



DEVELOPMENT OF A TECHNOLOGY-ENHANCED PJBL-SIM MODEL ASSISTED BY E-TRAINING IN E-COMMERCE EDUCATION: VALIDITY, PRACTICALITY, AND EFFECTIVENESS

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ABSTRACT

The mismatch between vocational higher education outputs and industry competency requirements — particularly in the rapidly expanding e-commerce sector — represents a critical challenge for graduate employability in Indonesia. This study developed and validated the PjBL-Sim model assisted by e-training (Project-Based Learning integrated with Simulation and a digital e-training platform) for e-commerce courses in vocational higher education. Employing a Research and Development (R&D) approach with the ADDIE model, the study produced an integrated learning ecosystem comprising a model book, training module, lecturer and student guidebooks, and an e-training website. Development involved 18 expert validators and was tested with 36 students (18 experimental, 18 control) at Institut Teknologi Padang. Construct validity was confirmed through SEM-PLS, with all Cronbach's Alpha values exceeding 0.88 and AVE exceeding 0.68. Practicality was rated Very Practical by both lecturers and students (80%–100%). Effectiveness was demonstrated by a significant improvement from pre-test ($M = 61.56$) to post-test ($M = 81.33$), confirmed by paired t -test and MANOVA (Pillai's Trace = 0.559, $p < 0.001$; Cohen's $d = 1.23$). The PjBL-Sim model provides a theoretically grounded, empirically validated, and practically applicable alternative for e-commerce vocational training, bridging the gap between academic learning and professional industry demands

KEYWORDS: ADDIE framework; blended learning; competency gap; digital training; instructional design; learning outcomes; project-based learning; simulation learning; vocational training programmes; work readiness

INTRODUCTION

The digital economy has fundamentally reshaped labour market expectations, with e-commerce emerging as one of the fastest-growing employment sectors in Indonesia. Statistics from Badan Pusat Statistik (BPS, 2022) indicate that employment in e-commerce enterprises increased by 28% between 2015 and 2020, with projections continuing upward. Despite this expansion, a persistent competency-industry mismatch (link and match gap) afflicts graduates of vocational Informatics Engineering programmes, who frequently enter the labour market without the professional skills demanded by digital industry employers (Eko et al., 2024; Rafidiyah & Kailani, 2020; Alvendri et al., 2023).

Analysis of graduate tracer data reveals that more than 50% of Informatics Engineering alumni pursue employment outside the digital technology sector, suggesting that existing pedagogical approaches fail to adequately develop field-relevant competencies (Dianita Pramesti et al., 2024). The structural causes include curricular misalignment with the Indonesian National Competency Standards (SKKNI), excessive emphasis on theoretical instruction, and the absence of simulation-based learning environments that approximate authentic workplace conditions.

Project-Based Learning (PjBL) has been widely endorsed in vocational education for its capacity to develop critical thinking, collaboration, and applied problem-solving skills (Nidhom et al., 2020; Aurora Tjokro et al., 2023; Perdana et al., 2024). However, PjBL alone remains insufficient without integration with realistic industry simulation and flexible digital access. Simultaneously, e-training platforms have demonstrated effectiveness in enabling self-directed, flexible, and blended learning environments (Amara & Atia, 2016; Ostlund, 2017; Rafifah et al., 2024; Swara et al., 2020).

The rapid expansion of e-commerce platforms in Indonesia — including Tokopedia, Shopee, and Bukalapak — has created demand for graduates proficient in digital marketing, inventory management, and data analytics. Yet conventional vocational instruction predominantly addresses theoretical knowledge, leaving graduates ill-equipped for the practical demands of the digital workplace (Tandirerung & Patta, 2022; Kuswana, 2013; Asshadri & Nanda, 2025).

The present study addresses this gap by developing and validating the PjBL-Sim model — an integrated instructional model combining Project-Based Learning, Simulation, and e-training — specifically designed for e-commerce courses in vocational higher education. The model operationalises a five-phase learning syntax (Introduction, Demonstration, Discussion, Simulation, Evaluation) delivered through a purpose-built e-training website. Research questions: (1) How valid, practical, and effective is the PjBL-Sim model for e-commerce

education? (2) What is its impact on student learning outcomes and professional readiness?

