

Research Article

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The Effectiveness of Marketing-Oriented Project-Based Mobile Learning in Improving Students' Critical Thinking and Collaboration Skills in Business Education

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Abstract

Background/purpose. The rapid advancement of technology, particularly in mobile learning, presents new opportunities for flexible, accessible education. In business education, especially marketing courses, integrating technology while cultivating essential 21st-century skills like critical thinking and collaboration remains challenging. This study was conducted to address this gap by developing and evaluating an interactive mobile learning platform tailored to business students' needs.

Materials/methods. This study utilized the ADDIE instructional design model (Analysis, Design, Development, Implementation, Evaluation) to develop and validate the Marketing-Oriented Project-Based Mobile Learning (MOPjBML) platform for business education. The research involved 63 undergraduate students (aged 18–22) enrolled in an Introduction to Business course at a university in Indonesia, alongside expert validators ($n=3$) in economics education, learning media, and business instruction. The data were collected through surveys, observations, and phased trials (small- and large-group implementations) to assess platform validity, practicality, and efficacy. Quantitative analyses (paired t-tests, validity/reliability assessments, normality testing) and qualitative evaluations (expert reviews, learner feedback) were conducted to examine the platform's educational impact and implementation outcomes.

Results. Results demonstrated significant improvements in critical thinking (23.4% gain, $p<0.001$) and collaboration (26.2% gain, $p<0.001$) using the MOPjBML platform. Expert validation confirmed high validity (85.6%) and practicality (88%). The multimedia-enriched platform effectively enhanced marketing comprehension through videos, quizzes, and textual materials, confirming its efficacy in business education.

Conclusion. This study concludes that the MOPjBML platform is an effective and innovative tool for enhancing 21st-century essential competencies in business education, particularly those related to critical thinking and collaboration skills.



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1. Introduction

The rapid advancement of technology in education has fundamentally transformed how students access and engage with learning materials (Papadakis, 2022). One such innovation is mobile learning (m-learning), which enables students to access educational content through smartphones and other mobile devices, providing unparalleled flexibility and convenience in the learning process (Yabanova & Demirkan, 2021). This learning mode supports self-paced engagement, which has been linked to improved knowledge retention and student motivation (Almaiah et al., 2020; Shdaifat & Obeidallah, 2019; Yağan, 2023). By integrating mobile devices into the educational process, learners can access resources anytime and anywhere, thereby overcoming the constraints of traditional classroom-based instruction (Nguyen & Hoang, 2020; Salas-Rueda et al., 2022; Volkovitckaia et al., 2020).

In today's dynamic and fast-paced environment, mobile learning empowers students to engage with content beyond the confines of the classroom (Karakose & Demirkol, 2021). This adaptability is particularly significant in business education, where developing theoretical knowledge and practical competencies, such as critical thinking and collaboration, is essential (Karakose, 2021). Mobile learning technologies enhance business education by providing flexible, interactive, and personalized learning experiences that adapt to individual student needs and can be accessed anytime and anywhere (Naveed et al., 2023; Kumar et al., 2024). Features such as real-time feedback (Alam & Mohanty, 2023), multimedia content (Zhao et al., 2024), and collaborative platforms (Zamiri & Esmaeili, 2024) collectively constitute a comprehensive pedagogical solution for addressing the evolving demands of modern business students. By providing ubiquitous access to learning resources via dedicated applications, mobile learning facilitates personalized and self-directed educational experiences (Pacheco-Velazquez et al., 2024). As mobile learning tools advance, their capacity to reshape business education and prepare students for success in technology-driven marketplaces is expected to increase substantially (Kousloglou et al., 2023; Liu & Pásztor, 2022). Studies by Li and Li (2024) and Chen et al. (2022) indicate that mobile platforms in business education enable students to learn and apply marketing concepts at their own pace, enhancing cognitive and collaborative skills. This learner-centred approach promotes experiential engagement with real-world challenges, aligning academic outcomes with the demands of an increasingly competitive and evolving business landscape.

Traditional pedagogical approaches have frequently been criticized for their limited effectiveness in fostering essential business competencies (Ye, 2024). Predominantly lecture-based instruction tends to focus on transmitting theoretical knowledge, offering minimal opportunities for students to develop practical skills such as problem-solving, critical thinking, and collaboration (Gong et al., 2023; Holmes, 2020). These methods are generally passive and do not support hands-on, experiential learning processes (Gong et al., 2023). As Kaeppl (2021) argues, conventional instructional models often fail to encourage active student engagement, a critical component in nurturing analytical and cooperative abilities. As a result, graduates may possess a solid theoretical understanding but lack the practical competencies to effectively analyze business challenges, make informed decisions, and function productively in team-oriented environments. This misalignment between academic training and industry expectations presents a substantial challenge, particularly in the context of rapid digital transformation and the increasing integration of technology into core business practices, including marketing (Blilat & Ibriz, 2020; Zhang, 2023).

As the global business environment evolves, the need for professionals equipped with robust critical thinking and collaboration skills becomes increasingly pronounced. These abilities are fundamental to success in marketing, where professionals must interpret market data, understand consumer behavior, and respond strategically to shifting competitive landscapes (Opstad & Pettersen, 2022). However, traditional educational models frequently struggle to prepare students for these demands (McDonald et al., 2022). Critical thinking, for instance, enables students to analyze

problems systematically, synthesize information from diverse sources, and make well-reasoned decisions (Calma & Cotronei-Baird, 2021). In marketing, this skill is essential for consumer analysis, trend forecasting, and strategy development (Allil, 2024). Calma and Cotronei-Baird (2021) found that students who engage in critical thinking tasks are more adept at navigating complex decision-making scenarios in their professional careers. Similarly, collaboration is indispensable in contemporary business practice. Organizations increasingly value individuals who can work effectively in diverse teams, resolve conflicts, and contribute meaningfully to group initiatives. According to Calma and Davies (2020), students who experience collaborative learning environments during their studies are better prepared for the team-based nature of modern workplaces.

Integrating project-based learning (PjBL) within mobile learning environments can further enhance the development of practical skills, enabling students to collaborate on projects that reflect real-world business challenges (Mota et al., 2025). When combined with project-based learning, mobile learning becomes a powerful pedagogical strategy. PjBL encourages students to apply theoretical knowledge to practical situations, promoting the development of critical thinking and teamwork skills. Research by Liniņa and Vēvere (2021) and Prater and Predki (2024) indicates that mobile learning platforms can effectively support PjBL by offering tools that facilitate group collaboration, communication, and resource sharing. By embedding these interactive elements into the curriculum, students gain hands-on experience while refining their problem-solving abilities and collaborative competencies.

Previous research has highlighted the benefits of mobile learning and project-based learning (PjBL) in promoting interactive and student-centred education. Previous research has highlighted the educational benefits of both mobile learning (Almaiah et al., 2020; Crompton, 2013) and project-based learning (PjBL) (Zhang & Hwang, 2023; Prater & Predki, 2024) in promoting active, student-centred learning experiences. Maphosa (2024) found that mobile learning platforms such as Moodle enhance accessibility and foster authentic, flexible engagement, particularly in under-resourced higher education settings. Similarly, Saad and Zainudin (2024) reported that integrating computational thinking into PjBL supports student collaboration and inquiry-based learning. Bui et al. (2025) demonstrated that using Trello in PjBL settings significantly boosts creativity and task management skills. Ratanaolarn et al. (2025) further showed that combining blended PjBL with design thinking enhances university students' creativity and openness to experience. Huang et al. (2025) also emphasized the role of generative AI in supporting collaborative problem-solving and higher-order thinking through interactive digital whiteboards. Despite these findings, there remains a lack of research on how mobile-supported PjBL (m-PjBL) can be effectively designed for business students, who must develop strong collaboration and critical thinking skills in increasingly digital, team-oriented environments.

To bridge the identified gap in business education, this study introduced the Marketing-Oriented Project-Based Mobile Learning (MOPjBML) platform, which combines the flexibility of mobile learning with the hands-on nature of project-based learning to enhance students' critical thinking and collaboration. This platform delivers interactive tools such as videos, quizzes, forums, and simulations, allowing students to engage in real-world marketing tasks like strategy development and consumer analysis, thereby fostering experiential learning and practical skill development (Kumar et al., 2024; Green et al., 2024; Zhang & Hwang, 2023). The innovation of this study lies in its focus on marketing education—a field where mobile-supported PjBL remains limited—by offering a contextualized, industry-aligned framework that goes beyond traditional academic outcomes to examine how students collaborate and think critically through team-based digital activities. Through this model, the research connects theoretical learning with business practice and provides a replicable, mobile-based pedagogical approach that aligns with the evolving demands of marketing professions.

