Journal of Nonformal Education
Vol. 12, No. 1 (2026) 194-207

p-ISSN 2442-532X | e-ISSN 2528-4541
https://journal.unnes.ac.id/journals/jone

Development and Effectiveness of eBizmate: A Project-Based Digital Simulation for Enhancing Business Opportunity Analysis Competence in Vocational Education

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Submitted: October 26, 2025. Revised: December 26, 2025. Accepted: January 26, 2026.

Abstract

Background – Business opportunity analysis is a fundamental yet cognitively critical demanding competency in the Entrepreneurship and Crafts (PKWU) subject. Prior studies indicate that students often struggle with abstract financial nature and risk analysis due to limited interactive scaffoldding and lack of contextualized leearning media.
Research Objective – This study aims to develop and provide preliminary evidence that examining the effectiveness of eBizmate, a digital based learning medium integrated with Project-Based Learning (PjBL) to enhance students' business analysis competence.
Research Method – Employing the ADDIE model, this Research and Development study developed a web-based prototype featuring AI-driven market simulations and automated feedback systems. The prototype was evaluateed through expert review (n=3) and a limiteed user trial (n=15) to assess feasibility and usability. Effectiveness was examined using a quasi-experimental pretest-posttest control group design involving 60 vocational students (experimental n=30: control n=30). Data were analyzed using N-gain scores and independent t-tests. Assumptions of normality and homogeneity were tested prior to analysis.
Research Findings – Expert appraisal (M= 4.47/5.0) and limited trial results suggest that eBizmate is feasible and usable as a learning medium, although these findings should be interpreted as a preliminary due to the small sample sizes. The experimental group demonstrated higher posttest performance (M= 82.7, SD= 5.9) compared to the control group (M= 68.4, SD= 6.3), with a statistically significant difference ($t(58)= 4.78$, $p < 0.001$). The magnitude of the effect depends on the calculation approach: using posttestt pooled standard deviation yields a very large effect (Cohen's $d \approx 2.33$), whereas the reported effect size ($d = 1.21$) likely reflects gain-score standardization; The most substantial gains occurred in financial and risk analysis. However, this requires further clarification. Confidence intervals were not estimated and should be included in future analyses.
Research Conclusion – The findings provide preliminary evidence that eBizmate may support students' business analysis competence within a PjBL environment. However, due to the quasi-experimental design, limited validation procedures and incomplete statistical reporting, conclusions regarding effectiveness should be interpreted cautiously.
Research Novelty/Contribution – This study contributes an empirically validated model for integrating simulation-based digital scaffolding within a project-based framework to master complex entrepreneurship competencies in vocational education.(This study contributes an exploratory design of a digital simulation tool that integrates multiple aspects of business analysis (market, financcial, and risk) within a structured PjBL sccaffold. Future studies should employ stronger experimental controls, transparent effect size reporting, and comprehensive validation procedures).

Keywords: business opportunity analysis; digital learning media; project-based learning.

How to Cite:
Ardyanti, Y., Yusuf, A.R., & Sumaji. (2025). Development of eBIZMATE Project-Based Learning Media to Improve Cognitive Scaffolding of Vocational High School Students in Entrepreneurship Subjects. *Journal of Nonformal Education, 12(*1), 194-207. https://doi.org/10.15294/jone.v12i1.41799

INTRODUCTION

Entrepreneurship education, embedded in the Entrepreneurship and Crafts (PKWU) subject in Indonesia, plays a crucial role in preparing learners to navigate economic uncertainty and workforce transformation in the era of Industry 4.0 and Society 5.0 (Kemendikbudristek, 2022). Within the Indonesian vocational curriculum, particularly in the Entrepreneurship and Crafts (PKWU) subject, one of the key competencies within this subject is business opportunity and feasibility analysis, which requires an integrated entrepreneurial competence that can be framed into the integration of cognitive (market and financial knowledge), affective (risk-taking attitude and creativity), and procedural skills (business planning and execution) (Sukomo, et.al, 2024). Such multidimensional competence is essential because entrepreneurial performance depends on the ability to combine knowledge, attitudes and practical skills in dynamic and uncertain environments to build students' readiness for real entrepreneurial practice (Siahaan, et. al, 2025: Rauch & Hulsink, 2021). Recent studies highlight that effective entrepreneurship education requires authentic, experiential and technology-supported learning environments to facilitate higher-order thinking and decision making (Makransky & Petersen, 2021: Radianti et al., 2023; Wekerle et al., 2022). In particular, simulation-based learning and digital tools have been shown to enhance learners' ability to understand complex systems, test decisions, and engage in iterative problem-solving (Sounthornwiboon,, et.al, 2025). Furthermore, Project-Based Learning (PjBL) has been widely recognized as an effective pedagogical approach for developing 21st-century skills, including critical thinking, collaboration, and problem-solving (Chen & Yang, 2023; Bell, 2021).

Despite its importance, empirical evidence indicates that entrepreneurship learning in vocational education often indicates that many vocational students experience substantial difficulty in mastering this competency, particularly in translating abstract financial and risk concepts into practical decision-making contexts (Widodo, et.al, 2025). Recent studies confirm that PKWU learning often remains theoretical, textual, and detached from dynamic business contexts (Rahmah & Sari, 2023). Students face concrete difficulties in visualizing the application of feasibility calculations, SWOT analysis, or market studies in real situations. Fauzi & Anwar (2022) found approximately 70% of vocational students struggle with financial feasibility analysis due to a lack of visual aids that contextualize abstract numbers (Aldianto & Anggadwita, 2021). Its learning composition visual aids buildings commonly used learning media are limited to PowerPoint, videos, or static case studies, which fail to provide deep experiential learning (Safitri et al., 2024).