1. THEORETICAL BACKGROUND

2.1 Project-Based Learning (PjBL)

PjBL is a student-centred instructional approach in which learners engage in sustained, collaborative, and authentic projects requiring application of knowledge to solve real-world problems (Joyce & Weil, 2003). In vocational contexts, PjBL generates instructional and companion impacts: knowledge and skill acquisition as well as metacognitive, affective, and social dispositions (Joyce et al., 2009). Research consistently demonstrates that PjBL improves critical thinking, self-efficacy, and work readiness in vocational students (Rusnawati et al., 2025; Fauziah, 2025). The constructivist foundation of PjBL aligns closely with e-commerce education, where students must integrate knowledge from marketing, logistics, information technology, and consumer behaviour to address authentic business challenges.

2.2 Simulation-Based Learning

Simulation-based instruction creates controlled virtual environments that replicate authentic professional scenarios, enabling learners to practise decision-making and technical skills without risk of real-world failure (Aldamen et al., 2021). Bandura's social cognitive theory (1997) provides a theoretical basis for simulation effectiveness: structured consequence-free performance rehearsal develops the self-efficacy required to transfer skills to authentic workplace environments. The growing adoption of technology-mediated simulation in Indonesian vocational education has been documented in a systematic literature review, confirming that media-based simulation produces measurable competency gains across vocational domains (Pratama et al., 2023). In the PjBL-Sim model, simulation exercises replicate the operational complexities of an online marketplace, including product listing optimisation and order fulfilment workflows.

2.3 E-Training in Digital Learning Environments

E-training refers to electronically mediated training using digital tools and internet connectivity to deliver knowledge, skills, and attitudinal development without requiring physical co-presence of trainer and trainee (Ostlund, 2017; Amara & Atia, 2016). E-training platforms enable asynchronous and synchronous interaction, self-paced progression, and multimedia-enriched content delivery (Horton, 2006; Naidu, 2006). Research in Indonesian higher education confirms its effectiveness in extending learning access and promoting learner autonomy, particularly in blended and mobile-based configurations (Rafifah et al., 2024; Nurhadi, 2020; Syahril et al., 2022).

2.4 The ADDIE Development Framework

The ADDIE model (Analysis, Design, Development, Implementation, Evaluation) provides a systematic instructional design framework ensuring each phase

informs and is validated by the subsequent phase (Branch, 2009). Its iterative, formative structure makes it particularly appropriate for complex technology-integrated instructional products requiring multi-expert

validation and empirical field testing (Plomp, 2013). Figure 1 illustrates the sequential ADDIE phases applied in this study.

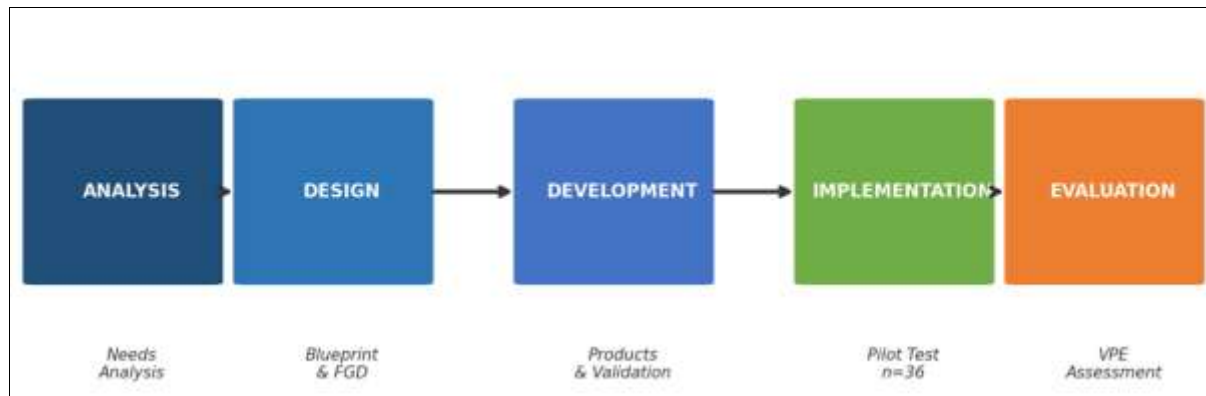


Figure 1. ADDIE Development Phases for PjBL-Sim Model

2.5 Competency Gap in Vocational E-Commerce Education

The Indonesian Ministry of Education and Culture has identified e-commerce as a priority competency area, mandating alignment between vocational curricula and SKKNI for e-commerce practitioners. Despite this mandate, empirical studies reveal persistent gaps: vocational graduates typically demonstrate adequate theoretical knowledge but insufficient practical skills in platform management, digital advertising, and data-driven decision-making (Eko et al., 2024; BPS, 2022). The PjBL-Sim model directly targets this gap by creating learning experiences that mirror the operational realities of e-commerce enterprises.