Building on this foundation, the study further delineates its specific research objectives and questions to systematically evaluate the effectiveness and implementation of the MOPjBML platform in marketing education. The research focuses on designing and testing this innovative platform that combines mobile learning with project-based learning (PjBL) to improve students' critical thinking and collaboration abilities. Specifically, it investigates: (1) What is the implementation process for Marketing-Oriented Project-Based Mobile Learning (MOPjBML) platform in delivering marketing content within the course? (2) Does MOPjBML enhance students' critical thinking and collaboration skills across all relevant indicators? (3) What are the combined effects of MOPjBML on collaboration and critical thinking skills in this academic context? Through this inquiry, the study seeks to offer evidence-based understanding of the educational advantages of integrating mobile technology with project-based learning to cultivate vital 21st-century skills.

2. Literature Review

2.1. Marketing-Oriented Project-Based Mobile Learning

Marketing-Oriented Project-Based Mobile Learning (MOPjBML) integrates mobile learning (m-learning) and project-based learning (PjBL) to enhance marketing education. While m-learning offers flexibility and accessibility (Naveed et al., 2023) and PjBL promotes active, real-world skill application (Mota et al., 2025), existing studies present conflicting findings. For instance, Al-Emran et al. (2018) highlight m-learning's engagement benefits, whereas Al-Rahmi et al. (2021) warn of its potential for superficial learning without structured pedagogy. Similarly, while PjBL is widely recognized for fostering collaboration (Loyens et al., 2023), its discipline-specific implementation in marketing remains underexplored. A key gap is the lack of empirical research on how MOPjBML bridges marketing theory and practice, particularly regarding long-term skill retention. This study addresses these gaps by evaluating MOPjBML's effectiveness in marketing education, resolving contradictions in m-learning outcomes through structured PjBL integration, and providing actionable insights for curriculum design. By doing so, it responds to calls for context-specific mobile learning frameworks and advances experiential marketing pedagogy. The research aims to fill the literature's missing focus on interdisciplinary integration, practical application, and sustained learning outcomes in marketing education.

The MOPjBML platform integrates comprehensive features to enhance student engagement, interactivity, and educational outcomes. Table 1 outlines the platform's key specifications and features.

Table 1. Specifications and key features of the marketing-oriented project-based mobile learning platform

No	Specification	Description	Key Features
1	Platform	Mobile learning based on Android/iOS apps and web platforms	High accessibility via mobile and desktop devices
2	User interface (UI/UX)	User-friendly and responsive interface for students	Interactive dashboard Intuitive navigation
3	Interactive learning modules	Marketing materials in multimedia formats, accessible anytime	Interactive videos Marketing infographics Digital e-books
4	Cognitive and collaborative assessment	Evaluating comprehension of marketing concepts and teamwork skills	Game-based quizzes Marketing simulations Group project assignments
5			Discussion forums

No	Specification	Description	Key Features
	Collaboration features	Supporting teamwork and discussions among students	Chat and video conferencing Collaboration on real-world marketing case studies
6	Gamification	Enhancing learning motivation through rewards and leaderboards	Points and badges for task completion Marketing simulation competitions
7	Real-world case studies	Offering learning experiences based on actual marketing cases	Case analysis of major companies Digital marketing strategy simulations
8	Adaptive learning	Personalizing content based on student progress	Recommended materials based on evaluations Personalized learning paths
9	AI support	Employing artificial intelligence to enhance learning	Chatbot for student inquiries Learning material recommendation system
10	Augmented reality (AR)/Virtual reality (VR)	Providing immersive experiences for visualizing marketing strategies	Virtual store simulations AR-based product placements
11	Data analysis and tracking	Monitoring student progress and performance	Progress dashboards Individual and group performance reports
12	Integration with social media and marketplace	Bridging learning with real-world digital marketing practice	Simulated social media campaigns E-commerce marketing practice
13	Accessibility and cloud storage	Cloud-based access to materials and assignments	Cloud-based learning system Automatic assignment storage
14	Offline learning mode	Enabling learning without an internet connection	Downloadable materials and assignments
15	Data security and privacy	Ensuring protection of user data and privacy	Data encryption system Two-factor authentication

Each of these features is purposefully designed to foster an interactive, accessible, and collaboration-driven learning environment while simultaneously cultivating critical thinking and practical marketing competencies. The incorporation of gamified learning and authentic case studies significantly improves student engagement. Moreover, AI-driven personalization and adaptive learning mechanisms provide tailored educational experiences to support diverse learning needs. Collaboration tools promote essential interpersonal and professional skills, preparing students for real-world marketing environments. Offline accessibility and cloud-based content management further support continuity in learning, even in contexts with limited internet access.

2.2. Critical Thinking in Business Education

Critical thinking is essential in marketing education, enabling students to analyze data, evaluate strategies, and make evidence-based decisions (Askary & Askarany, 2024). While scholars agree on its importance, operationalization remains debated—Aulia et al. (2019) prioritize interpretation, whereas Liu and Pásztor (2022) emphasize analytical skills for digital marketing. In isolation, existing frameworks often examine dimensions like evaluation (Wakhidah & Indana, 2020) or inference (Shin & Yu, 2021), neglecting their integrated application in marketing contexts. Recent research on self-regulation (Lee et al., 2023) shows promise but lacks cross-cultural validation, and digital marketing advancements challenge traditional models (Molokhina et al., 2021). This study addresses these gaps by developing a unified critical thinking model for marketing education and testing its dimensions in digital scenarios, responding to calls for context-specific frameworks.

Critical thinking assessment in education entails evaluating students' abilities to think reflectively, analyze information rigorously, and solve problems effectively. In business education, especially marketing, this involves determining how well students understand, interpret, and apply core marketing concepts to diverse and often complex situations. Table 2 presents a framework for assessing critical thinking in marketing education, highlighting key dimensions, operationalization, and associated indicators.

Table 2. Indicators of critical thinking skills

No	Dimension	Operationalization	Indicator	Source
1	Interpretation	Ability to understand and organize marketing information accurately	Identifying relevant marketing concepts from case studies	Aulia et al. (2019); Liu and Pásztor (2022).
			Understanding and explaining marketing strategies in a business context	
2	Analysis	Ability to break down and critically assess marketing information	Breaking down the elements of a marketing strategy systematically	Askary and Askarany (2024); Nguyen and Hoang (2020).
			Using data and facts to evaluate the marketing strategies implemented	
3	Evaluation	Ability to assess the validity and credibility of marketing information sources	Distinguishing valid from invalid marketing information	Wakhidah and Indana (2020); Liniņa and Vēvere (2021)
			Critiquing marketing strategies implemented by companies	
4	Inference	Ability to conclude collected marketing data	Formulating marketing decisions based on data analysis	Shin and Yu (2021); Costa et al. (2020)
			Concluding the effectiveness of marketing strategies based on case studies	
5	Explanation	Ability to communicate critical thinking clearly and systematically	Explaining the reasons for choosing specific marketing strategies	Parker et al. (2023); Liniņa and Vēvere (2021)
			Developing a marketing analysis report with strong arguments	
6	Self-regulation	Ability to reflect on one's thinking related to marketing	Identifying weaknesses in previously made marketing analyses	Molokhina et al. (2021); Lee et al. (2023)
			Developing strategies to improve critical thinking in marketing	

2.3. Collaboration Skills in Business Education

Collaboration refers to the capacity to work effectively with others in a team setting, integrating diverse skills, perspectives, and resources to achieve shared objectives. Collaboration is vital in marketing education, enabling students to integrate diverse skills and perspectives for shared objectives (Marthinus et al., 2022). While existing research highlights its importance, operational approaches vary—Murdiany (2021) emphasizes communication, whereas Kusuma et al. (2021) prioritize conflict resolution in team settings. Current frameworks assess isolated dimensions like teamwork (Suriaman et al., 2024) or problem-solving (Cao, 2022), but lack integration for comprehensive evaluation. Recent studies on group reflection (Lines et al., 2021) demonstrate progress, yet fail to address digital collaboration challenges in modern marketing contexts. This study bridges these gaps by (1) developing a unified collaboration assessment model and (2) validating its applicability in virtual marketing team environments, responding to calls for adaptive business education frameworks (Blilat & Ibriz, 2020).

Various dimensions and indicators are employed to evaluate the development of collaboration skills in students, especially within business education. These dimensions assess students' abilities to work cohesively, communicate effectively, and engage in team-based problem-solving. Table 3 presents a structured framework outlining the dimensions, operational definitions, and indicators used to measure collaboration skills in a business education context.

