, where employers increasingly seek not only technical proficiency but also adaptability and problem-solving ability (Moust et al., 2021) LMS-based PBeWs may provide a supportive learning environment for cultivating these skills within the structure of formal vocational instruction.

The study also observed that N-Gain values and effect sizes were consistently higher in the public school experimental group than in the private school experimental group, although both groups substantially outperformed their respective control groups. While the study did not directly measure the variables that may account for this difference, possible contextual factors include differences in digital infrastructure, prior student preparation, and access to learning resources between public and private school settings. These differences warrant cautious interpretation and suggest that contextual factors in vocational schools merit further investigation.

Practical Implications, Limitations, and Future Research

The findings also suggest practical potential for implementation in vocational learning contexts. The LMS-based PBeWs model appears adaptable to digital vocational learning environments, as it enables educators to distribute, collect, and monitor worksheet activities systematically through the LMS platform, potentially reducing administrative burden and allowing teachers to focus more on their facilitative role. The capacity to update and modify PBeWs in response to developments in industry practice may also represent a practical advantage of this approach, although this was not directly measured in the present study. LMS-based PBeWs offer a promising instructional approach for vocational educators seeking to integrate problem-based learning with digital platforms, particularly in technical subjects requiring the application of abstract concepts to practical problems. However, the broader scalability and sustainability of this model require further investigation beyond the current study context.

Several limitations of this study should be acknowledged. First, the quasi-experimental design with intact class assignment, rather than random individual assignment, limits the strength of causal inference. Second, purposive sampling restricted the study to two vocational schools in Cimahi, Indonesia, which constrains the generalisability of the findings to other vocational contexts, school types, or subject domains. Third, the study focused exclusively on problem-solving skills as the primary outcome measure; other potentially relevant outcomes, such as collaborative learning, student engagement, and long-term knowledge retention, were not formally assessed. Fourth, while differences in outcomes between public and private school settings were observed, the variables that may account for these differences such as infrastructure quality, teacher experience, or student prior knowledge were not directly controlled or measured.

Future research should consider larger multi-site studies involving a more diverse range of vocational schools to enhance generalisability. Longitudinal designs would enable examination of whether the observed gains in problem-solving skills are sustained over time. Mixed-method approaches incorporating classroom observation or student interviews could provide deeper insight into the cognitive and motivational processes underlying the observed improvements. Additionally, further investigation into the differential outcomes between public and private school contexts would strengthen understanding of the contextual conditions necessary for effective LMS-based PBeWs implementation in vocational education.

5. CONCLUSION

This study suggests that LMS-based Problem-Based e-Worksheets (PBeWs) may support stronger problem-solving performance than conventional worksheets in vocational learning contexts. The developed LMS-based PBeWs combined problem-based learning syntax, contextual vocational tasks, multimedia support, and automated feedback within a Moodle LMS environment, producing a structured pedagogical scaffold designed to support problem-solving processes in vocational learning settings. Expert validation indicated that the LMS-based PBeWs were feasible for implementation in vocational learning, with positive evaluations covering content quality, instructional design, and technical usability; content and construct-related validation findings further supported their relevance to vocational education objectives. The implementation of LMS-based PBeWs was associated with greater improvement in students' problem-solving abilities than conventional worksheet instruction, as evidenced by medium-category N-Gain values and large effect sizes across all logic gate topics in both public and private school settings. This finding suggests that the proposed learning strategy may provide stronger support for analytical and contextual problem-solving in vocational education. Several limitations should be acknowledged. The quasi-experimental design with purposive sampling restricted to two vocational schools limits the generalisability of the findings to broader vocational contexts. Future research should examine the effectiveness of LMS-based PBeWs across larger and more diverse samples, through longitudinal designs, and in varied vocational subject domains to further establish the robustness and transferability of this instructional approach.

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