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Effectiveness of phenomenon-based peer assessment learning model on college students' entrepreneurship skills and critical thinking

Ye Yue[1], Jirarat Sitthiworachart[2*], Thanin Ratanaolarn[3]
[1,2,3]School of Industrial Education and Technology, King Mongkut's Institute of Technology Ladkrabang, Thailand; 63603106@kmitl.ac.th (Y.Y.) jirarat.si@kmitl.ac.th (J.S.) thanin.ra@kmitl.ac.th (T.R.).

Abstract: Entrepreneurial skills and critical thinking skills have become indispensable for adapting to market demands and securing suitable future career positions for today's college students. This study integrated Phenomenon-Based Learning, peer assessment, and generative AI into the PhBLPA model to examine its effectiveness in enhancing students' entrepreneurial skills and critical thinking in entrepreneurship education. A two-group posttest-only experimental design was employed, involving two groups selected through cluster sampling, with 40 students per group, totaling 80 students. The experiment spanned eight weeks as part of an entrepreneurship course. Entrepreneurial skills were assessed through students' entrepreneurial business project plans, while critical thinking was measured using a five-point Likert scale questionnaire. The data obtained were analyzed using MANOVA, revealing significant differences between groups. The results supported Research Hypothesis 1 (RH1): students who studied the PhBLPA model demonstrated higher entrepreneurial skills than those who studied with traditional learning methods ($P < .001$). Similarly, Research Hypothesis 2 (RH2): students who studied the PhBLPA model exhibited higher critical thinking skills than those who studied with traditional methods ($P < .001$). Overall, the findings suggest that the PhBLPA model is more effective than traditional methods for cultivating 21st-century entrepreneurial skills and critical thinking among university students.

Keywords: *Critical thinking, Entrepreneurial skills, Generative AI, Peer assessment, Phenomenon-based learning.*

1. Introduction

China's higher education system is shifting from knowledge transmission to capability cultivation in support of national priorities for innovation-driven development and "mass entrepreneurship and innovation" [1]. In this context, entrepreneurship education has proliferated across universities to cultivate students' entrepreneurial skills that empower students to turn ideas into action, start their own ventures, and contribute to innovation in various fields. Furthermore, critical thinking is central to the success of entrepreneurial activities, enabling students to analyze problems, make informed decisions, and solve complex issues creatively, which underpins robust entrepreneurial decision-making [2]. However, the traditional teaching method characterized by exam-oriented practices, disciplinary silos, and limited access to authentic, interdisciplinary, and iterative learning experiences can constrain the development of entrepreneurial skills and critical thinking among Chinese undergraduates [3]. Hence, there is an urgent need for pedagogical models that connect theory to real-world phenomena, scaffold disciplined inquiry, and foster students' entrepreneurial skills and critical thinking for their future careers.

To meet the above urgent need, the researcher of this study developed a Phenomenon-based peer assessment learning model (PhBLPA model) with generative AI. Under this model, phenomenon-based learning stimulates students' innovative thinking and entrepreneurial skills by immersing them in real-world entrepreneurial scenarios and challenges [4]. Meanwhile, generative AI can enhance ideation,

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* Correspondence: jirarat.si@kmitl.ac.th

hypothesis generation, multilingual market scanning, rapid prototyping, and formative feedback in the process of forming solutions for real-world entrepreneurial scenarios [5]. Furthermore, peer assessment reinforces this model by encouraging students to evaluate each other's entrepreneurial projects, which fosters collaboration, communication, and the development of critical thinking as students learn to provide constructive feedback, think independently, reason logically, and express their ideas clearly [6]. This triadic design combines authentic inquiry (pedagogy), AI-augmented cognition (technology), and peer-mediated accountability (assessment), systematically embedding disciplined inquiry and reasoning within entrepreneurship education, leading students to gains in entrepreneurial skills and critical thinking in the learning process.

To study the effectiveness of the PhBLPA model, the researcher experimented, and a comparison was made between the entrepreneurial skills and critical thinking of students who engaged in learning activities based on the PhBLPA model and those students who followed the traditional learning method. Thereby, the researcher formulated the following research hypotheses.