Table 3. Indicators of collaboration skills

No	Dimension	Operationalization	Indicator	Source
1	Communication	Ability to convey information clearly within a team	Effectively communicating during group discussions Clearly and openly expressing ideas.	Murdiany (2021); Sulistyowati (2019)
2	Teamwork	Ability to work efficiently with others to achieve shared goals	Collaborating to complete marketing tasks Taking responsibility for assigned team tasks	Marthinus et al. (2022); Suriaman et al. (2024)
3	Conflict management	Ability to resolve disagreements and manage interpersonal dynamics	Constructively resolving team conflicts Respecting differing opinions and seeking consensus	Kusuma et al. (2021); Komarudin (2023)
4	Problem-solving	Ability to jointly solve marketing-related challenges	Identifying group marketing problems and developing solutions Co-creating marketing strategies	Cao (2022); Sumardeni et al. (2023)
5	Engagement	Degree of active participation in collaborative processes	Actively contributing to group meetings and discussions Sharing ideas to support team progress	Oktaviani (2022); Ratna and Gemintang (2022)
6	Group reflection	Ability to assess and reflect on overall team performance	Evaluating teamwork effectiveness post-task Identifying roles and individual contributions	Lines et al. (2021); Blilat and Ibriz (2020)

3. Methodology

This study adopted the ADDIE instructional design framework (Branch, 2009) to systematically guide the development and evaluation of the Marketing-Oriented Project-Based Mobile Learning (MOPjBML) platform. The primary objective of using ADDIE was to ensure a structured, iterative, and learner-centred approach to instructional design, allowing for continuous refinement of the learning platform based on analysis, expert input, and user feedback. Each phase of ADDIE—Analysis, Design, Development, Implementation, and Evaluation—played a critical role in aligning the platform's content, features, and pedagogical strategies with the intended learning outcomes, specifically enhancing critical thinking and collaboration skills among business students. This framework also enabled the integration of project-based learning (PjBL) principles and mobile technologies in a theoretically grounded and practically applicable way.

3.1. Participants

Participants were involved at multiple stages of the research, each contributing to the iterative development and evaluation of the Marketing-Oriented Project-Based Mobile Learning (MOPjBML) platform. All participants provided informed consent before their involvement, ensuring ethical compliance and voluntary participation throughout the study. The small-scale trial phase included five fourth-semester undergraduate students who had previously completed the Introduction to Business course at a university in Indonesia. This group was selected to identify usability issues and provide initial feedback on the prototype's functionality and relevance, which informed early revisions. In the large-scale trial, 57 first-semester students enrolled in the Introduction to Business course to evaluate the platform's effectiveness in enhancing critical thinking, collaboration, and engagement in marketing-related project work. In addition to student participants, the study engaged three expert validators to assess the platform from pedagogical and practical perspectives. These included a subject matter expert in marketing, a learning media expert, and a field practitioner who teaches business-related courses. Each expert evaluated different platform aspects, such as content validity, instructional design quality, usability, and alignment with real-world applications. The specific criteria and evaluation aspects for each group of participants are detailed in Table 4.

Table 4. Criteria for research subjects

No	Validator/ Practitioner/ Subject	Profession	Quantity (Persons)	Criteria	Aspects Evaluated	Number of Items
1	Subject matter/content expert	Economics education lecturer	1	- Expert in marketing content - Holds a Master's or a Doctorate	- Content alignment with academic standards - Accuracy of digital marketing concepts - Relevance to industry needs - Depth of content for developing critical thinking - Clarity of presentation - Alignment with learning outcomes - Inclusion of real-world case examples	15
2	Learning media expert	Learning media lecturer	1	- Expert in educational media development	- Interface quality (UI/UX) - Media interactivity - Ease of navigation - Clarity of structure - Alignment with digital learning strategies	15

				- Holds a Master's or a Doctorate	- Support for student collaboration - Effectiveness of multimedia elements	
3	Field practitioner	Business lecturer	1	- Teaches the <i>Introduction to Business</i> course - Holds a Master's or a Doctorate	- Practical applicability in class - Effectiveness in supporting active learning - Encouragement of student collaboration - Suitability for student learning needs - Features for formative and summative assessment	10
4	Small group	Students	5	- Undergraduate students who have completed the <i>Introduction to Business</i> course - Students are in their 4th semester - Male = 2, Female = 3	- Ease of access and navigation - Comprehension of content - Suitability of features for learning needs - Application's effectiveness in enhancing marketing analysis skills - Visual appeal and usability	10
5	Large group	Students	57	- Active students enrolled in the <i>Introduction to Business</i> course (Students are in their 1st semester, Academic Year 2024/2025) - Male = 24, Female = 33	- Improvement in critical thinking - Enhancement of collaboration skills	24

3.2. Procedures

This study applied the ADDIE instructional design model (Branch, 2009) to design and assess the Marketing-Oriented Project-Based Mobile Learning (MOPjBML) platform. The research process was conducted over six months, following five structured phases: Analysis, Design, Development, Implementation, and Evaluation. Each phase was crucial in ensuring the platform's educational relevance and instructional effectiveness.

The Analysis Phase, lasting one month, focused on identifying gaps in traditional marketing education through surveys conducted with students and lecturers. This stage also assessed students' readiness for mobile learning by evaluating their access to digital devices and digital literacy. The Design Phase spanned six weeks, during which the app's structure and features were meticulously planned. Key elements included interactive learning modules, collaborative forums, and gamification features such as leaderboards and badges to promote engagement.

The Development Phase took two months and involved building and validating the platform's prototype. Marketing lecturers and instructional designers acted as material and media experts, respectively, ensuring the content's accuracy and usability. The Implementation Phase aligned with the academic semester, extending over eight weeks. It began with a two-week pilot test involving five students to refine usability, followed by a full-scale deployment to 57 students in a quasi-experimental setup. The experimental group used the mobile learning app alongside Project-Based Learning (PBL) tasks, while the control group continued with traditional learning methods.

Finally, the Evaluation Phase involved analyzing quantitative and qualitative data to assess the platform's effectiveness. Pre- and posttest scores, collaboration rubrics, and student feedback were collected. Statistical analyses were applied to validate the findings, including paired t-tests and normality tests (Kolmogorov-Smirnov, Levene's Test). The platform's content featured multimedia materials, real-world case studies, and interactive assessments accessible via Android/iOS or a web platform. Students engaged in individual tasks and collaborative projects, such as designing marketing campaigns. Advanced features like AI chatbots, AR simulations, and cloud storage enhanced interactivity and offline access. Feedback from each phase informed iterative improvements, ensuring that the final platform effectively supported the development of critical thinking and collaboration skills.

3.3. Data Collection

The study utilized both primary and secondary data sources to ensure a comprehensive evaluation of the MOPjBML platform. Primary data were collected through surveys, questionnaires, and observations. Surveys and questionnaires were utilized to collect quantitative data on students' improvement in critical thinking and collaboration skills, enabling measurable comparisons of outcomes before and after the intervention. These tools assessed the platform's effectiveness and were administered to students participating in the mobile learning trials. In addition, observations were conducted during group activities to examine students' behavioural engagement and collaborative interactions within real-time learning environments. The researcher directly observed student interactions and teamwork during project-based learning activities supported by the platform.

To complement the primary data, secondary data sources, including institutional documents such as syllabi and learning objectives, were utilized to ensure alignment between the platform's content and curriculum standards. Additionally, relevant literature on mobile learning and project-based learning (PBL) was reviewed to provide theoretical grounding and contextual support for the study's instructional design and evaluation processes. These secondary data sources included academic documents like institutional learning materials and curriculum outlines for the Introduction to Business course, which were analyzed to confirm consistency with academic requirements. Furthermore, prior research on mobile learning, project-based pedagogy, and developing critical thinking and collaboration in business education was examined to contextualize and strengthen the study's analytical framework.

To ensure the research instruments' robustness, data on students' critical thinking and collaboration skills were gathered using a researcher-developed questionnaire, which was designed based on well-established theoretical indicators (see Tables 2-3). The instrument exhibited strong

construct validity, with all items surpassing the critical Pearson correlation value ($r > 0.361$, $p < 0.05$). Furthermore, reliability analysis indicated high internal consistency, as evidenced by Cronbach's alpha coefficients of 0.907 for critical thinking and 0.935 for collaboration, confirming the stability of the measurement tool. These results established a solid foundation for subsequent data collection and analysis.

Before implementation in the classroom, the developed product—the MOPjBML platform, grounded in Project-Based Learning (PjBL) principles—underwent a rigorous validation process to ensure its educational suitability. The assessment used a structured validation sheet featuring a 5-point Likert scale (1–5) and an open-ended section for expert feedback. Subject-matter specialists in marketing and instructional media design evaluated the platform, confirming its alignment with pedagogical objectives. Following validation, a practicality test was administered both before and after classroom deployment to assess the platform's usability and accessibility from the perspectives of students and lecturers. Data were collected using a practicality assessment sheet, which included a 5-point rating scale and a section for qualitative feedback, ensuring comprehensive insights into the platform's real-world applicability.