Although PjBL approach mandated in the Merdeka Curriculum promising framework for effective method on fostering collaboration skills employing critical thinking and problem solving sklls are fundamental skills needed in the 21st century, its implementation in complex domains such as business analysis is often constrained by the absence of structured instructional support (Wibowo, F.A, 2024). Previous studies have identified a "scaffolding gap," where learners are expected to perform complex analytical tasks without sufficient guidance, leading to cognitive overload and suboptimal learning outcomes (Huang et al., 2022).This indicates that PjBL requires more concrete instructional scaffolding to be experientially and meaningfully being implemented in the learning processes. From a theoretical perspective, this isssue can be explained through the lens of Vygotsky's sociocultural theory, particularly the concept of the *Zone of Proximal Development (ZPD)*, where learners require structured support (scaffolding) to move from assisted to independent performance (Rahman, 2024). Instructional scaffolding involves temporary, adaptive support that guides learners through complex tasks until competence is achieved (Dominguez, 2023). In the context of entrepreneurship learning, scaffolding is essential because business analysis tasks involve multi-step reasoning, uncertainty, and dynamic variables. However, in some many cases in vocational PKWU classrooms, scaffolding remains implicit and highly dependent on teacher explanation, resulting in what previous studies describe as a "scaffolding gap" in Project-Based learning (PjBL) environments (Sari & Pratiwi, 2022).

To address this challenge, recent advances in educational technology propose digital scaffolding as a mechanism solution, to operationalize instructional support through interactive systems (Ifenthaler & Schumacher, 2021). Digital scaffolding refers to technology-mediated guidance-such as step-by-step prompts, simulations, feedback systems, and visualizations that dynamically support learners' cognitive processes (Zhang et al., 2022). From a cognitive load theory perspective, such digital tools can reduce intrinsic and extraneous cognitive load by externalizing complex calculations and structuring problem-solving pathways, thereby allowing learners to focus on higher-order reasoning (Barbieri, C.A & Rodrigues, 2025). However, existing studies on digital scaffolding tools reveal several limitations in supporting learners' cognitive competencies and business skills. First, digitals tools may focus only on single-domain competencies, such as

p-ISSN 2442-532X | e-ISSN 2528-4541
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marketing or financial analysis, without integrating multiple aspects of business decision-making (Putra et al., 2024; Nugroho et al., 2023). Second, few studies explicitly integrate digital scaffolding within the pedagogical structure of PjBL, resulting in fragmented and uncoordinated learning experiences (Bond et al., 2024). Third, the alignment between technological features and theoretical constructs such as scaffolding and cognitive load is often underdeveloped, limiting the explanatory and instructional value of these tools (Zawacki-Richer et al., 2022; Sweller at al., 2021). Within a PjBL framework, digital scaffolding can function as a "cognitive partner" that supports learners throughout the project cycle, particularly in analytically demanding phases such as feasibility analysis (Larsen I.B, 2025). In addition, previous studies often lack comprehensive empirical validation particularly in non-formal and vocational education contexts where learners' diversity and instructional constraints require adaptive and structured learning solutions (Chui, Q., 2024; Li. J., et al, 2025; Plooy et. al, 2024; Ramdani, Z, 2022). Thus, there remains a significant gap in developing and evaluating empirically integrated digital learning models that combine scaffolding simulation PjBL framework in the business teaching and learning, a gap particularly acute in non-formal education and vocational education sector.

Initial needs analysis through interviews with PKWU teachers in several vocational schools revealed three primary needs: (1) media that can simulate interactive and dynamic market conditions; (2) tools to visualize financial calculations in real-time; and (3) a platform that guides students step-by-step through business analysis within a project. Despite this theoretical potential, empirical studies on digital learning media in entrepreneurship education show several limitations. Existing tools, such as interactive e-modules or simulation applications, have demonstrated positive effects on specific competencies aligns with the trends in learning media development research; for example, in financial calculations, Nugroho et al (2023) successfully improved student learning outcomes by 25% using an interactive e-module with a break-even point simulation, emphasizing the importance of step-by-step guidance. Similarly, Putra et al. (2024) developed the "BizSim" business simulation application, showing improved marketing understanding.

However, these literature studies reveal a research gap generally focus on single-domain simulations either marketing or finance only and lack explicit integration with the pedagogical structure of PjBL as a seamless scaffold (Aldianto & Anggadwita, 2021). Moreover, while there is a growing body of literature on digital entrepreneurship in Indonesian secondary education (PKWU) and separate research on businesss simulations, studies that integrate all these elements (simulations, feedback and visualization) specifically to teach rigorous business analysis are virtually non-existent. In vocational schools, project-based learning is a suitable model since it brings products as an output. The example of learning activities with the product as the output that can be conducted long distanced is in several competencies, such as software engineering programs (Yusuf et al., 2021). As a result, the integration between scaffolding theory, digital tools, and PjBL practice remains underdeveloped. Based on this gap, this study proposes a conceptual model of digital scaffolding in PjBL, in which, simulation features represent real-world business dynamics (market, financial, and risk variables); guided project workflows provide structured, step-by step scaffolding aligned with PjBL phases, and automated feedback and visualization support learners' decision-making and reflection processes. These components are hypothesized to enhance business analysis competence by reducing cognitive overload and supporting progressive knowledge construction within the learner's ZPD.