2. Research Hypothesis

RH1: Students who study the PhBLPA model have higher entrepreneurial skills than those who study with traditional learning methods.

RH2: Students who study the PhBLPA model have higher critical thinking skills than those who study with traditional learning methods.

3. Literature Review

The researcher of this study has reviewed the related concepts and theories of the Phenomenon-based Peer Assessment Learning Model, critical thinking, and entrepreneurial skills to provide a comprehensive understanding of this topic.

3.1. Phenomenon-based Peer Assessment Learning Model

Phenomenon-based Learning (PhBL) is an interdisciplinary, student-centered pedagogical approach that enables holistic learning through the exploration of real-world phenomena and encourages students to synthesize knowledge across disciplines to solve complex problems [7]. PhBL emphasizes real-world phenomena to ensure students are exposed to the complexities of entrepreneurship, including identifying opportunities, analyzing challenges, and developing innovative solutions. This approach is particularly suited to entrepreneurship education, where success often depends on the ability to navigate uncertainty, think innovatively, and apply diverse skills to real-life challenges [8]. In addition, PhBL also aligns with Kolb's [9] experiential learning theory, which emphasizes learning through experience and reflection. With the application of PhBL in entrepreneurship education, students can work on entrepreneurial projects to address societal issues and gain entrepreneurial skills in tackling real-world challenges through their solutions.

Peer assessment (PA) refers to an educational process that enables students to assess and evaluate their peers' academic work, performance, and contributions according to the established rubric criteria [10]. The integration of PA and PhBL is called the PhBLPA model, which further enhances its impact by fostering collaboration, critical reflection, and iterative improvement. Peer assessment is supported by social constructivist theories, emphasizing collaborative learning and shared knowledge construction through the process of students evaluating and providing feedback on each other's work, which not only improves their ability to critically assess ideas but also develops their critical thinking during the learning process [11]. In entrepreneurship education, this process mirrors real-world scenarios where feedback from team members, stakeholders, and customers is essential for refining ideas and strategies. The researcher has summarized the eight steps of the PhBLPA model for entrepreneurship education as follows: contents and Figure 1 [4, 8, 11].

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Step 1: Identifying the phenomenon and setting goals: Students form teams to brainstorm and research societal phenomena relevant to entrepreneurship, select and submit a topic, while the teacher facilitates discussion and sets the entrepreneurial project planning goal.

Step 2: Designing the learning process and assessment criteria: The teacher constructs and explains the overall learning plan, providing clear assessment rubrics and examples to guide student understanding.

Step 3: Introducing students to the process and training in peer assessment: Through interactive workshops and role-play, students familiarize themselves with peer assessment as teachers lead training sessions, distribute guidelines, and offer immediate feedback on practice exercises.

Step 4: Guiding phenomenon exploration and inquiry: Students work together to investigate their chosen phenomenon, develop inquiry questions, and gather evidence from various sources, with teachers supporting research and facilitating progress discussions.

Step 5: Conducting peer assessment, providing and receiving feedback: Teams conduct peer assessments using established criteria, exchange anonymous constructive feedback, and identify steps for project enhancement under teacher supervision.

Step 6: Revising and refining work: Students revise their entrepreneurial project plans based on feedback, collaborate on improvements, and benefit from additional teacher guidance and resources.

Step 7: Final presentation and consolidation: Teams prepare and deliver comprehensive presentations of their entrepreneurial solutions, engaging peers and receiving final feedback from both teachers and audiences.

Step 8: Reflection and evaluation of the process: Students write reflective pieces and participate in discussions to evaluate their learning and critical thinking, while teachers facilitate reflection sessions and assess the effectiveness of the learning process for ongoing improvement.

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Figure 1.
Steps of PhBLPA.

Generative AI is a natural ally for PhBL, as it provides students with access to diverse and real-time information, fosters collaboration, and supports multimodal exploration of phenomena. The unique capability of generative AI tools is to provide a powerful platform for students to explore phenomena and obtain information efficiently, and simulate human-like interactions, answering questions, explaining concepts, and offering suggestions for further learning [12]. When implementing phenomenon-based learning, generative AI enables students to explore and investigate real-world societal phenomena, promoting critical thinking, creativity, and innovative problem-solving. Through its ability to process vast amounts of information, uncover insights, generate predictive models, and facilitate the development of entrepreneurial solutions that are both practical and ethical.