A quasi-experimental, nonrandomized control group pretest-posttest design was employed to measure the intervention's impact. The study comprised two groups: an experimental group that engaged with the MOPjBML platform during the Introduction to Business course and a control group that received traditional instruction without the platform. This methodological approach, as detailed in Table 5, facilitated a systematic comparison of students' critical thinking and collaboration skills before and after exposure to the intervention, thereby providing empirical evidence of the platform's effectiveness.

Table 5. Quasi-experimental research design

No	Group	Pretest	Treatment	Posttest
1	Experimental group	O ₁	X _I	O ₂
2	Control group	O ₁	-	O ₂

(Adapted from Leedy and Omrod, 2005)

Notes:

- O₁: Pretest scores for critical thinking and collaboration skills
- O₂: Posttest scores for critical thinking and collaboration skills
- X_I: Implementation of the MOPjBML platform

3.4. Data Analysis

The analysis of data validity comprised quantitative and qualitative components. Quantitative data were analyzed descriptively to present the results of evaluations conducted by validators on the developed learning media product. This data was derived from validation questionnaire scores provided by media experts and subject matter experts in marketing. The percentage scores were calculated based on the responses received. The product's validity was categorized according to the percentage results, as outlined in Table 6.

Table 6. Validity criteria

No	Criteria	Percentage
1	Highly valid	$81.25\% < P \leq 100\%$
2	Valid	$62.5\% < P \leq 81.25\%$
3	Somewhat valid	$43.75\% < P \leq 62.5\%$
4	Not valid	$\leq 43.75\%$

(Adapted from Arikunto, 2013, p. 144)

Practicality data also included quantitative and qualitative elements. Quantitative data was obtained from practicality questionnaires completed by lecturers and students who had utilized the MOPjBML platform. The calculation of response percentages followed the same method used for the validation data. The degree of practicality was evaluated using the criteria presented in Table 7.

Table 7. Practicality criteria

No	Criteria	Percentage
1	Highly practical	$81.25\% < P \leq 100\%$
2	Practical	$62.5\% < P \leq 81.25\%$
3	Somewhat practical	$43.75\% < P \leq 62.5\%$
4	Not practical	$\leq 43.75\%$

(Adapted from Arikunto, 2013, p. 144)

Qualitative data, including comments and suggestions from lecturers and students, were analyzed descriptively. This feedback informed necessary revisions to improve the product's validity, practicality, and effectiveness.

The study employed a quasi-experimental design to evaluate the effectiveness of the PjBL-integrated MOPjBML platform in enhancing students' critical thinking and collaboration skills. Statistical analyses were conducted following a systematic approach. First, the Kolmogorov-Smirnov test was applied to examine data normality, a fundamental assumption for parametric testing, where a p -value > 0.05 indicated normal distribution. Subsequently, Levene's test evaluated variance homogeneity between experimental and control groups, with $p > 0.05$ confirming equal variances - a critical requirement for subsequent t -tests. Finally, independent samples t -tests were performed to compare mean scores between groups, with specific hypotheses testing for significant differences in skill development between platform users (experimental group) and traditional instruction recipients (control group). This comprehensive analytical approach ensured rigorous assessment of the platform's educational impact while maintaining appropriate statistical assumptions. The hypotheses were formulated as follows.

- H_0 : The two groups have no significant difference in critical thinking and collaboration skills.
- H_1 : There is a significant difference in critical thinking and collaboration skills between the two groups.

A p -value greater than 0.05 indicated no significant difference, while a p -value less than or equal to 0.05 suggested a statistically significant difference.

4. Results

In the Development stage of the ADDIE model, the development team initiated the creation of the MOPjBML platform following a comprehensive needs analysis and instructional design process. This stage involved building the platform using mobile and web technologies to ensure optimal accessibility for students. Interactive learning components, such as marketing tutorial videos, gamified quizzes, and real-world marketing case studies, were developed to support an engaging and applied learning experience. Additional features such as discussion forums and project-based collaborative spaces were integrated into the platform to promote student interaction and collaboration. A preliminary trial was conducted with a small group of users to identify and resolve technical issues and evaluate the user interface's effectiveness.

Following the Development stage, the MOPjBML platform was implemented in a classroom setting with a larger group of students enrolled in the Introduction to Business course. This implementation aimed to assess student engagement and evaluate the platform's effectiveness in improving critical thinking and collaboration skills. Student feedback was collected to evaluate usability, content relevance, and the overall learning experience. Insights gained during this stage were used to inform the Evaluation stage, enabling continuous improvements based on student needs and learning objectives. A detailed description of the developed product is presented below to provide a comprehensive view of the Development process.

4.1. Product Development Results

This study resulted in developing the MOPjBML platform tailored for the Introduction to Business course. The platform includes several key components, as detailed below.

The platform's initial interface features a visually appealing and intuitive design, utilizing a purple gradient colour scheme that imparts a modern and professional aesthetic. This design approach is intended to engage student users while facilitating smooth navigation through well-organized menus that cover core marketing concepts, ranging from foundational principles to evaluation through quizzes. The sections are presented in detail in Table 8 below.

Table 8. Sections of the MOPjBML platform

No	Section	Description
1	Objective	Outlining the learning objectives related to the marketing course content.
2	Schema	Presenting a structural overview of marketing concepts.
3	Concept	Discussing foundational theories and principles of marketing.
4	Marketing	Providing a broader context and definition of marketing practices.
5	Pricing	Explaining various pricing strategies within marketing.
6	Promotion	Highlighting promotional strategies and their implementation.
7	Selling	Covering sales strategies and selling techniques.
8	Video	Offering audiovisual materials to enhance conceptual understanding.
9	Quiz	Including interactive assessments to monitor student progress.
10	References	Listing sources and references used in the development of the content.

The design elements, such as illustrations of students reading books, contribute to an educational and approachable user experience (see Figure 1). Additionally, the Indonesian flag and the "Indonesian" language label signify that the content is presented in the local language, supporting

better comprehension among Indonesian students. Attribution to the media designer at the bottom of the screen adds a layer of professionalism and credibility to the product. With its interactive and student-friendly design, the MOPjBML platform aimed to improve students' educational experience by making marketing concepts more accessible, understandable, and applicable to real-world business contexts.



Figure 1. User interface of the MOPjBML platform

4.2. Content Expert Validation Results

This section presents the results of the content expert validation for the MOPjBML platform developed for the Introduction to Business course. This validation aimed to evaluate the contents' alignment with academic standards, relevance to industry needs, and capacity to support the development of students' critical thinking skills. Additionally, it assessed the clarity of content presentation and its alignment with the intended learning outcomes as specified in the curriculum (see Table 9).

Table 9. Content expert validation results

No	Aspect	Indicator	X	X _i	Score (%)
1	Content alignment with academic standards	The material aligns with academic standards and the curriculum of the <i>Introduction to Business</i> course.	4	5	80%
		The material covers basic to advanced concepts in digital marketing appropriate for higher education.	5	5	100%
2	Accuracy of digital marketing concepts	The digital marketing concepts are aligned with current theories and practices in the business world.	4	5	80%
		The material reflects valid digital marketing strategies that can be applied in real-world contexts.	5	5	100%
3	Relevance to industry	The material reflects the current needs of the marketing industry.	4	5	80%
		The material provides insights into the challenges and opportunities in digital	3	5	60%

No	Aspect	Indicator	X	X _i	Score (%)
		marketing in the era of technological transformation.			
4	Depth of content for critical thinking development	The material encourages students to think critically when evaluating marketing strategies.	5	5	100%
		The material offers opportunities for in-depth analysis of marketing cases.	4	5	80%
		Assignments/case studies enable students to develop strategic solutions to marketing problems.	5	5	100%
5	Clarity of content presentation	The material is presented systematically, easily understood, and supports student comprehension.	4	5	80%
		The language used in the material is clear, straightforward, and appropriate to student characteristics.	4	5	80%
6	Content alignment with learning outcomes	The material is aligned with the learning outcomes of the <i>Introduction to Business</i> course.	5	5	100%
		The material helps students achieve the competencies set out in the curriculum.	4	5	80%
7	Case example relevance to real-world practices	Case examples are relevant to marketing practices in the industry.	3	5	60%
		Examples reflect real-world scenarios that can be analyzed to improve critical thinking skills.	5	5	100%
TOTAL			64	75	85%

The overall score obtained from the validation was 85%, placing the content in the “Valid” category (where $62.5\% < P \leq 81.25\%$). The highest scores were recorded in Accuracy of Digital Marketing Concepts and Depth of Content for Critical Thinking Development, both receiving 100%, suggesting that the content was strongly aligned with contemporary business theory and effectively cultivated critical thinking. However, areas such as Relevance to Industry and Case Example Relevance to Real-World Practices scored lower (60% and 80%, respectively), indicating the need for improvements in contextualizing the material with practical, industry-based applications and case studies.