A preliminary needs analysis was conducted to ground the development process involving PKWU teachers (n=5) and vocational students (n=30) from two schools. Participants were selected using purposive sampling to represent active PKWU instructors and students who had completed basic entrepreneurship modules. Data were collected through semi-structured interviews focusing on learning difficulties, media usage, and desired features of digital tools. The interview protocol consisted of three domains: (1) challenges in teaching/learning business analysis, (2) limitations of existing media, and (3) expectations for interactive learning tools. Data were analyzed using thematic analysis involving initial coding, category development, and cross-validation between researchers. The findings consistently indicated three key needs: (1) interactive simulation of market dynamics, (2) real-time visualization of financial calculations, and (3) structured guidance for step-by-step business analysis within projects.

To address this gap, based on the theoretical and empirical considerations above, this study develops eBizmate (Educational Business Simulation Mate), a digital learning medium designed to integrate multi-aspect business simulation with structured scaffolding within a PjBL framework. This study offers an incremental and design-based contribution by proposing and empirically exploring a more integrated approach to digital scaffolding in vocational entrepreneurship education. Unlike previous digital learning media, which tended to be partial or focused on only one aspect of simulation, eBizmate offers something new through

functional integration as a comprehensive cognitive scaffolding instrument. Theoretically, these medium bridges the 'scaffolding gap' in the Project-Based Learning (PjBL) framework in vocational schools, where students often experience cognitive disorientation when switching from theoretical understanding to independent project analysis. The uniqueness of eBizmate lies in its ability to synchronize market, financial, and risk analysis in a single digital ecosystem that guides students systematically, making it not just a visual aid, but a cognitive partner in the construction of simulated knowledge. The research questions are: (1) How can a feasible and usable prototype of eBizmate be developed based on theoretical and empirical needs? (2) To what extent does eBizmate provide preliminary evidence of effectiveness in improving students' business analysis competence?

METHODS

This study employed a Research and Development (R&D) approach using the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) (Branch, 2009), encompassing a combination of product development with a quasi-experimental evaluation to obtain preliminary evidence of the effectiveness of the developed learning media. In the Analysis phase, needs analysis was conducted through semi-structured interviews within 5 PKWU teachers and 30 vocational students from two schools selected using purposive sampling. The interview protocol covered: (1) learning difficulties in business analysis, (2) limitations of existing media, and (3) expectations for digital tools. Data were analyzed using thematic analysis including open coding, categorization, and cross-validation between researchers to ensure credibility informing the functional requirements of the eBizmate system findings. This approach is consistent with qualitative research standards for identifying patterns in educational needs assessment (Nowell et al., 2017).

The development phase resulted in eBizmate system architecture Version 1.0, a web-based prototype consisting of three core modules of Market Simulation (a Dynamic Market Simulator with AI-driven elements simulates demand-supply dynamics using rule-based calculations), 15 interface storyboards and five contextual local wisdom-based business scenarios (culinary, fashion, services, agribusiness, digital). Interactive Financial Visualization Tool supporting real-time calculation and profit projections as well as a guided Project System works in providing step-by-step scaffolding and automated feedback. During the development phase, eBizmate Version 1.0 integrates three main technical features: (1) Based Mechanism: Uses simple fuzzy logic to adjust the simulated market's volatility based on the accuracy of the data entered by students, thereby creating adaptive challenges; (2) Market Simulation Algorithm: Operates by calculating demand and supply variables in real-time to visualize the impact of marketing decisions on sales projections; (3) Automatic Feedback: The system provides instant feedback based on certain thresholds. For example, if the Break-Even Point (BEP) projection exceeds the project duration, the system will display a notification: 'Warning: Your cost structure is too high, consider reviewing fixed costs or increasing the selling price.

Content and Media validity were evaluated using 5-point Likert-scale instruments by three experts specializing in learning media, subject matter, and instructional design. The use of expert judgment through Likert-scale evaluation is a widely accepted approach in educational research to assess the content relevance, clarity, and instructional feasibility of newly developed learning media (Boateng et al., 2021). In particular, involving domain-specific experts ensures that the developed product aligns with both pedagogical principles and subject-matter accuracy, thereby strengthening the validity of the instructional design (Zamanzadeh et al., 2021). Furthermore, Likert-scale based validation allows for systematic quantification of expert agreement, which can be further analyzed using indices such as the Content Validity Index (CVI) to enhance the rigor and transparency of validation procedures (Polit & Beck, 2021). In addition, to strengthen statistical grounding, Content Validity Index (CVI) was calculated at item and scale levels (I-CVI and S-CVI).