The generative AI used in this study is Kimi AI (https://www.kimi.com), which is an intelligent assistant developed by Moonshot AI, based on advanced deep learning and natural language processing technologies. It has a wide range of applications, especially in the field of education in China. With the assistance of Kimi AI, students ask questions to identify interesting phenomena in our society and select topics to work on for entrepreneurial project planning in step 1. In step 4, students can further explore and inquire about the selected topic, preparing evidence and related concepts to support solutions in their entrepreneurial project planning. In step 6, students receive feedback from their peers during peer assessment, and they can evaluate this feedback with the help of Kimi AI. Meanwhile, in step 7, students can seek presentation skills guidance from Kimi AI to improve their performance during presentations.

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Additionally, when asking questions on Kimi AI, the right side of the main interface displays relevant information websites, allowing students to further verify the links and evaluate the reliability of the answers provided by Kimi AI, as shown in Figure 2.

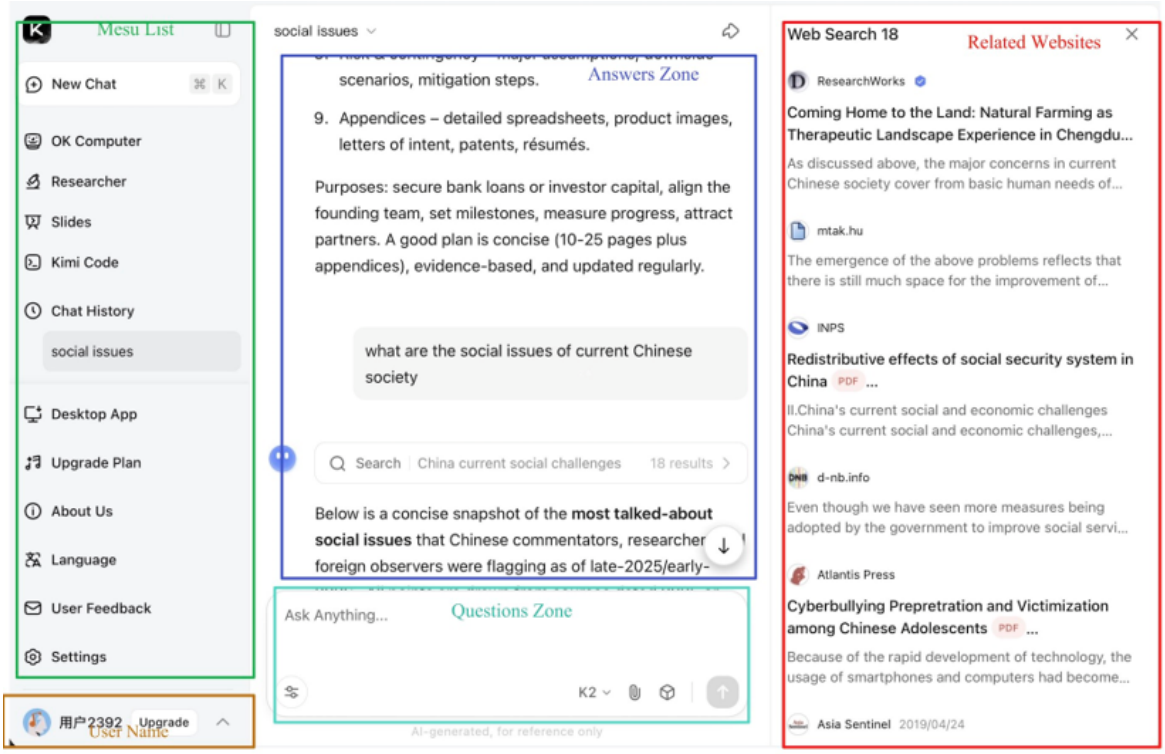

Figure 2.
Main Interface with Website Link.