4.3. Media Learning Expert Validation Results

This section outlines the results of the media expert validation for the MOPjBML platform designed to support the Introduction to Business course. The validation focused on evaluating the quality of the user interface (UI/UX), interactivity of the media, ease of navigation, clarity of the information structure, consistency with digital learning strategies, and facilitation of student collaboration. It also assessed the effectiveness of multimedia elements in enhancing the comprehension of marketing concepts (see Table 10).

Table 10. Media learning expert validation results

No	Aspect	Indicator	X	X _i	Score (%)
1	UI/UX quality	The interface display is attractive, modern, and follows sound design principles.	4	5	80%
		The interface design supports user comfort in accessing marketing learning materials.	4	5	80%
2	Media interactivity	The application provides interactive features for active participation in learning.	4	5	80%
		Interactive features enhance student engagement (quizzes, simulations, and discussions).	5	5	100%
3	Ease of navigation	The menu structure and navigation are easy for students and lecturers to use.	4	5	80%
		Access to learning materials and features can be done easily without technical obstacles.	4	5	80%
4	Clarity of information structure	Information is organized systematically and is easy for students to understand.	5	5	100%
		The layout and content organization support the effectiveness of marketing learning.	4	5	80%
5	Alignment with digital learning strategies	The application is designed according to practical digital learning approaches.	4	5	80%
		Features in the application support project-based and case study learning methods in marketing.	3	5	60%
6	Support for student collaboration	The application provides features for collaboration in group assignments or interactive discussions.	4	5	80%
		The media facilitates effective communication and interaction among students.	5	5	100%
7	Effectiveness of multimedia elements	Multimedia elements help students understand marketing concepts.	4	5	80%
		The use of multimedia elements increases student interest and motivation to learn.	4	5	80%
TOTAL			58	70	83%

The validation results yielded an overall score of 83%, classifying the platform in the “Valid” category ($62.5\% < P \leq 81.25\%$). The platform performed strongly in Media Interactivity and Support for Student Collaboration, both achieving the highest score of 100%. These findings suggest that the platform successfully facilitated interactive and collaborative learning experiences. Moreover, Ease of Navigation and Clarity of Information Structure received favourable scores (80% and 100%, respectively), indicating that the interface was user-friendly and supported efficient knowledge acquisition. However, Alignment with Digital Learning Strategies (60%) was an area where further refinement is recommended to enhance pedagogical coherence.

4.4. Practicality Test Results

This section presents the results of the practicality test for the MOPjBML platform, which was conducted to evaluate the platform's effectiveness in supporting the learning process. The test involved evaluations by lecturers and students, focusing on various aspects, including ease of use, effectiveness in facilitating active learning, engagement in collaborative activities, alignment with learners' needs, and the availability of formative and summative assessment features. The findings offer insight into whether the platform met user expectations within an educational context, as shown in Table 11 below.

Table 11. Practicality test results

No	Aspect	Indicator	X	X _i	Score (%)
1	Ease of use	The application is easy to use in classroom learning activities.	5	5	100%
		Lecturers and students can access and operate the application without significant technical barriers.	4	5	80%
2	Effectiveness in facilitating active learning	The application enhances interaction between lecturers and students in marketing learning.	5	5	100%
		The application helps students understand marketing concepts through project-based or case study approaches.	5	5	100%
3	Engagement in collaborative activities	The application features encourage students to collaborate in group assignments.	4	5	80%
		Students are more motivated to discuss and share ideas in marketing learning using the application.	4	5	80%
4	Alignment with learners' needs	The application provides materials, features, and learning resources that suit students' needs.	4	5	80%
		The application addresses challenges and gaps in marketing education compared to conventional methods.	4	5	80%
5	Availability of formative and summative assessment features	The application offers features to assess students' understanding formatively and summatively.	4	5	80%
		The assessments in the application effectively measure students' critical thinking and collaboration skills.	5	5	100%
TOTAL			44	50	88%

The results indicate that the MOPjBML platform achieved a total score of 88%, classifying it as valid and practical for integration into the learning process. Notably, the ease-of-use aspect achieved a perfect score of 100%, demonstrating that lecturers and students found the platform highly accessible and user-friendly. Similarly, the aspects of Effectiveness in Facilitating Active Learning and Availability of Formative and Summative Assessment Features also received 100%, highlighting the platform's strong capacity to facilitate interactive learning and practical assessment.

Implementing PjBL through the MOPjBML platform in marketing education aimed to provide students with a more applied and engaging learning experience. Instead of merely learning theories through traditional lectures, students were immersed in real-world projects that reflected authentic marketing practices. In the present study context, mobile learning enabled access to learning resources anytime and anywhere, supporting flexibility and self-directed learning. Through this model, students could use mobile devices to complete practical marketing tasks such as market analysis, strategy development, and digital campaign design. The platform offered interactive features such as quizzes, instructional videos, and marketing case studies to help contextualize theoretical concepts.

In the mobile learning-based PjBL framework, students could collaborate in teams to develop real marketing projects. The application facilitated collaboration, discussion, and problem-solving through integrated tools. For example, students might be assigned to design a marketing strategy for a new product or analyze consumer behavior using up-to-date market data. This teamwork cultivated communication skills, critical thinking, and cooperative problem-solving. Moreover, the platform allowed for immediate feedback from instructors and peers, creating a responsive and dynamic learning environment. As a result, integrating mobile learning into PjBL could improve student engagement and competency in marketing and better prepare them to face industry challenges. This implementation was carried out across small and large student groups, as detailed in the following section.

4.5. Small-Group Trial Results

This section presents the findings of a practical trial conducted with a small group of five students. The primary aim of this trial was to evaluate several key dimensions of the MOPjBML platform in the context of educational use. The aspects assessed included ease of access and navigation, material comprehension, alignment of features with learning needs, capacity to enhance marketing analysis skills, and overall visual appeal and usability. These results offer valuable insights into whether the application met students' expectations for practicality, as depicted in Table 12.

Table 12. Small-group trial results

No	Aspect	Indicator	X	X _i	Score (%)
1	Ease of access and navigation	The application is easily accessible through commonly used devices (smartphones, tablets, and laptops).	24	25	96%
		Navigation within the application is straightforward and facilitates finding learning materials and features.	21	25	84%
2	Material comprehension	Marketing materials are easy to understand and aligned with students' needs.	25	25	100%
		The application provides sufficient explanations and case examples to help understand marketing concepts.	24	25	96%
3	Alignment of features with learning needs	The application features meet students' needs in learning marketing.	21	25	84%
		Collaborative features in the application support students in discussions and teamwork.	21	25	84%
4	Enhancement of marketing analysis skills	The application helps students analyze marketing strategies in various business scenarios.	20	25	80%
		The application offers a case-based learning experience that improves students' critical thinking skills.	25	25	100%
5	Visual appeal and ease of use	The application design is engaging and supports comfortable learning.	21	25	84%
		The application layout, colour scheme, and graphic display facilitate students' understanding of the material.	24	25	96%
TOTAL			226	250	90%

The results indicate that the MOPjBML platform achieved an overall score of 90%, placing it within the "Highly Practical" category ($81.25\% < P \leq 100\%$) based on the predefined practicality criteria. Notably, the Material Comprehension aspect received a perfect score of 100%, indicating that the application could effectively deliver marketing content in a way that was accessible and easily understood by students. Furthermore, other evaluated aspects, such as ease of access and navigation, enhancement of marketing analysis skills, visual appeal, and ease of use, also received high ratings (84% to 96%). These findings demonstrate that the application could facilitate smooth navigation and interaction and support learning through an engaging and user-friendly interface while enhancing students' analytical competencies in marketing.

4.6. Large-Group Trial Results

4.6.1. Instrument validity test

The validity test is crucial in determining the extent to which the instrument reliably measures critical thinking skills. In this study, the validity test assessed the applicability of six dimensions of critical thinking, namely interpretation, analysis, evaluation, inference, explanation, and self-regulation, within the context of marketing strategies. The indicators used were aligned with core marketing concepts, elements of strategy, and the ability to analyze and evaluate marketing data. The results indicated that all indicators had r-scores exceeding r-tables, confirming the validity of these indicators for measuring critical thinking skills in the marketing context. The following Table 13 portrays the necessary details.