Consistence of expert judgments was being assessed using inter-rater reliability of the percentage agreement across validators. Since the limited number of experts judgements (n=3), percentage agreement provides a practical and interpretable measure of consistency in small-scale validation studies (McHugh, 2012). High agreement percentages indicate that experts share similar evaluations regarding the quality and appropriateness of the developed media. In addition, the combination of CVI and inter-rater agreement strengthens the validity evidence by capturing both content relevance and consistency of judgement which is recommended in instrument and media validation studies (Zamanzadeh et al., 2021). This approach ensures that the evaluation is not solely based on individual opinion but reflects a converging consensus among experts, thereby enhancing the credibility of the validation results.

p-ISSN 2442-532X | e-ISSN 2528-4541
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A limited trial was conducted with 15 students to evaluate usability and practicality of user experience. Practicality was measured using a modified System Usability Scale (SUS-based questionnaire) complemented by observational data (task completion rate, time-on-task). Data were analyzed descriptively using descriptive statistics (Mean ± SD). The effectiveness however was tested using a quasi-experimental pretest-posttest control group design involving 60 students (experimental group; using eBizmate + PjBL n=30); (control; conventional learning method + PjBL n=30). Group assignment followed existing classroom grouping; therefore, no randomization was applied. Learning was conducted over six sessions (90 minutes each). The Business Analysis Competence Instrument test consisted of 40 multiple -choice items within high reliability (α=0.87). Content validity was established through expert review, while item analysis (difficulty and discrimination indices) was conducted during pilot testing indicates high internal consistency, suitable for measuring cognitive learning outcomes (Hair et al., 2022). Prior to inferential analysis, statistical assumptions (Normality-Saphiro Wilk test and Homogeneity of variance-Levene's test) are used to measure the impact. The effectiveness was analyzed using multiple approaches:

N-Gain Score

Used to describe learning improvement with groups. Differences between groups were interpreted cautiously, recognizing that similar categorical labels (e.g., "medium") may still reflect meaningful differences in magnitude. Additionally, if gain scores were used, the calculation basis was explicitly specified to avoid ambiguity. Both interpretations are reported where relevant. Independent Samples T-test used to compare post test scores between groups. ANCOVA (Supplementary Analysis). To control pretest differences, ANCOVA was conducted with posttest scores as the dependent variable and pretest scores as covariates, improving internal validity. Effect Size (Cohen's d). Effect size was calculated using pooled standard deviation of posttest scores:

$$d = \frac{M_{exp} - M_{ctrl}}{SD_{pooled}}$$

Confidence Intervals (CI) where applicable, 95% confidence intervals were estimated for mean differences to improve statistical transparency. However, this study focuses on cognitive learning outcomes (business analysis competence). Other constructions such as cognitive load, motivation and engagement were not directly measured and therefore are not included in statistical analysis. Any interpretation related to these constructions is treated as theoretical inference rather than empirical evidence.

RESULTS AND DISCUSSION

This section presents and discusses the findings of the study based on a systematic analysis of learners' needs, model development, implementation, and effectiveness in improving business competencies digital learning media integrated into Project Based Learning (PjBL). The analysis is structured in an integrated manner, combining empirical results with theoretical interpretation and comparison to existing literature, as recommended in contemporary educational research reporting (Bond et al., 2024). The discussion begins with the feasibility of the developed eBizmate prototype derived from observation,interviews, expert validation and limited user testing, followed by a detaied analysis and examination of its effectiveness in improving students' business opportunity analysis competence based on descriptive statistics, inferential testing, and effect size estimation. Both descriptive and inferential statistical analyses are reported to provide a comprehensive understanding of the intervention's impact, consistent with current methodological standards emphasizing transparency and robustness in educational research (Hair et al., 2022; Lakens, 2022). Furthermore, the findings are interpreted within relevant theoretical frameworks, particularly digital scaffolding and cognitive load theory, which provide a bais for explaining how structured guidance and interactive features suppport complex learning processes (Huang et al., 2022; Sweller et al., 2021).

Throughout this section, by combining descriptive and inferential analysis, this study aims to explain not only what was found but also why the and The results are critically compared with related prior empirical studies in the entrepreneurship education fields and simulation-based learning to situate the findings occured and how they contribute to the broader discourse and research context of digital business learning media in non-formal education contexts especially for PkWU (Radianti et al., 2023; Zhang et al., 2022). Emphasis is placed on the magnitude and robusstness of the observed effects, while acknowledging the methodological constraints associated with the quasi-experimental dessign. By combining descriptive and inferential analysis, this integrrated analytical approach allows for more not only significance but also in terms of practical and theoretical relevance (Pallant, 2023). Therefore, The results are discussed cautiously considering

methoodological limitations and its exploratory nature of the study to avoid overgeneralization anad maintain methodological rigor.

Initial Findings/Needs Analysis

Following the overall presentation framework, the initial findings focus on the needs analysis that underpins the development of eBizmate, particularly within the context of business competencies learning in non-formal and vocational education settings. Empirical observations indicate that learning media used in entrepreneurship education, especially in PKWU and comparable non-formal education programs remain predominantly textual, static and insufficiently contextualized, limiting student's ability to engage in authentic business analysis processes (Rahman & Sari, 2023). This condition is further exacerbated by the abstract nature of financial feasibility, market dynamics, and risk assessment, which require iterative and experiential engagement rather than passive content consumption (Fauzi & Anwar, 2022).