3.2. Entrepreneurial Skills

Entrepreneurship skills refer to a broad set of competencies that enable individuals to identify opportunities, innovate, take initiative, and translate ideas into viable actions or sustainable ventures [13]. These skills encompass both technical abilities, such as financial planning and market analysis, and soft skills, such as leadership, communication, and creativity, all of which are essential for navigating uncertainty and achieving goals. Galvão et al. [14] define entrepreneurship skills as the combination of knowledge, behaviors, and attitudes required to turn opportunities into value through risk-taking, innovation, and strategic execution. In today's fast-paced, globalized world, these skills are no longer limited to entrepreneurs but are considered universally important for students pursuing diverse career paths. The growing complexity of markets, rapid technological advancements, and economic shifts demand that students not only possess academic knowledge but also the entrepreneurial mindset needed to adapt, innovate, and create value in any environment [15]. Whether students plan to launch startups, work in established firms, or engage in societal projects, entrepreneurship skills equip them with the adaptability and problem-solving abilities required for success in modern economies. In addition, critical thinking is as important as entrepreneurship skills in the case of students preparing to tackle both complicated challenges and issues in the business world [3].

Based on the uncertainty and complexity of the current business world, the researcher has summarized and adopted six core competencies of entrepreneurial skills for Chinese college students from [3, 13, 15]. They are respectively as follows: First, innovation and creativity refer to the competency that enables students to generate innovative solutions and differentiate themselves in

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competitive markets; second, opportunity recognition refers to the competence that identifies business opportunities from customer and societal needs; third, financial planning and risk management refer to the competency of identifying and evaluating potential risks, while setting reasonable and feasible financial goals, and creating clear budgets for their entrepreneurial projects; fourth, strategic thinking and execution refer to the competency that allows students to translate visionary ideas into actionable plans, optimize resources, and achieve measurable outcomes; fifth, communication and presentation refer to the competency that enables students to build collaboration across teams, persuade stakeholders, negotiate effectively, and build relationships that drive success; sixth, leadership and collaboration refer to the competency that empowers students to inspire teams, resolve conflicts, and integrate diverse perspectives for their entrepreneurial activities. Together, these interrelated competencies form a comprehensive set of entrepreneurial skills to equip Chinese college students to be innovative, adaptable, and impactful entrepreneurs in the 21st century.

3.3. Critical Thinking

Critical thinking helps aspiring entrepreneurs navigate uncertainty, adapt to change, and make informed, effective choices for their ventures [16]. In entrepreneurship education, critical thinking equips students with the skills to interpret multifaceted issues in their academic business projects that are meant to solve real-world challenges [17]. It also enhances students' abilities to analyze solutions from multiple perspectives to ensure the responses are not only effective but also contextually appropriate to current societal needs. Furthermore, critical thinking fosters adaptability that enables students to apply theoretical knowledge flexibly in dynamic scenarios. As modern career paths demand individuals who can evaluate outcomes and reflect on results, critical thinking helps students conclude and justify their decisions with evidence [18]. In the context of China's shift toward innovation-driven development and global integration, mastering these dimensions of critical thinking allows students to transition from passive learners to proactive problem-solvers capable of contributing to interdisciplinary success and societal progress.

The researcher summarized critical thinking as a holistic process consisting of five interrelated components that build upon one another to foster deeper intellectual engagement and problem-solving ability. The process, adopted with Peschl et al. [16] and Molokhina et al. [17], begins with interpreting problems, where students must grasp the complexity of an issue, identify its root causes, and situate it within a broader context. This ability poses challenges in China's traditionally structured and answer-focused education system. Second, analyzing solutions, once students thoroughly understand a problem, they advance to break down potential responses, assess their feasibility, and compare underlying mechanisms. This step encourages moving beyond routine models towards more original and multidimensional thinking. Third, applying gained solutions requires students to transfer theoretical knowledge or previously learned solutions into unfamiliar or practical situations, thereby narrowing the prevalent "knowing-doing gap." Fourth, evaluating the gained solutions involves students exercising independent judgment, critiquing outcomes, and making necessary refinements, addressing limitations that arise from authority-centered classrooms and limited opportunities for self-assessment. Fifth, concluding with supportive evidence, the critical thinking process culminates in the ability to synthesize findings, justify reasoning with credible sources, and communicate conclusions logically. When these components are developed and integrated as a seamless process, Chinese college students are far better equipped to address academic, professional, and societal challenges with depth, flexibility, and rigor.