2. RESEARCH METHOD

3.1 Research Design

This study employed a Research and Development (R&D) approach, specifically Educational Design Research following the ADDIE model (Borg, 1983; Plomp, 2013). The five phases — Analysis, Design, Development, Implementation, and Evaluation — structured the systematic development, validation, and field testing of the PjBL-Sim model and its supporting products.

3.2 Development Phases

Phase 1 — Analysis: Needs analysis was conducted through student questionnaires ($n = 35$), graduate tracer surveys, structured interviews with lecturers and industry professionals, and curriculum document analysis. Technology readiness was assessed across four dimensions: technological motivation, technology access, digital skills, and technology utilisation. Analysis revealed that 82.2%–88.9% of students expressed high motivation to use digital tools and 80%–

91.1% demonstrated adequate digital skills, confirming technical readiness.

Phase 2 — Design: A conceptual blueprint was developed comprising the learning syntax, instructional principles, social system, support systems, and instructional and companion impacts. Supporting products were concurrently designed following Focus Group Discussion (FGD) with domain experts. The e-training website architecture was designed following UI/UX best practices (Hafidz et al., 2022) to ensure intuitive navigation and accessibility.

Phase 3 — Development: All products were developed and subjected to expert validation using Likert-scale instruments validated for content validity (Aiken, 1980). SEM-PLS (SmartPLS 4) was employed to assess construct validity and reliability across all model components. The e-training website was developed incorporating responsive design, multimedia content modules, discussion forums, and integrated assessment tools.

Phase 4 — Implementation: The validated model was piloted with 36 Information Engineering students at Institut Teknologi Padang, divided into experimental ($n = 18$) and control ($n = 18$) groups. The experimental group received PjBL-Sim instruction over eight weeks; the control group followed conventional PjBL instruction with equivalent contact time and topic coverage.

Phase 5 — Evaluation: Post-intervention data were analysed for validity (SEM-PLS), practicality (lecturer and student questionnaires), and effectiveness (pre/post-test with t-tests and MANOVA). Formative evaluation feedback was gathered throughout implementation to guide iterative refinement of the e-training platform.

3.3 Participants and Sampling

Expert validators ($n = 18$; 9 per instrument panel) were recruited from vocational education, instructional design, information technology, and e-commerce domains. All validators held doctoral qualifications with a minimum of five years of domain expertise. Student participants ($n = 36$) were enrolled in the E-Commerce course at Institut Teknologi Padang. Pre-test baseline equivalence between groups was confirmed by independent t-test ($t = 1.289$, $p = 0.215$).

3.4 Instruments and Data Analysis

Validation instruments comprised six Likert-scale questionnaires covering: (1) model book construct validity; (2) syntax validation; (3) module validation; (4) website validation; (5) lecturer guide; and (6) student guide. Learning outcomes were measured through 30-item pre-test and post-test instruments (Cronbach's $\alpha = 0.906$). Validity thresholds: $\alpha \geq 0.70$, $AVE \geq 0.50$. Effectiveness was assessed using Kolmogorov-Smirnov normality testing, Levene's homogeneity test, paired-samples t-test, independent t-test, MANOVA, and Cohen's d. Ethical approval was obtained; all participants provided informed consent.

3. RESULTS

4.1 PjBL-Sim Model: Architecture and Syntax

The PjBL-Sim model integrates Project-Based Learning and Simulation within a blended learning framework supported by a purpose-built e-training website. The model operates through five sequential phases. Supporting products include: (1) Model Book — theoretical foundations and operational guidelines; (2) Training Module — learning materials aligned to SKKNI; (3) Lecturer Guide — implementation protocols; (4) Student Guide — self-directed learning support; and (5) E-Training Website — digital platform hosting all content, simulation modules, discussion forums, and assessment tools. Figure 2 illustrates the five-phase learning syntax.