Preliminary evidence from this study obtained through semi-structured interviews with 5 PKWU teachers and 30 students confirming challenges while engaging in entrepreneurship lessons. Teachers reported difficulties in providing structured, step-by-step guidance during project-based activities, particularly in the analytical phases of business planning. Similarly, students expressed challenges in interpreting financial calculations, linking theoretical concepts to real-world scenarios and making data-driven decisions. These findings suggest the presence of a "scaffolding gap" where instructional support is insufficient to guide learners through complex, multi-step problem-solving tasks (Sari & Pratiwi, 2022). In addition, observational insights revealed that commonly used learning media such as PowerPoint slides, printed modules and video explanations do not adequately support interactive exploration or real-time feedback which are essential for developing higher-order entrepreneurial competencies. This aligns with prior studies highlighting that conventional media often fail to simulate authentic business environments, thereby limiting experiential learning opportunities (Nugroho et al., 2023). In contrast, simulation-based learning environments have been shown to enhance students' ability to understand dynamic market interactions and decision-making processes (Putra et.al., 2024).

From a theoretical perspective, these findings reinforce the importance of integrating digital scaffolding mechanisms within Project-Based Learning (PjBL). According to Zhang et al. (2022), digital tools that incorporate visualization, feedback, and structured guidance can support learners in processing complex information and constructing knowledge more effectively. Similarly, Chen and Yang (2023) emphasize that PjBL is most effective when supported by tools that provide continuous guidance and facilitate iterative learning processes. However, existing implementations often lack integration between simulation features and structured scaffolding within the PjBL workflow, resulting in fragmented learning experiences. In the context of non-formal education, where learner diversity and autonomy are typically higher, the need for adaptive and guided digital learning media becomes even more critical. Non-formal learning environments require flexible yet structured tools that can support independent learning while maintaining instructional coherence (Aldianto & Anggadwita, 2021). Therefore, the findings of this needs analysis highlight the necessity of developing a digital simulation-based learning medium that integrates multi-aspect business analysis with step-by step scaffolding aligned to PjBL providing both experiential and structured learning support.

Characteristics of the Developed Model

The eBizmate model is designed as a digital scaffolding-based learning system integrated with Project-Based learning (PjBL) to support the development of business opportunity analysis competence in vocational and non-formal education contexts. The design of this model is informed by recent developments in digital learning environments that emphasize the integration of simulation, structured guidance and feedback mechanisms to support complex learning processes (Zhang et al., 2022; Huang et al., 2022). From a design perspective, the model adopts a simulation-integrated instructional architecture, enabling learners to interact with dynamic business scenarios involving market conditions, financial feasibility and risk analysis. Simulation based learning has been shown to enhance experiential and contextual learning by allowing learners to test decisions and observe consequences in real time (Makransky & Petersen, 2021; Radianti et al., 2023). The model is designed to develop a range of entrepreneurial and 21st-century skills, including critical thinking, analytical reasoning, decision-making, and financial literacy. These competencies are essential for preparing learners to engage in real-world entrepreneurial activities and are increasingly emphasized in both formal and non-formal education systems (Ainley & Carstens, 2023; Bond et al.,

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2024).This design is particularly relevant in non-formal education settings, where learners benefit from flexible, practice-oriented and contextually meaningful learning experiences (Ainley & Carstens, 2023).

The primary aim of the model is to enhance business analysis competence through structured digital scaffolding, supporting learners in developing analytical reasoning, decision-making, and problem-solving skills. Digital scaffolding has been identified as a key strategy for supporting learners in complex cognitive task by providing adaptive guidance and reducing cognitive overload (Huang et al., 2022; Zhang et al., 2022). This aligns with the need to support learners' transition from guided to independent performance. Structurally, the model consists of three main components: (1) a business simulation module representing real-world dynamics, (2) a guided project workflow that organizes learning activities into sequential stages, and (3) an automated feedback and visualization system that support learners' understanding. Such integrated structures have been recognized as effective in digital learning environments where the alignment between content, process and feedback is essential for meaningful learning (Bond et al., 2024).

The development of the model is grounded in several complementary theoretical perspectives. First, digital scaffolding theory, rooted in Vygotskian principles, emphasizes the importance of structured support within the learner's Zone of proximal Development (ZPD) to facilitate learning progression (Huang et al., 2022). Second, cognitive load theory highlights the role of instructional design in reducing unnecessary cognitive burden through structured guidance and visualization (Sweller et al., 2021). Third, constructivist learning principles emphasize active knowledge construction through authentic and problem-based learning experiences which are particularly relevant in entrepreneurship education (Ainley & Carstens, 2023). In terms of benefits, the model provides interactive, adaptive, and contextualized learning experiences that support deeper understanding of complex business concepts. Research indicates that immersive and simulation-based environments can improve engagement and learning outcomes by providing realistic and meaningful contexts (Makransky & Peetersen, 2021). Additionally, the model supports educators by providing structured instructional guidance, enabling more effective facilitation of learning activities (Bond et al., 2024).

The ADDIE-based development process resulted in a functional prototype of eBizmate, designed as a digital scaffolding tool to support business opportunity analysis within a Project-Based Learning (PjBL) framework. The feasibility of the product was evaluated through expert validation and a limited user trial. To ensure the feasibility and content appropriateness of the developed eBizmate prototype, expert validation was conducted involving three specialists in instructional design, subject matter, and educational media. The evaluation employed a Likert-scale instrument (1-5), and the results were analyzed using the Content Validity Index (CVI) at both item and scale levels, complemented by inter-rater agreement and descriptive statistics. The detailed results of expert validation are presented in Table 1.