4. Research Method

Two-group posttest-only experimental design has been used to implement the PhBLPA Model to evaluate its effectiveness on entrepreneurship skills and critical thinking in comparison with traditional methods.

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4.1. Participants of the Experiment

The participants of the experiment in this study have been selected from second-year students in the Bachelor of International Trade program at Shanxi University of Finance and Economics (SXUFE). The population consisted of four second-year classes enrolled in entrepreneurship education courses in 2025. The participants comprised two groups: an experimental group (taught with the PhBLPA model) and a control group (taught with traditional learning methods). Each group consisted of 40 students, totaling 80 students. The researcher used cluster random sampling to select the experimental and control groups. First, the researcher randomly selected two classes out of the four classes. Second, the researcher randomly selected one of these two classes to be the experimental group, with the remaining class serving as the control group.

4.2. Research Instruments

Critical thinking was measured through a questionnaire with five Likert scale points (strongly disagree 1 to strongly agree 5) adopted from Peschl et al. [16] and Molokhina et al. [17] to assess students' critical thinking during their entrepreneurship project planning. This questionnaire covers five dimensions: 1) interpreting problems; 2) analyzing solutions to problems; 3) applying gained solutions; 4) evaluating the gained solutions; and 5) concluding with supportive evidence. Each dimension has three items, totaling 15 items. The Items Objective Convergence (IOC) test was conducted with five experts from related fields to measure the content validity of the questionnaire. The IOC values of the 15 items ranged from 0.8 to 1.0, which is greater than 0.5, indicating high validity in terms of item content. Furthermore, the Cronbach's alpha test was used to assess the reliability of the questionnaire. The alpha values for each dimension ranged from 0.83 to 0.89, which are greater than 0.7, suggesting that the questionnaire has good internal consistency.

Entrepreneurial skills were tested by an entrepreneurship project business plan adopted from the Shanxi University of Finance and Economics, Faculty of Entrepreneurship Education. It covers 12 components respectively: project title, executive summary, problem statement, solution, market analysis, business model, marketing and sales strategy, operational plan, financial plan, risk analysis, and conclusion. Furthermore, the researcher also designed a rubric for entrepreneurship skills based on six dimensions of entrepreneurship: 1) innovation and creativity, 2) opportunity recognition, 3) financial planning and risk management, 4) strategic thinking and execution, 5) communication and presentation, 6) leadership and collaboration, from Ratten and Usmanij [3], Akhmetshin et al. [13] and Jardim [15] to measure the entrepreneurial skills based on students' entrepreneurship project business plan. This rubric contained 5 levels of score (1-5) and was used by students in conducting peer assessments for their peers' entrepreneurship project planning in week 6. Furthermore, the teacher also used it to evaluate students' final presentation of the entrepreneurship project planning in week 7 of the experiment. Inter-rater reliability was conducted, and the Cohen's kappa value was 0.75, suggesting good consistency of the entrepreneurial skill rubric in terms of rating.

4.3. Data Collection

The Experimental Group consisted of 40 students. The experimental group used the PhBLPA model, as shown in the literature review section above, in the learning process. The control group also consisted of 40 students but was taught with a traditional teaching method, where the teacher takes the lead and controls the overall learning process. Students follow the teacher's lead in the onsite classroom and passively receive knowledge from the teacher's explanations. The experiment lasted for 8 weeks, with 3 hours per week. In the final week, both groups of students attended posttests: presenting an entrepreneurship business project plan and filling out a questionnaire on critical thinking to measure students' entrepreneurship skills and critical thinking, respectively. The following figures show the activities in the experiment.

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Figure 3.
Student Doing Presentation.

Figure 4.
Student Using Kimi AI.