Phase 1 — Introduction: The instructor orients students to the e-commerce project context, learning objectives, and platform navigation. **Phase 2 — Demonstration:** Expert demonstration of professional e-commerce processes is delivered via multimedia on the e-training platform. **Phase 3 — Discussion:** Students engage in collaborative analysis via online discussion forums and face-to-face seminars. **Phase 4 — Simulation:** Students undertake controlled simulation exercises replicating authentic e-commerce scenarios, with immediate feedback. **Phase 5 — Evaluation:** Student work is presented and critiqued across cognitive, affective, and psychomotor dimensions.



Figure 2. PjBL-Sim Five-Phase Learning Syntax

4.2 Validity Results

Expert validation involved nine validators per instrument. SEM-PLS analysis confirmed all model comparison of all three psychometric indices.

components met validity and reliability thresholds. Table 1 presents construct validity results for the model book and learning syntax. Figure 3 provides a visual

Table 1. Construct Validity of PjBL-Sim Model Components (SEM-PLS, $n = 9$)

Component	Cronbach's α	CR (ρ_A)	CR (ρ_C)	AVE
Model Impact (DM)	0.891	0.945	0.926	0.762
Novelty & Characteristics (KKM)	0.917	0.925	0.942	0.803
Theoretical Foundation (LKM)	0.929	0.940	0.947	0.782
Support System (SP)	0.925	0.934	0.947	0.818
Learning Syntax (SiP)	0.933	0.940	0.952	0.833

All Cronbach's Alpha values exceeded 0.88, composite reliability exceeded 0.90, and AVE exceeded 0.76 — comfortably surpassing recommended thresholds of 0.70 and 0.50. Syntax validation produced similar results across all five phases (α : 0.887–0.933; AVE: 0.689–0.754). Table 2 presents the extended validity summary across all product components.

Table 2. Summary Validity Ratings Across All Product Components

Product Component	α Range	AVE Range	Category
Model Book	0.891–0.933	0.762–0.833	Very Valid
Learning Syntax	0.887–0.933	0.689–0.754	Very Valid
Training Module	0.880–0.929	0.681–0.804	Very Valid
Lecturer Guide	0.893–0.921	0.698–0.812	Very Valid
Student Guide	0.885–0.918	0.693–0.807	Very Valid
E-Training Website	0.897–0.935	0.704–0.836	Very Valid

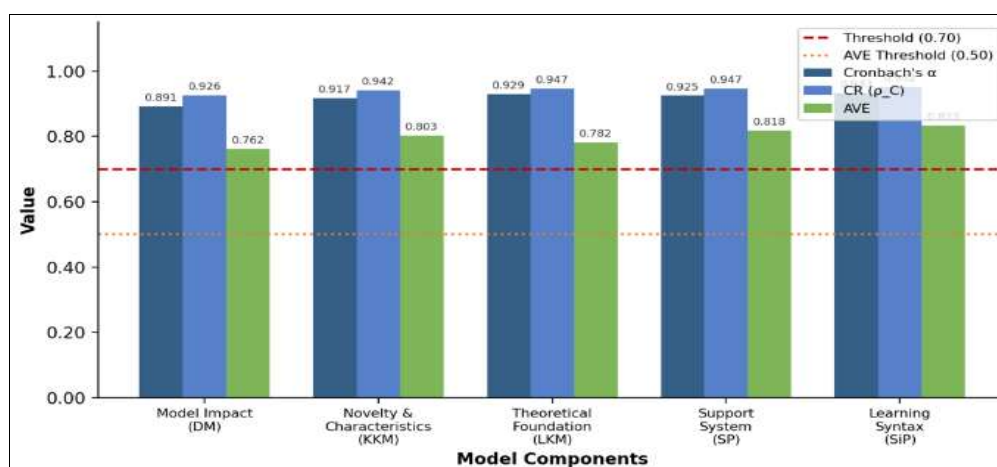


Figure 3. Construct Validity Indices Across PjBL-Sim Model Components

4.3 Practicality Results

Practicality was assessed by three lecturers and 18 students following the implementation phase. Table 3 presents summary scores across product dimensions. Figure 4 shows a comparative radar chart of lecturer and student practicality ratings.