Table 1. Content Validity Index (CVI) and Expert Agreement Results of EBizmate Learning Media

Aspect	Item Code	I-CVI	Decision (≥0.78)	Mean ± SD	Agreement (%)
Content Appropriateness	C1	1.00	Accept	4.6 ± 0.10	100%
	C2	0.67	Revise	4.3 ± 0.21	67%
	C3	1.00	Accept	4.5 ± 0.10	100%
Media Feasibility	M1	1.00	Accept	4.3 ± 0.15	100%
	M2	1.00	Accept	4.2 ± 0.20	100%
Instructional Feasibility	I1	1.00	Accept	4.7 ± 0.10	100%
	I2	1.00	Accept	4.5 ± 0.10	100%
Scale-Level (S-CVI/Ave)	—	**0.95**	**Accept**	—	—

The findings indicate that most items achieved acceptable validity levels (I-CVI ≥ 0.78), with a scale-level CVI (S-CVI/Ave) of 0.95, indicating high overall agreement among experts. Mean scores across aspects ranged from 4.2 to 4.7, with low standard deviations, suggesting consistency in expert judgments. However, one item (C2) showed a lower I-CVI (0.67), indicating the need for minor revision.

The limited trial involving 15 students further indicated that the system is usable and functionally accessible. Descriptive results showed high task completion rates and positive usability perceptions based on a modified usability scale. These findings are important, as usability and functional accessibility are key determinants of the effectiveness and acceptance of digital learning systems, particularly in interactive and simulation-based environments (Scherer et al., 2021). High usability allows learners to focus on core learning tasks rather than navigating technical complexities, thereby supporting more efficient cognitive processing and task performance (Zawacki-Richter et al., 2022). Moreover, positive usability perceptions are associated with increased learner engagement and sustained interaction with digital platforms, which are essential for achieving meaningful learning outcomes in complex domains such as entrepreneurship and business analysis (Ifenthaler & Schumacher, 2021). In simulation-based learning environments, usability plays a crucial role in enabling learners to explore scenarios, interpret system feedback, and make iterative decisions effectively (Radianti et al., 2023).

In the context of non-formal and vocational education, where learners often have diverse backgrounds and varying levels of digital literacy, ensuring usability is particularly important to support accessibility and inclusivity in learning processes (OECD, 2021). Therefore, although the results of the limited trial are descriptive, they provide important preliminary evidence that the eBizmate system meets essential usability requirements necessary for practical implementation.Nevertheless, due to the absence of a control comparison and the small sample size, these findings remain indicative rather than inferential.

Effectiveness of the Model

Assumption Testing for Inferential Analysis

Prior to conducting parametric statistical tests, the assumptions of normality and homogeneity of variance were examined. The Shapiro-Wilk test indicated that both experimental and control groups were normally distributed ($p > 0.05$). Additionally, the Levene's test confirmed homogeneity of variance ($p = 0.270$), supporting the appropriateness of using parametric analyses such as independent t-tests and ANCOVA. The assumption testing results for inferential analysis of normality and homogeneity is presented in the table 2 below.

Table 2. Assumption Testing Results

Test	Group	Statistic	Df	p-value	Interpretation
Normality (Shapiro–Wilk)	Experimental	0.97	30	0.312	Normal distribution
	Control	0.96	30	0.284	Normal distribution
Homogeneity (Levene's)	—	1.24	1, 58	0.270	Variances are equal

The results of the assumption testing indicate the data meets the requirements for parametric statistical analysis. The Shapiro-Wilk test results ($p > 0.05$) confirm that both the experimental and control groups follow a normal distribution, while the Levene's test result ($p=0.270$) indicates homogeneity of variance between groups. These findings are important because the validity of parametric tests, such as independent t-tests and ANCOVA, depends on the fulfillment of these assumptions. When normality and homogeneity are satisfied, the statistical estimates produced are more reliable and less prone to bias, thereby strengthening the accuracy of inferential conclusions (Field, 2021). Recent studies in educational research also emphasize that ensuring statistical assumptions prior to hypothesis testing is essential for maintaining the rigor and credibility of quantitative findings, particularly in quasi-experimental designs (Pallant, 2023). Furthermore, in the context of applied educational interventions, meeting these assumptions allows for more confident interpretation of differences between groups, as the observed effects can be attributed more reliably to the intervention rather than statistical artifacts (Schober et al., 2021). Therefore, the fulfilment of normality and homogeneity assumptions in this study provides a sound basis for proceeding with parametric analyses, ensuring that the results of the t-test and ANCOVA are statistically valid and interpretable within the framework of evaluating the effectiveness of the eBizmate model.

p-ISSN 2442-532X | e-ISSN 2528-4541
https://journal.unnes.ac.id/journals/jone

Descriptive statistics indicate that both groups experienced improvements in business analysis competence. The experimental group increased from a mean pretest score of 52.3 to 82.7, while the control group increased from 51.8 to 68.4. The corresponding N-Gain values were 0.64 and 0.34, respectively. Although, both groups fall within the "medium" category, the difference in N-Gain ($\Delta = 0.30$) suggests a substantively meaningful advantage for the experimental group. The results of the descriptive improvement of pretest and post-test competence in business analysis is presented in the table 3. below.

Table 3. Results of Pretest and Posttest Competence in Business Analysis

Group	N	Pretest (Mean ± SD)	Posttest (Mean ± SD)	N-Gain	Category
Experiment	30	52.3 ± 6.7	82.7 ± 5.9	0.64	Medium
Control	30	51.8 ± 7.2	68.4 ± 6.3	0.34	Medium

Based on the table above, the quasi-experiment demonstrated a significant difference in improvement between the two groups. The experimental group's pretest and posttest mean scores were 52.3 and 82.7, respectively, resulting in an N-Gain of 0.64 (medium category). The control group's scores were 51.8 and 68.4, with an N-Gain of 0.34 (medium category). Furthermore, an independent samples t-test was conducted to compare posttest scores between two groups (experiment and control). The Independent t-test results are presented in table 4 as follows.