4.4. Data Analysis

Multivariate Analysis of Variance (MANOVA) is a statistical technique that evaluates whether there are significant differences in the means of multiple dependent variables across different groups, allowing researchers to analyze the effects of one or more independent variables simultaneously with the assumptions of normal distribution of the dependent variables and homogeneity of variance-covariance as the preliminary agreement [19]. In this study, the researcher used the MANOVA method to analyze the obtained data on entrepreneurship skills and critical thinking from both the experimental group and the control group, to determine the effectiveness of the PhBLPA model on entrepreneurship skills and critical thinking in comparison to the traditional method.

5. Results

The following table displays the results of the normality tests for the posttest data of critical thinking (CT) and entrepreneurial skills (ES) across both the experimental and control groups. The Shapiro-Wilk test produced p-values of 0.237 for CT in the experimental group, 0.053 for CT in the control group, 0.109 for ES in the experimental group, and 0.425 for ES in the control group. As all four p-values exceeded 0.05 ($P > 0.05$), the results indicate that the posttest data for both CT and ES in the experimental and control groups are normally distributed. Therefore, the assumption of normality was satisfied, providing a sound basis for subsequent parametric analyses.

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Table 1.
Results of Normality Test.

Variable	Group	Shapiro-Wilk		
		Statistic	df	P
CT	Experimental Group	0.964	40	0.237
	Control Group	0.946	40	0.053
ES	Experimental Group	0.955	40	0.109
	Control Group	0.972	40	0.425

The homogeneity of variance-covariance was assessed using Box's test. Table 2 showed that Box's M statistic was 9.657, F (3,130), P (0.025); the significance level was P > 0.001, indicating that the assumption of equality of covariance matrices was not violated, aligning with the preliminary agreement of MANOVA. Additionally, the correlation analysis between CT and ES produced a Pearson correlation coefficient of 0.816, with a significance level of P < 0.001. This positive correlation demonstrates a significant relationship between the two variables.

Table 2.
Posttest Results of the Assumption Test of MANOVA.

Variable	Box's Test of Equality of Covariance					Correlations	
LA & LM	Box's M	F	df 1	df 2	P	Pearson Correlations	P
	9.657	3.130	3	1095120.000	0.025	0.816	<0.001

Table 3 presents the results of the multivariate analysis conducted on the posttest scores for critical thinking (CT) and entrepreneurial skills (ES). The multivariate tests demonstrated that the group factor had a significant effect on both CT and ES, indicating notable differences in the posttest scores between the two groups. These results suggest that different instructional methods as interventions may have contributed to the observed variations in students' critical thinking and entrepreneurial skills.

Table 3.
Results of Multivariate Test.

	Effect	Value	F	P
Group	Pillai's Trace	0.951	744.303[b]	<0.001
	Wilks' Lambda	0.049	744.303[b]	<0.001
	Hotelling's Trace	19.333	744.303[b]	<0.001
	Roy's Largest Root	19.333	744.303[b]	<0.001

Table 4 illustrates that the experimental group (EG) achieved a mean score of 4.43 (SD = 0.12), while the control group (CG) attained a mean of 3.60 (SD = 0.18). The MANOVA test demonstrated a significant effect of group on critical thinking (CT) (F = 1329.944, P < 0.001), with the experimental group outperforming the control group. These results support the research hypothesis: RH1, which states that students who study the PhBLPA model have higher entrepreneurial skills than those who study with traditional learning methods. Similar findings emerged for entrepreneurial skills (ES), with the experimental group reporting a mean ES score of 4.36 (SD = 0.23), compared to 3.53 (SD = 0.31) in the control group. MANOVA results indicated a significant impact of the intervention on ES (F = 185.181, P < 0.001), with the experimental group achieving significantly higher ES scores than the control group. Therefore, the results also support the research hypothesis: RH2, which states that students who study the PhBLPA model have higher critical thinking than those who study with traditional learning methods.

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Table 4.
Results of the MANOVA on Posttest.