Table 3. Practicality Assessment Results — Lecturers and Students

Product Component	Lect. Mean	Stud. Mean	Score %	Category
Overall Model	4.2	4.1	83%	Very Practical
Model Book	4.3	4.2	86%	Very Practical
Training Module	4.0	4.1	80%	Practical
Lecturer Guide	4.3	N/A	87%	Very Practical
Student Guide	N/A	4.2	84%	Very Practical
E-Training Website	4.7	4.5	93%	Very Practical

The e-training website received the highest practicality scores (lecturers: 93%; students: 90%), reflecting its intuitive interface and accessibility. No component received a rating below Practical ($\geq 76\%$), demonstrating broad usability. Students particularly valued the simulation modules and asynchronous access capabilities.

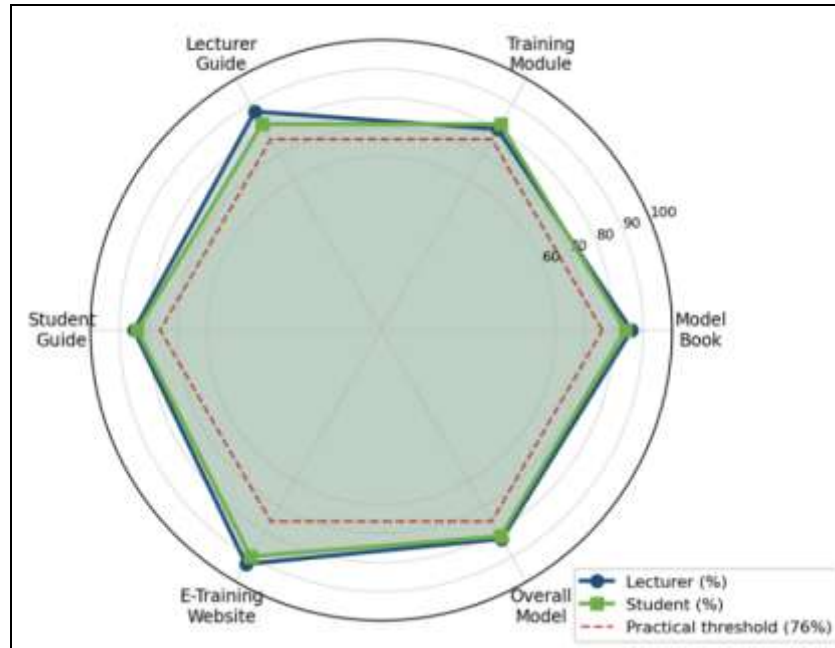


Figure 4. Practicality Assessment Radar: Lecturers vs Students (%)

4.4 Effectiveness Results

Prior to inferential analysis, normality (Kolmogorov-Smirnov: $p > 0.05$) and homogeneity of variance (Levene’s test: $p = 0.412$) were confirmed. Table 4 presents descriptive statistics for both groups across both time points.

Table 4. Descriptive Statistics — Pre-test and Post-test Scores

Group	Test	n	Mean	SD
Experimental	Pre-test	18	61.56	9.14
Experimental	Post-test	18	81.33	7.32
Control	Pre-test	18	65.44	10.95
Control	Post-test	18	71.78	9.51

The experimental group demonstrated a mean increase of 19.77 points (32.1% improvement) from pre- to post-test, compared to 6.34 points (9.7%) in the control group. The SD of experimental post-test scores decreased from 9.14 to 7.32, indicating greater learning homogeneity following the intervention. Table 5 presents inferential statistics.