Table 13. Validity test results for the critical thinking skills instrument

No	Dimension	Indicator	r-score	r-table	Description
1	Interpretation	Identifying relevant marketing concepts from case studies.	0.705	0.361	Valid
		Understanding and explaining marketing strategies in a business context.	0.670	0.361	Valid
2	Analysis	Systematically outlining the elements of a marketing strategy.	0.719	0.361	Valid
		Using data and facts to evaluate the implemented marketing strategies.	0.704	0.361	Valid
3	Evaluation	Distinguishing between valid and invalid marketing information.	0.624	0.361	Valid
		Critically assessing the marketing strategies carried out by a company.	0.785	0.361	Valid
4	Inference	Formulating marketing decisions based on data analysis.	0.770	0.361	Valid
		Concluding the effectiveness of a marketing strategy based on case studies.	0.653	0.361	Valid
5	Explanation	Explaining the rationale behind the selection of specific marketing strategies.	0.780	0.361	Valid
		Preparing a marketing analysis report with strong arguments.	0.724	0.361	Valid
6	Self-regulation	Identifying weaknesses in the developed marketing analysis.	0.745	0.361	Valid
		Developing strategies to enhance critical thinking in marketing.	0.589	0.361	Valid

Based on the validity test results, it can be concluded that all indicators within each dimension of critical thinking skills had r-scores greater than the r-table (0.361). This result indicates that the indicators were valid measures of critical thinking skills in the context of marketing strategies.

The validity test for collaboration skills aimed to determine the reliability of indicators in representing individuals' collaborative competencies within a group context, particularly in marketing

tasks. This test covered six dimensions: communication, teamwork, conflict management, problem-solving, engagement, and group reflection. The details are presented in the following Table 14.

Table 14. Validity test results for the collaboration skills instrument

No	Dimension	Indicator	r-score	r-table	Description
1	Communication	Effectively communicating in group discussions.	0.755	0.361	Valid
		Expressing ideas openly and clearly.	0.562	0.361	Valid
2	Teamwork	Collaborating with group members to complete marketing tasks.	0.794	0.361	Valid
		Demonstrating a sense of responsibility toward team assignments.	0.803	0.361	Valid
3	Conflict management	Resolving conflicts among group members constructively.	0.738	0.361	Valid
		Respecting differing opinions and seeking joint solutions.	0.788	0.361	Valid
4	Problem-solving	Identifying marketing problems within the group and formulating solutions together.	0.781	0.361	Valid
		Collaborating in designing effective marketing strategies.	0.753	0.361	Valid
5	Engagement	Actively participating in group meetings and discussions.	0.867	0.361	Valid
		Contributing ideas for the group's progress.	0.809	0.361	Valid
6	Group reflection	Evaluating the effectiveness of teamwork after completing marketing tasks.	0.790	0.361	Valid
		Identifying the roles and contributions of each group member.	0.774	0.361	Valid

Based on the validity test results, it can be concluded that all indicators in each dimension of collaboration skills had r-scores greater than the r-table (0.361). This indicates that the indicators were valid for measuring collaboration skills in the context of marketing strategies.

4.6.2. Instrument reliability test

Reliability was measured using Cronbach's Alpha. A high Cronbach's Alpha value indicated that the instrument consistently measured the intended construct. Hence, the results confirmed excellent internal consistency for critical thinking skills, as presented in Table 15.

Table 15. Reliability test results for the critical thinking skills instrument

No	Cronbach's Alpha	Number of Items	Description
1	0.907	12	Reliable

The Cronbach's Alpha value of 0.907 indicates excellent reliability, demonstrating that the instrument consistently measured critical thinking skills in this study.

The reliability test for the collaboration skills instrument produced a high Cronbach's Alpha value, confirming the instrument's consistency in measuring collaboration. The test results are presented in Table 16 below.

Table 16. Reliability test results for the collaboration skills instrument

No	Cronbach's Alpha	Number of Items	Description
1	0.935	12	Reliable

The Cronbach's Alpha value of 0.935 indicates excellent reliability, suggesting that the instrument was highly consistent in measuring collaboration skills within groups engaged in marketing tasks.

4.6.3. Normality test

The normality test assessed whether the data distribution within each group followed a normal distribution. In this study, the researcher employed the Kolmogorov-Smirnov and Shapiro-Wilk tests. A significance value (Sig.) greater than 0.05 indicated that the data were normally distributed, whereas a value less than 0.05 suggested that they were not. Accordingly, the pretest and posttest results indicated that the data followed a normal distribution, as depicted in Table 17 below.

Table 17. Normality test results for the critical thinking skills

No	Test	Group	Statistic	Sig.
1	Kolmogorov-Smirnov	Pretest	0.106	0.168
		Posttest	0.094	0.200*
2	Shapiro-Wilk	Pretest	0.972	0.197
		Posttest	0.982	0.559

**Note: A lower bound of the true significance.*

The same tests were applied to the data on collaboration skills, which also followed a normal distribution. The detailed results are presented in Table 18.

Table 18. Normality test results for the collaboration skills

No	Test	Group	Statistic	Sig.
1	Kolmogorov-Smirnov	Pretest	0.061	0.200*
		Posttest	0.103	0.200*
2	Shapiro-Wilk	Pretest	0.988	0.839
		Posttest	0.989	0.877

**Note: A lower bound of the true significance.*

The Kolmogorov-Smirnov and Shapiro-Wilk tests for both the pretest and posttest indicated that the data on collaboration skills were normally distributed (Sig. > 0.05).

4.6.4. Effectiveness test (paired t-test)

After conducting validity and reliability tests on the instruments and normality tests on the data, the following section presents the data and descriptions for each indicator of the collaboration and critical thinking variables.

The paired t-test was conducted to analyze differences in collaboration skills between the pretest and posttest across various dimensions, including communication, teamwork, conflict management, problem-solving, engagement, and group reflection. The results indicated significant improvements in all dimensions, as evidenced by very small p-values ($p < 0.05$), suggesting that the learning intervention effectively improved students' collaboration skills. The results are presented in detail in Table 19.

Table 19. Paired t-test results for collaboration skills

No	Pair	Mean Difference	Std. Deviation	t	Sig. (2-tailed)
1	Pretest vs. Posttest – Communication	-2.49123	.86855	-21.655	0.000
2	Pretest vs. Posttest – Teamwork	-2.78947	1.20619	-17.460	0.000
3	Pretest vs. Posttest – Conflict management	-2.96491	1.41377	-15.833	0.000
4	Pretest vs. Posttest – Problem-solving	-2.91228	1.12251	-19.588	0.000
5	Pretest vs. Posttest – Engagement	-2.63158	0.89904	-22.099	0.000
6	Pretest vs. Posttest – Group Reflection	-2.64912	0.89625	-22.316	0.000

The paired t-test results indicated a significant difference between the pretest and posttest scores across all dimensions of collaboration skills. The p-values for all dimensions, including communication, teamwork, conflict management, problem-solving, engagement, and group reflection, were significantly below 0.05 ($p = 0.000$), confirming that the learning intervention effectively improved students' collaboration skills in all indicators.

The paired t-test was conducted to compare the differences between two related groups: the pretest and posttest critical thinking skills scores. This test aimed to determine whether scores differed significantly across each dimension of critical thinking, including interpretation, analysis, evaluation, inference, explanation, and self-regulation. The results exhibited significant differences between the pretest and posttest in all tested dimensions, with p-values less than 0.05, indicating that the learning intervention effectively improved students' critical thinking skills. The detailed results are presented in Table 20 below.

Table 20. Paired t-test results for critical thinking skills

No	Pair	Mean Difference	Std. Deviation	t	Sig. (2-tailed)
1	Pretest vs. Posttest – Interpretation	-2.17544	0.57080	-28.774	0.000
2	Pretest vs. Posttest – Analysis	-2.40351	0.77597	-23.385	0.000
3	Pretest vs. Posttest – Evaluation	-2.59649	0.97942	-20.015	0.000
4	Pretest vs. Posttest – Inference	-2.49123	0.75882	-24.786	0.000
5	Pretest vs. Posttest – Explanation	-2.43860	0.70755	-26.021	0.000
6	Pretest vs. Posttest – Self-regulation	-2.43860	0.70755	-26.021	0.000

The paired t-test results for critical thinking skills indicated a significant difference between the pretest and posttest scores across all tested dimensions. The p-values for each dimension, including interpretation, analysis, evaluation, inference, explanation, and self-regulation, were well below the 0.05 threshold ($p = 0.000$), suggesting that the learning intervention effectively improved students' critical thinking skills across all indicators assessed.