Descriptive statistics					MANOVA					Result
DV	**G**	**n**	**X**	**SD**	SS	MS	F	df	P	
CT	EG	40	4.43	0.12	13.555	13.555	1329.944	1	<0.001	EG>CG
	CG	40	3.60	0.18						
ES	EG	40	4.36	0.23	14.162	14.162	185.181	1	<0.001	EG>CG
	CG	40	3.52	0.31						

6. Discussion

6.1. Entrepreneurial Skills

The results from this research provided strong empirical evidence that the design and iterative activities inherent to the PhBLPA model foster deeper and more transferable entrepreneurial competencies. Unlike traditional methods, which often emphasize abstract knowledge, decontextualized lectures, and passive reception, the PhBLPA model immerses students in the dynamic, uncertain conditions that mirror real-world entrepreneurship. This fundamental shift is seen from the outset with Step 1: identifying phenomena and goal setting. Here, students participate in authentic problem finding, a process identified by Yanti et al. [4] as central to the development of both entrepreneurial alertness and opportunity recognition. This early engagement requires students to draw from multiple personal and disciplinary perspectives, increasing the likelihood that they develop genuinely creative and opportunity-centered entrepreneurial thinking [20].

In Steps 2 and 3, which emphasize collaborative process design and peer assessment training, students are required to articulate their plans and test their comprehension of assessment standards publicly and collaboratively. This public articulation, as noted by Rodrigues [21], boosts entrepreneurial self-efficacy, and strategic planning is a skill set traditionally underdeveloped in lecture-based courses. Furthermore, the scaffolding provided by iterative peer evaluation aligns closely with Kytle's [10] social learning theory, which identifies observation, imitation, and modeling as crucial for acquiring complex skills such as leadership, risk-taking, and effective communication.

The core learning occurs in Steps 4–6: collaborative inquiry, structured peer assessment, and iterative revision. These phases operationalize "learning-by-doing," which has repeatedly been demonstrated to lead to both higher entrepreneurial intention and actual venture creation rates. Iterative peer review enhances social capital and mutual accountability within and across teams, while providing repeated exposure to diverse business concepts and execution strategies to accelerate the acquisition of both hard and soft entrepreneurial skills. The final presentation and reflection phases (Steps 7 and 8) simulate the entrepreneurial process of pitching to stakeholders and reflecting on outcomes, both successful and otherwise. These authentic activities support findings by Pisoni et al. [22] who emphasize the necessity of experiential, reflective learning cycles for consolidating entrepreneurial identity, resilience, and growth mindset.

Importantly, this study also found that the deployment of generative AI tools such as Kimi AI throughout the PhBLPA process was useful in extending entrepreneurial skills in forming entrepreneurial solutions. These findings were aligned with the research of Dwivedi [23], who claimed that the use of AI-driven platforms accelerates ideational fluency and market analysis skills among business students. Similarly, Ratniyom et al. [12] emphasized that there was a positive impact of technology-mediated inquiry on entrepreneurial intention and creative thinking.

6.2. Critical Thinking

In a similar vein, the effectiveness of the PhBLPA model in promoting critical thinking is also reflected in the large effect size of the experimental group. According to previous research, critical thinking in traditional methods is usually limited to specific assessment tasks, whereas critical thinking is widely embedded in each phase of the project learning cycle by the PhBLPA model. Interpreting phenomena in Step 1, as situated ambiguity supported by Tsai and Lin [24], encourages students to

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build analysis and decision-making in an ambiguous context. Hasanah and Malik [25] defined multimodal literacy as the students' need to routinely encounter and analyze various information sources in Step 4 of deep inquiry and data gathering. The focus of evaluation in Step 5 and revision in Step 6 of peers' work is almost identical to the following international research findings.

Pisoni et al. [22] found that assessment by peers is particularly powerful for developing evaluative judgment and self-regulation, two key elements of critical thinking. In addition, the repeated dialogue among peers and justifications required in evaluation (Step 5) also prompt students not only to stand for their solutions but also to listen to and respond to other peers' alternative views. This finding is consistent with the research on peer-led argumentation that improves students' reasoning over time [26]. The mandatory final reflections in Step 8 of the PhBLPA model reinforce the habit of concluding based on evidence. Darvishi et al. [27] also found that frequent metacognitive reflection leads to long-lasting critical thinking dispositions in students.