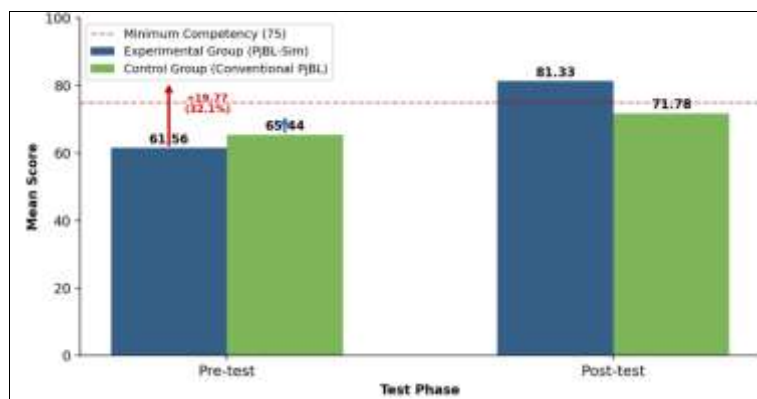


Figure 5. Pre-test and Post-test Mean Scores: Experimental vs Control Group

Table 5. Inferential Statistics — Effectiveness Testing

Statistical Test	Statistic	df / Trace	p-value
Paired t-test (Exp. pre/post)	t = 9.84	df = 17	< 0.001
Independent t-test (post)	t = 3.12	df = 34	0.004
MANOVA — Pillai's Trace	F = 20.93	0.559	< 0.001
MANOVA — Wilks' Lambda	F = 20.93	0.441	< 0.001
Effect Size (Cohen's d)	d = 1.23	—	Large

The paired t-test confirmed highly significant pre-to-post improvement within the experimental group ($t = 9.84$, $p < 0.001$). The independent t-test revealed a significant difference between experimental and control post-test means ($t = 3.12$, $p = 0.004$). MANOVA (Pillai's Trace = 0.559, $F = 20.93$, $p < 0.001$) indicated approximately 55.9% of variance in combined outcome variables was attributable to the intervention. Cohen's $d = 1.23$ indicates a large practical effect size, substantially exceeding the threshold for educational significance ($d > 0.80$).

4. DISCUSSION

5.1 Validity and Theoretical Soundness

The PjBL-Sim model demonstrates strong validity across all assessed dimensions, confirming satisfaction of the theoretical criteria for quality instructional models as delineated by Joyce and Weil (2003): strong theoretical foundation, internal consistency, social system coherence, and implementational adequacy. The convergent validity demonstrated through SEM-PLS validates not only individual components but the structural interrelationships among the five syntax phases — confirming that simulation mediates the transition from introductory and demonstrative learning to evaluative mastery.

These findings extend previous research on PjBL effectiveness in vocational settings (Aurora Tjokro et al., 2023; Rusnawati et al., 2025) by demonstrating that the integration of simulation and e-training amplifies PjBL's theoretical integrity. The multi-expert validation process ($n = 18$ validators) provides unusually robust evidence for content validity, exceeding the validation scope of most comparable instructional development studies in Indonesian vocational education.

5.2 Practicality and Implementation Feasibility

The consistent Very Practical ratings (80%–100%) across all components indicate that the PjBL-Sim model can be adopted without significant operational barriers in vocational higher education settings. The particularly high practicality scores for the e-training website (lecturers: 93%; students: 90%) suggest that the platform's UI/UX design successfully addressed the usability requirements identified during the analysis phase. This is consistent with research demonstrating that perceived ease of use is a primary determinant of digital learning platform adoption (Horton, 2006; Naidu, 2006).

The persistent preference for face-to-face interaction noted during implementation is consistent with blended learning research indicating that instructor social presence remains a critical mediator of learner engagement in hybrid environments (Nurhadi, 2020; Oktarina & Yusra, 2025). This confirms that the PjBL-Sim model functions optimally as a blended — rather than purely online — learning environment.

5.3 Effectiveness and Effect Size

The large effect size (Cohen's $d = 1.23$) substantially exceeds effect sizes typically reported for PjBL-alone interventions in similar vocational contexts ($d \approx 0.50$ – 0.80 ; Nidhom et al., 2020), as visualised in Figure 6. This suggests the simulation and e-training components contribute meaningfully and independently to learning outcomes beyond the PjBL foundation, supporting the theoretical argument that simulation provides experiential self-efficacy development (Bandura, 1997) that PjBL alone cannot fully achieve.