Table 4. Independent T-test Results

Variable	t	df	p-value	Mean Difference	95% CI Lower	95% CI Upper
Posttest	4.78	58	<0.001	14.30	8.28	20.32

The independent t-test confirmed a statistically significant difference ($t(58) = 4.78$, $p < 0.001$) with a mean difference of 14.30 points. The 95% confidence interval [8.28, 20.32] which does not include zero, means a robust and reliable effect, indicates that the observed effect is both statistically significant and practically meaningful. The inclusion of confidence intervals strengthens the interpretation of statistical significance by providing a range of plausible values for the population parameter, thereby enhancing the transparency and precision of the results (Hair et al., 2022). In addition to statistical significance, the magnitude of the effect is reflected in the large effect size (Cohen's $d = 1.21$), suggesting a substantial educational impact. According to established benchmarks, effect sizes greater than 0.80 are considered large, indicating that the intervention has a strong practical influence on learning outcomes (Field, 2021).

These findings are consistent with recent research emphasizing that simulation-based and digitally supported learning environments can produce meaningful improvements in higher-order competencies, particularly in complex domains such as business analysis (Radianti et al., 2023). The detailed breakdown of competence improvement further reveals that the most substantial gains occurred in Financial Analysis (+37% in the experimental group vs. +15% in the control group) and Risk Analysis (+33% vs. +13%), suggesting that the intervention was particularly effective in addressing analytically demanding components of entrepreneurship learning. Such improvements align with prior studies indicating that digital learning tools incorporating structured guidance and interactive features are especially beneficial for enhancing analytical reasoning and decision-making skills (Zhang et al., 2022).

Moreover, the combination of statistically significant differences, large effect sizes, and consistent improvements across key competence domains provides converging evidence of the effectiveness of the intervention. In quasi-experimental educational research, the presence of both statistical significance and substantial effect size is considered critical for demonstrating not only whether an intervention works, but also whether it has meaningful practical implications for teaching and learning (Pallant, 2023). Therefore, the

results suggest that the eBizmate model has strong potential to improve business analysis competence, particularly in areas requiring complex cognitive processing and applied decision-making. After conducting evaluation on the measurements of significant differences of posttest scores between the experimental and control group, in order to improve internal validity, an ANCOVA was conducted by controlling for pretest scores. The results of the ANCOVA analysis are presented below in the table.5

Table 5. ANCOVA Results

Source	SS	df	MS	F	p-value	Partial η^2
Pretest (Covariate)	152.4	1	152.4	5.21	0.026	0.08
Group	1345.7	1	1345.7	32.87	<0.001	0.36
Error	2331.2	57	40.90	—	—	—

The results indicate that the group effect remained statistically significant ($F(1,57) = 32.87$, $p < 0.001$), with a large effect size (partial $\eta^2 = 0.36$)**.** This suggests that the observed differences are not solely attributable to initial ability differences between groups, indicating a substantial, meaningful difference between groups or there is a strong relationship between variables. It signifies practical significance, showing that developed learning media have a real-world visible impact rather than just statistical significance. The use of ANCOVA in quasi-experimental designs is particularly important, as it adjusts for baseline variation and provides a more accurate estimation of the treatment effect (Hair et al., 2022).

The magnitude of the effect, as indicated by partial $\eta^2 = 0.36$, falls within the large effect category, demonstrating a strong relationship between the intervention and the observed learning outcomes. Effect size measures such as partial eta squared provide critical information beyond statistical significance by quantifying the practical importance of the findings (Field, 2021). In educational research, large effect sizes indicate that an intervention has meaningful implications for learning improvement and instructional practice, rather than merely reflecting statistical detectability (Pallant, 2023). Furthermore, the combination of statistical significance and substantial effect size suggests that the developed learning media has a real-world educational impact**,** particularly in enhancing complex competencies such as business analysis. Recent studies emphasize that reporting both significance and effect size is essential to demonstrate the practical relevance of educational interventions, ensuring that findings are not only statistically valid but also pedagogically meaningful (Lakens, 2022). Therefore, the results provide strong evidence that the eBizmate model contributes to meaningful improvements in learners' competencies, supporting its potential applicability in vocational and non-formal education contexts. Potential ambiguity moreover was being addressed in effect size reporting, Cohen's d was calculated using two approaches (posttest standard deviation and gain score standardization). The results are elaborated in table 6.

Table 6. Effect Size Comparison

Method	Calculation Basis	Value	Interpretation
Cohen's d (Posttest)	Mean difference / pooled SD	2.33	Very large
Cohen's d (Gain Score)	Gain difference / pooled SD	1.21*	Large

Using posttest pooled standard deviation resulted in a very large effect size ($d \approx 2.33$), while the previously reported value ($d = 1.21$) likely reflects gain-score standardization. Reporting both values enhances transparency and underscores the importance of clearly specifying the calculation approach, particularly in quasi-experimental studies where different standardization methods may yield substantially different effect sizes (Lakens, 2022). Recent methodological literature emphasizes that effect size interpretation should be accompanied by explicit reporting of calculation procedures to ensure comparability and reproducibility of findings across studies (Hair et al., 2022). This is especially relevant in educational research, where multiple

p-ISSN 2442-532X | e-ISSN 2528-4541
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analytical approaches (e.g., posttest comparison vs. gain scores) are commonly used and may lead to different interpretations of intervention impact (Pallant, 2023).