5. Discussion

The study aims to develop and validate CTTH, an instrument specifically designed to measure CT in the context of temperature and heat topics in physics. The importance of CT in science is

5.1. Implementation of the Marketing-Oriented Project-Based Mobile Learning Platform for Marketing Materials in the Introduction to Business Course

The development of the MOPjBML platform as an interactive learning medium for the Introduction to Business course, specifically in marketing, offers an innovative solution to challenges in teaching marketing, which is often perceived as abstract and theoretical. This study's findings demonstrate that mobile learning significantly enhances flexibility and accessibility, addressing traditional constraints of time and location. This aligns with Seta et al. (2022), who argue that learning media capture learners' attention and direct their focus toward effective learning.

The MOPjBML platform was designed to engage students through interactive features and visual design, making complex marketing concepts more comprehensible and applicable in real-world business contexts. Huang and Li (2022) also emphasize the importance of technology in optimizing students' learning potential. Through mobile learning, students can learn more flexibly and access educational content without time or location limitations, making marketing education more accessible and aligned with contemporary educational demands. Similarly, Zhao (2025) asserts that diverse learning approaches, such as mobile learning, can facilitate students' understanding of complex marketing concepts. In the present study context, features like Objective, Schema, Concept, Pricing, Promotion, and Video allowed students to access structured information engagingly and systematically, enriching their learning experience.

A key strength of the platform lies in its evidence-based instructional strategies. The Objective section, which clearly outlines learning goals, was found to increase student motivation, supporting Yuzianah's (2023) research on the importance of goal clarity. Similarly, the Schema section—a systematic guide to marketing content—helped learners navigate complex topics with greater ease, reinforcing Ninghardjanti and Dirgatama's (2021) findings on the value of well-organized materials. Askary and Askarany (2024) note that interactive and intuitive design enables students to access key information more efficiently. The app's use of interactive navigation buttons guides students through marketing topics sequentially, creating a cohesive and comprehensive learning journey. This is especially critical in marketing education, which integrates theory and practical application. Crompton (2013) claims mobile learning supports deeper engagement through content interaction and social collaboration.

The platform's audiovisual elements, including videos on the Marketing Mix and strategies for launching new products, were instrumental in facilitating the integration of theoretical concepts with practical application. While Klímová (2019) discusses the broad advantages of multimedia use in educational settings, the present study highlights the specific contribution of video case studies in enhancing students' ability to apply marketing theories within authentic contexts. Additionally, the Quiz section incorporated an immediate feedback system that reinforced learning outcomes, consistent with Yağan's (2023) findings on the significance of prompt assessment feedback. Students valued the opportunity to assess their comprehension and revisit complex material, thereby fostering

a more autonomous learning process. This aligns with Zhao et al.'s (2025) emphasis on the importance of feedback in cultivating critical thinking skills and promoting student development.

The material and media validation results indicate that the developed MOPjBML platform for the Introduction to Business course met most essential criteria for effective learning; however, certain areas required improvement. According to material experts, the content aligned with academic standards and incorporated key marketing concepts from theoretical and practical perspectives. The content's alignment with the Introduction to Business course curriculum received a score of 80%, reflecting the material's overall appropriateness for the course. This finding aligns with Volkovitckaia et al. (2020), who emphasize the importance of learning modules that reflect the nature of the course, allowing students to grasp theoretical knowledge and apply it in real-world contexts.

However, aspects such as material relevance to industry and the inclusion of real-world case examples received lower scores—60% and 80%, respectively—suggesting that the connection between the content and current industry challenges needed strengthening. Media validation further showed that the app's user interface (UI/UX) was well-designed, achieving a score of 83%. This supports El-sabagh (2021), who highlights the importance of interactive design in enhancing student engagement. Validation of interactivity, ease of navigation, and the systematic information structure confirmed that the app provided an intuitive and accessible learning experience. Askary and Askarany (2024) also emphasize that a clear and well-organized information structure is essential for facilitating the understanding of complex subjects such as marketing.

Regarding practicality testing, the results indicate that the app was user-friendly for lecturers and students, achieving a total score of 88%. This supports the findings of Criollo-C et al. (2021), who underscore the importance of flexibility and ease of access in technology-based learning environments. The app also promoted interaction between lecturers and students, encouraging active participation through quizzes and collaborative tasks. This is consistent with Sayekti et al. (2023), who argue that collaboration in learning, particularly in marketing, is vital for enhancing students' understanding and practical skills. While the app included collaborative features, this aspect should be further developed to support teamwork better and promote more meaningful communication among users.

5.2. Descriptive Condition of Each Indicator Within the Collaboration Variable in the Context of Mobile Learning and Project-Based Learning for Marketing Materials

The integration of project-based learning (PjBL) with mobile technologies created a dynamic environment where students demonstrated measurable growth in key collaborative competencies—teamwork, communication, and problem-solving. This synergy between pedagogical approach and technological support proved particularly effective in marketing education, where real-world application of concepts requires coordinated group effort. Observations revealed that students not only engaged more deeply with course material but also developed stronger interpersonal skills as they worked collectively to complete marketing projects through the mobile platform. The success of this approach aligns with established educational theories emphasizing the value of active, socially constructed learning. As noted by Hartati et al. (2022) and Kinasih & Ratnawati (2024), PjBL inherently fosters collaboration by requiring students to negotiate roles, share perspectives, and jointly develop solutions—a process that was markedly enhanced through mobile technology. The portable nature of the platform allowed for continuous communication and document sharing, enabling teams to maintain momentum outside classroom hours. This finding extends the work of Rasyid & Khoirunnisa (2021) by demonstrating how mobile tools can amplify PjBL's benefits, particularly in developing the social competencies needed for modern marketing careers. It also supports the idea that meaningful learning environments encourage students to work collectively towards shared goals, an essential aspect of modern education (Belwal et al., 2020; Isa & Azid, 2021; Rupavijetra et al., 2022).

Moreover, integrating technology into learning frameworks strengthens these collaborative efforts, particularly within mobile learning environments. Prior research indicates that technology-supported learning could substantially improve cognitive engagement, enhancing academic and social outcomes (Lu et al., 2023; Ma et al., 2024). In technology-rich settings, such as smart classrooms, students use advanced educational tools that foster collaborative skills. These interactions are vital for student engagement as they promote a sense of purpose and enhance peer communication, reinforcing teamwork during project tasks (Bond et al., 2020; Lu et al., 2023).

The intersection of PjBL and mobile learning also addressed common collaboration challenges identified in prior research. Where Safaruddin et al. (2020) found that students sometimes struggle with unequal participation in group projects, the transparency afforded by the mobile platform—through features like contribution tracking and chat logs—encouraged more balanced involvement. Similarly, the study supports Pan's (2022) findings that digital project spaces can improve the quality of peer feedback, as students in this intervention provided more specific, actionable suggestions compared to traditional classroom-based teamwork. Therefore, mobile platforms can streamline group work logistics and enrich peer interaction quality, resulting in a more dynamic and productive learning atmosphere (Alfaeni et al., 2022; Pan, 2022). In conclusion, collaborative skills were significantly improved through PjBL, particularly when supported by mobile technology. This integrated approach could create a learning environment to promote teamwork, effective communication, and problem-solving, which align closely with educational goals aimed at preparing students for future demands.

5.3. Descriptive Condition of Each Indicator Within the Critical Thinking Variable in the Context of Mobile Learning and Project-Based Learning for Marketing Materials

The integration of mobile learning technologies with project-based learning (PjBL) methodologies demonstrated substantial improvements in students' critical thinking capacities, particularly in analyzing and evaluating marketing strategies. Indicators like the ability to critique marketing tactics and make informed decisions exhibited significant improvement, reflecting the success of mobile learning in promoting critical thinking. Pretest and posttest comparisons revealed that mobile learning integrated with project-based learning helped develop skills such as analysis, evaluation, and inference, making students more adept at interpreting marketing data and drawing conclusions based on their analyses. Utilizing mobile platforms in education has significantly improved students' analytical and evaluative capabilities, particularly when examining complex tasks such as marketing strategies.

The findings align with contemporary research on technology-enhanced learning. Syahputra et al. (2023) and Uma'iyah et al. (2023) similarly observed that mobile learning platforms facilitate the development of evaluative skills by providing immediate access to diverse marketing case studies and analytical tools. The current study extends this understanding by demonstrating how mobile technology, when embedded within PjBL frameworks, creates iterative cycles of analysis, application, and reflection - a process that appears particularly effective for developing marketing-specific critical thinking competencies. Integrating mobile learning with project-based approaches fosters environments where critical thinking can flourish, enabling students to analyze and interpret marketing data effectively.