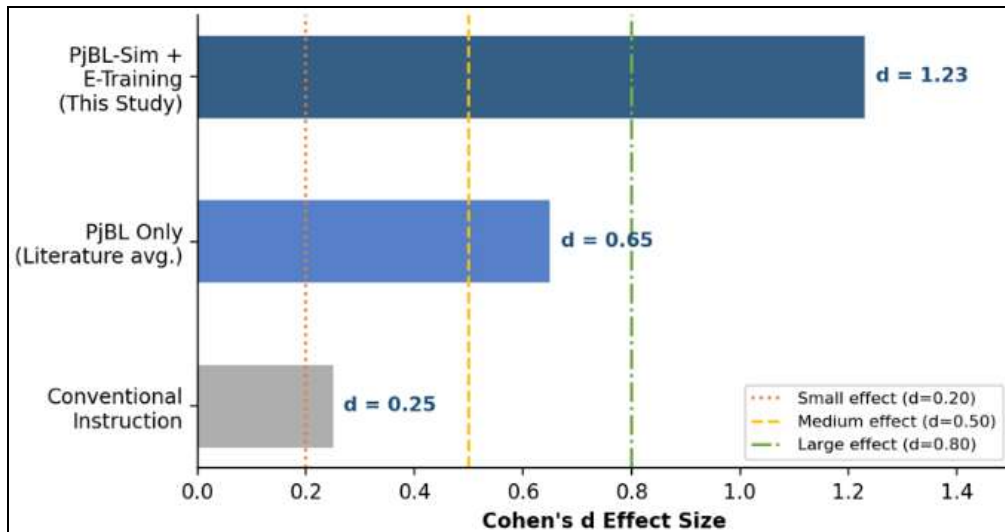


Figure 6. Effect Size Comparison: PjBL-Sim vs Baseline Instructional Approaches

The MANOVA findings (Pillai's Trace = 0.559) indicate that the intervention accounted for 55.9% of variance across combined outcome measures encompassing cognitive, affective, and psychomotor domains. This multivariate coverage confirms the model produces holistic competency development consistent with the three-domain framework of vocational education, rather than isolated cognitive gains.

5.4 Soft Skills and Professional Readiness

Qualitative analysis of student project outputs and lecturer observation notes revealed meaningful improvements in soft skills: collaborative problem-solving, professional communication, project management discipline, and creative adaptation to simulated market challenges. These findings align with Sutirman (2019) and are further corroborated by studies demonstrating that technology-based soft skill development programmes for vocational contexts produce transferable professional competencies (Suryati et al., 2022; Mustofa et al., 2020). They extend evidence for PjBL's social and managerial competency development to a blended, simulation-enhanced context. Development of professional readiness through simulated performance represents a methodological advance over prior PjBL studies relying exclusively on written assessment data.

5.5 Limitations

Several limitations constrain the generalisability of these findings. First, the relatively small sample ($n = 36$) and single-institution context limit statistical power and transferability. Second, the focus on short-term outcomes does not address longitudinal indicators of professional readiness such as actual workplace performance. Third, the control group received conventional PjBL instruction rather than a no-treatment condition, meaning the effect size reflects

incremental benefit of the PjBL-Sim enhancements rather than absolute model effectiveness. Future research should conduct multi-institutional randomised controlled trials with longitudinal outcome tracking.

5. CONCLUSIONS

This study successfully developed and empirically validated the PjBL-Sim model assisted by e-training as an innovative instructional approach for e-commerce courses in vocational higher education. Three principal conclusions are drawn.

Validity: The model and all supporting products demonstrate high construct validity and internal consistency (Cronbach's $\alpha > 0.88$; AVE > 0.68), confirming their theoretical soundness and measurement integrity across all five model components and five product types.

Practicality: Both lecturers and students rated all components as Practical to Very Practical (80%–100%), indicating that the model can be adopted without significant operational barriers in vocational higher education settings.

Effectiveness: The model produced a significant and large improvement in student learning outcomes (pre-test $M = 61.56 \rightarrow$ post-test $M = 81.33$; $d = 1.23$; MANOVA Pillai's Trace = 0.559, $p < 0.001$), substantially outperforming conventional PjBL instruction in developing e-commerce professional competencies across cognitive, affective, and psychomotor domains.

The PjBL-Sim model represents a theoretically grounded, empirically validated, and practically applicable solution for bridging the competency-industry gap in Indonesian vocational e-commerce education. Adoption is recommended for e-commerce and related digital technology courses, supported by

structured faculty development in simulation facilitation and e-training platform management.

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7. AUTHOR CONTRIBUTIONS

Conceptualization, G.Y.S.; methodology, G.Y.S. and M.G.; software, G.Y.S.; validation, M.G. and M.M.; formal analysis, G.Y.S.; investigation, G.Y.S.; data curation, G.Y.S.; writing — original draft preparation, G.Y.S.; writing — review and editing, M.G. and M.M.; supervision, M.G. and M.M. All authors have read and agreed to the published version of the manuscript

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