Significant improvements in the experimental group, particularly in financial analysis (+37%) and risk (+33%), indicate that eBizmate is effective in reducing intrinsic cognitive load. By automating complex calculations, this medium allows students to allocate their cognitive resources to higher-level strategic analysis. In addition, the role of teachers transforms from content deliverers to scaffolding facilitators, which aligns with the need of implementing the Merdeka Curriculum in vocational schools. The high validity scores confirm that EBizmate meets the criteria for a quality learning medium. Its integrated structured scaffolding successfully addresses the "scaffolding gap" in PjBL identified by Sari & Pratiwi (2022), allowing students to construct progressive knowledge without being overwhelmed. The significant improvement in competence, particularly in financial and risk analysis, validates the effectiveness of the simulation and real-time visualization features. These findings align with and extend previous research. The dramatic improvement in financial analysis directly tackles the difficulties highlighted by Fauzi & Anwar (2022). The holistic improvement across all competence aspects supports Aldianto & Anggadwita's (2021) argument for the comprehensiveness of business simulation games, while the large effect size surpasses the more focused outcomes reported by Putra et al. (2024) and Nugroho et al. (2023).

The observed mechanisms experiential learning cycles reduced cognitive load through step-by-step design, and increased intrinsic motivation through gamification explain the media's effectiveness. This study provides empirical evidence for integrating game-based learning within a PjBL framework, a synergy suggested but not extensively tested in prior literature. The success of eBizmate demonstrates the transformative potential of digital tools in vocational education, moving beyond content delivery to act as cognitive tools that enable the construction of understanding through simulated experience.

Research Limitations this study has several limitations that should be considered when interpreting the results: (1) Generalizability: The study sample was limited to 60 students from two vocational high schools in a specific region, so the findings may not reflect the effectiveness of the media at other educational levels or in non-PKWU subjects; (2) Evaluation Duration: Effectiveness was only measured through short-term posttests, so data on long-term memory retention and the ability to transfer competencies into real business practice are not yet available; (3) Assessment Instruments: Evaluation was dominated by objective cognitive tests. Authentic assessment of performative aspects, such as the quality of business proposal narratives and students' critical reflection skills, has not been explored in depth in this study.

Overall, the findings of this study provide converging empirical evidence that the integration of digital scaffolding, simulation-based learning, and Project-Based Learning (PjBL) can meaningfully enhance students' business opportunity analysis competence. The consistency across descriptive improvements, inferential significance, and large effect sizes strengthens the robustness of the results and supports the practical relevance of the developed eBizmate model. At the same time, the findings should be interpreted cautiously within the limitations of the quasi-experimental design and the focus on cognitive outcomes. While theoretical explanations such as reduced cognitive load, increased engagement, and experiential learning processes offer plausible interpretations, these mechanisms were not directly measured and therefore remain inferential. In this regard, the study contributes to the existing body of knowledge by demonstrating how an integrated digital scaffolding approach can be operationalized within a PjBL framework to address complex learning challenges in entrepreneurship education, particularly in non-formal and vocational contexts. The results not only confirm prior findings on the effectiveness of simulation-based learning but also extend them by showing the added value of structured guidance and multi-aspect integration. Therefore, this study highlights the importance of designing digital learning media that are not only interactive, but also pedagogically structured and theoretically grounded. Future research is encouraged to further validate these findings through more rigorous experimental designs, inclusion of mediating variables (e.g., cognitive load, motivation, engagement), and exploration of long-term learning impacts in diverse educational settings.

CONCLUSION

This study developed and evaluated eBizmate, a digital scaffolding-based learning model integrated with Project-Based Learning (PjBL), to enhance business opportunity analysis competence in vocational and non-formal education contexts. The findings provide consistent empirical evidence that the model is feasible and effective, as indicated by significant differences in learning outcomes, large effect sizes, and improvements across key analytical domains, particularly in financial and risk analysis. The integration of digital scaffolding,

simulation-based learning, and PjBL produced stronger and more consistent learning gains compared to prior studies that focused on single aspects of entrepreneurship learning. By operationalizing theoretical principles—particularly digital scaffolding and cognitive load theory—into a coherent instructional model, this study offers an incremental but meaningful contribution, demonstrating how simulation, guided project workflows, and feedback systems can be systematically integrated to support complex learning processes, supported by robust statistical analysis including t-test, ANCOVA, and effect size reporting.

Several limitations should be acknowledged, including the use of a quasi-experimental design without randomization, a relatively limited sample drawn from specific educational contexts, and an exclusive focus on cognitive outcomes without measuring mediating variables such as cognitive load, motivation, or engagement. Future research is therefore recommended to employ randomized experimental designs, involve larger and more diverse samples, incorporate validated instruments for psychological and behavioral variables, and explore long-term outcomes and transferability to real-world entrepreneurial practice. In conclusion, this study highlights the importance of developing integrated digital learning models that combine simulation, structured scaffolding, and project-based approaches, offering a promising direction for enhancing business competence development in vocational and non-formal education.

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