Research has consistently shown that mobile learning promotes higher-order thinking skills, which foster critical analysis and evaluation (Kandriasari et al., 2023; Uma'iyah et al., 2023). For instance, a meta-analysis of mobile learning interventions demonstrated that these technologies could improve students' reasoned decision-making and inference capabilities (Talan, 2020). Such improvements were substantiated by pretest and posttest comparisons, highlighting growth in the

ability to evaluate marketing strategies within project-based learning frameworks (Ariningsih et al., 2021).

Moreover, mobile learning environments encourage collaboration and support peer learning structures, essential for developing critical thinking. Students interacting within these platforms contribute diverse perspectives, fostering deeper discussions and reflections on marketing concepts (Abidin et al., 2023; Kandriasari et al., 2023). Thus, mobile learning supports self-paced learning and cultivates a collaborative culture that enhances critical thinking through shared insights and analyses (Grosemans et al., 2020). In summary, integrating mobile learning with project-based methodologies significantly improved students' critical thinking skills. These enhancements were reflected in their improved capacities to analyze, evaluate, and make informed decisions regarding marketing strategies, emphasizing the overall efficacy of mobile learning in contemporary educational settings.

5.4. Effectiveness of the Marketing-Oriented Project-Based Mobile Learning Platform in Improving Students' Critical Thinking and Collaboration Skills in Marketing Materials

The Marketing-Oriented Project-Based Mobile Learning (MOPjBML) platform demonstrated significant effectiveness in developing students' higher-order thinking skills, as evidenced by robust statistical analysis. The platform's impact was particularly notable across all dimensions of critical thinking - interpretation, analysis, evaluation, inference, explanation, and self-regulation - with statistically significant improvements ($p < 0.05$) between pre- and post-intervention assessments. These findings substantiate Crompton's (2013) assertion that mobile learning creates dynamic environments conducive to cognitive engagement, while extending our understanding of how specific platform features contribute to different critical thinking competencies. Significant improvements were especially evident in the interpretation and analysis dimensions following the implementation of mobile learning. This supports the findings of Bendraou and Sakale (2023), who emphasized that mobile learning could facilitate critical thinking by offering platforms that allow students to engage directly with content through features such as quizzes, videos, and interactive discussions. The interactive features of the MOPjBML platform enabled students to test and reflect on their understanding through real-time evaluations, strengthening their ability to evaluate and analyze information more deeply.

The significant improvement in the evaluation and inference dimensions further illustrates that m-learning helped students develop skills to assess and draw accurate conclusions from information. Manggu and Kiliç (2022) and Yunikawati and Tuanani (2022) argue that technology-based learning, particularly m-learning, allows students to explore ideas more deeply and connect theoretical concepts with real-world applications. This was evident in students' improved ability to identify arguments and draw conclusions based on data presented in the learning materials. Significant improvements in the explanation and self-regulation suggest that m-learning also fostered self-reflection and personal regulation of information processing. Klímová (2019) and Tshewang and Wangdi (2021) argue that m-learning allows students to control their own learning pace, supporting the development of self-regulation in critical thinking. By allowing students to learn independently and manage their study time, the app enhances their ability to absorb and understand each topic effectively. The t-test results indicate that mobile learning in marketing education improved students' comprehension of course content and played a vital role in developing their critical thinking skills. With its features that support active interaction and continuous evaluation, such as quizzes and discussions, m-learning is an effective tool for cultivating critical thinking, as noted by Crompton (2013) and Moundy et al. (2022). Thus, mobile learning is a medium for delivering instructional content and a powerful platform for developing critical thinking skills, essential for success in higher education and the modern workforce.

5.5. Effect of the Marketing-Oriented Project-Based Mobile Learning Platform on Collaboration and Critical Thinking Variables in Marketing Materials within an Introduction to Business Course

The implementation of the Marketing-Oriented Project-Based Mobile Learning (MOPjBML) platform in the Introduction to Business course demonstrated significant improvements in students' collaboration and critical thinking skills, as evidenced by rigorous statistical analysis. The platform's effectiveness was particularly notable across all measured dimensions of collaboration, including communication, teamwork, conflict management, problem-solving, engagement, and group reflection, with statistically significant improvements ($p < 0.05$) between pre- and post-intervention assessments. These findings suggest that the mobile learning environment successfully created conditions conducive to developing essential collaborative competencies. The most pronounced enhancements appeared in communication and teamwork dimensions, where students exhibited greater openness and more frequent peer engagement during group activities. This aligns with contemporary research by Ye (2024), which highlights how technology-mediated learning environments can foster richer interpersonal interactions through structured collaborative features. Similarly, Lee (2023) explained that learning technologies can strengthen communication among team members, enabling students to share ideas and collaborate more effectively. Improvements in conflict management and problem-solving dimensions further suggest that m-learning supported students in addressing disagreements and finding collaborative solutions within group projects. Gong et al. (2023) emphasized that technology-supported learning environments allow students to solve problems more systematically by utilizing the information available through m-learning platforms, encouraging teamwork and collective problem-solving. Thus, m-learning not only facilitates theoretical understanding but also fosters the development of practical workplace skills.

The platform's impact extended beyond immediate task performance to influence deeper learning processes. Significant gains in engagement and group reflection dimensions indicate that students not only participated more actively in collaborative work but also developed greater metacognitive awareness of their team contributions. This finding resonates with Costa's (2020) work on technology-enhanced reflective practice, suggesting that the platform's built-in reflection mechanisms successfully promoted critical examination of both individual and group learning processes.

The results have important implications for marketing education, highlighting how thoughtfully designed mobile learning platforms can address the dual imperative of developing both conceptual understanding and practical teamwork abilities. The study suggests that future implementations could further enhance these benefits by incorporating more sophisticated peer feedback systems, industry-relevant collaborative scenarios, and explicit bridges between academic collaboration and professional practice norms. Ultimately, these findings position mobile project-based learning as a valuable approach for preparing business students to meet the complex interpersonal and cognitive demands of contemporary marketing careers.

6. Conclusion

This study successfully developed the MOPjBML platform as an interactive learning medium for the Introduction to Business course, explicitly focusing on marketing materials. The platform was designed with an engaging, intuitive, and interactive visual approach, enabling students to learn marketing concepts in a more structured and accessible way. Its user-friendly interface and interactive features, such as Objective, Schema, Concept, Pricing, Promotion, Selling, Video, Quiz, and References, support students in understanding marketing concepts more effectively and enjoyably. The findings also indicate that mobile learning significantly improved students' critical thinking and collaboration skills. Paired t-test results demonstrated significant improvements across all

dimensions of critical thinking and collaboration, namely communication, teamwork, conflict management, and problem-solving, highlighting that mobile learning effectively improved students' abilities to collaborate, think critically, and communicate more proficiently.

This study has several limitations that should be addressed in future research. First, while the MOPjBML platform effectively improved collaboration and critical thinking, its industry relevance was limited due to the lack of real-world case studies. It updated marketing practices, which may restrict students' ability to apply theoretical knowledge in professional settings. Second, the platform's collaborative features, though functional, could be further enhanced with structured discussion forums or virtual group workspaces to foster deeper peer interaction and teamwork. Third, while engaging, the current multimedia elements were insufficient in covering complex marketing scenarios, suggesting a need for expanded simulations and interactive videos to support conceptual understanding better. Addressing these limitations in line with the proposed enhancements—such as integrating more industry-aligned case studies, improving collaborative tools, and enriching multimedia content—would strengthen the platform's practicality and educational impact.

7. Suggestion

Several research directions are recommended to advance the development and implementation of mobile-based project learning platforms in marketing education. First, future studies should prioritize enhancing the industry relevance of learning materials by incorporating contemporary case studies and real-world marketing challenges. This could be achieved through strategic collaborations with industry partners to ensure content remains aligned with current market trends and practices. Second, researchers should investigate the effectiveness of advanced collaborative features such as structured discussion forums, real-time group workspaces, and peer-review systems in fostering deeper student interaction and teamwork. Third, expanding the platform's multimedia components through interactive simulations, virtual reality scenarios, and gamified elements could provide valuable insights into their impact on student engagement and knowledge retention.

Additionally, longitudinal studies are needed to assess the sustained effects of the platform on students' critical thinking and collaboration skills over extended periods. Comparative research with other learning models would help identify the platform's unique advantages and areas for improvement. Finally, future investigations should explore the platform's adaptability across diverse educational contexts, including disciplines, learning environments (hybrid or entirely online), and student demographics. Addressing these research gaps would refine the MOPjBML platform and contribute significantly to the broader understanding of technology-enhanced, project-based learning in business education. Such efforts would provide educators with evidence-based strategies for optimizing mobile learning tools to meet the evolving needs of 21st-century learners.

Declarations

Conflicts of Interest. The author declares no conflict of interest.

Data Availability Statement. Research data are available upon request from the corresponding author.

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