It is not worth mentioning that the stepwise design and technological integration have added value to the learning brought by generative AI throughout the learning cycle. In agreement with Ratniyom et al. [12], an enriched learning environment provides instant feedback and various information streams, which are essential for the development of critical analysis and decision-making in digital-age learners. Cui et al. [28] also found that university students benefited from AI-supported critical dialogue, which enhanced their ability to evaluate and synthesize evidence.

In summary, the stepwise design and technological integration of the PhBLPA model are consistent with the international research consensus that immersed peer-mediated and tech-augmented instruction lead to optimal learning outcomes in both entrepreneurial skills and critical thinking.

7. Conclusion

This study systematically integrated Phenomenon-Based Learning, Peer assessment, and generative AI into the PhBLPA model for entrepreneurship education, leading students to gains in entrepreneurial skills and critical thinking in the learning process. Under the PhBLPA model, students were enabled to engage in collaborative, real-world problem-solving supported by structured peer assessment and generative AI. In addition, the findings of this study have identified the significant effectiveness of the PhBLPA model in strengthening students' entrepreneurial skills and critical thinking. The positive outcomes of this study demonstrated the effectiveness of combining active inquiry, peer-sourced feedback, and AI integration to prepare students for the intricate demands of entrepreneurial practice and prudent decision-making in dynamic contexts. It also assumes that the PhBLPA model is more effective than traditional teaching methods in cultivating entrepreneurs for the 21st century.

8. Limitations

Despite its significant findings, this study is subject to several limitations that may affect the generalizability and interpretation of its results.

1. The sample for this study was obtained from only one institution, which might affect the validity of the results when applied to other institutions.
2. The sample size of this study was relatively small, with only 80 students in total, which might affect the confidence in the robustness and reproducibility of the findings.
3. The duration of this study was relatively short, with only 8 weeks, and may not capture the long-term effectiveness of the PhBLPA model in enhancing both entrepreneurial skills and critical thinking.

9. Suggestions

9.1. Suggestions for Applying Research Results

1. Educators should be trained in both the facilitation of phenomenon-based learning environments and the integration of AI-powered resources, ensuring they can effectively support and guide

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students through the model's dynamic processes.
2. Selecting and adopting user-friendly generative AI platforms in classroom activities can personalize learning, provide rapid feedback, and give students broader access to information, ultimately enhancing both skill development and critical thinking.
3. Educators should develop clear rubrics and protocols for peer assessment to ensure constructive feedback and continuous improvement, closely aligning with the real-world entrepreneurial and analytical skills required in the workplace.

9.2. Suggestions for Future Research

1. Assessing how students with different backgrounds, learning preferences, and prior experience interact with and benefit from the PhBLPA model to inform further customization and equitable teaching strategies.
2. Trying different generative AI tools in the PhBLPA model to find which AI tools are more suitable for students in the learning process. For Chinese students, other generative AI tools such as Deep Seek, Doubao, etc., are recommended. For international students, ChatGPT, Grok, Gemini, etc., are recommended.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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Appendix

Appendix A.
Questionnaire of Critical Thinking.
Dear students, please recall the process of working on the business project in class and fill out the following questionnaire, according to the agreement level: Strongly disagree (1); Disagree (2); Neutral (3); Agree (4); Strongly agree (5).

Dimension	**Items/when I worked on the business project…..…..**	**1**	**2**	**3**	**4**	**5**
Interpreting problems	I have mapped the information based on the problems					
	I have determined the known and the unknown					
	I have identified similarity and dissimilarity patterns					
Analyzing the solution to the problem	I reviewed the information					
	I have correlated the information gained with solving concepts and strategies.					
	I have found relevant evidence to find a solution					
Applying the gained solution	I have described or illustrated problems through exemplifying or modeling.					
	I have applied the solution and used gained strategies to solve the problems					
	I have carefully and systematically worked on the business projects					
Evaluating the gained solution	I have rechecked each solving step					
	I have reviewed and identified information					
	I have verified the referential and supportive evidence					
Concluding with supportive evidence	I have created the right conclusion					
	I have attached supportive evidence					
	I have explained logical reasons					

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