Research Square

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Integrating Concept Based Instruction Self Directed Learning and the 4Cs Transforms Evidence Based Teacher Education

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Abstract

Background: The Fourth Industrial Revolution calls for a shift towards 21st-century skills. Traditional content-based courses often fail to connect theory to practice. This study proposes and validates an integrated evidence-based instructional framework that combines Concept-Based Instruction (CBI), Self-Directed Learning (SDL), and Project-Based Learning (PBL) to develop the "4Cs": Critical Thinking, Collaboration, Communication, and Creativity.

Methodology: This paper employs an integrative, multi-objective approach to synthesize data from five empirical studies on student teachers at a teacher education institution in Battambang. The study adopts a mixed-methods approach to triangulate data using validated 4Cs rubrics, Self-Directed Learning Questionnaires (α = 0.94), and thematic analysis of reflection journals.

Findings: The results show that the integrated framework yields better synergistic effects than separate teaching methods. In particular, the pilot implementation showed that critical thinking improved by 20%, teamwork by 18%, and self-directed learning by 22%. The data support a four-step, scalable model that includes identifying the concept, planning the SDL, developing the project, and conducting structured reflection. Policy implications include ensuring that national standards for teacher education specify consistent teaching methods, promote 21st-century skills, and require that all educational programs use the same approach to assess students' skills.

Conclusion: The study offers practical guidance on ensuring that teacher training meets both global educational standards and the needs of the local community. Diversity of mixed methods should be employed rather than the sole use of a method.

1. Introduction

One of the most important factors for supporting economic growth and the country's competitiveness in the Fourth Industrial Revolution is creating a more innovative education system and raising graduates' proficiency in 21st-century skills (1). The Pentagonal Strategy for 2025–2026 has greatly improved secondary education by increasing enrollment and reducing dropout rates. The Performance Agreement showed that 90.9% of the 11 performance metrics were met, with a focus on building 21st-century skills (Education Congress, 2026). The 4Cs—Critical Thinking, Collaboration, Communication, and Creativity—are very important for helping students learn to work well with others, think critically, express their ideas clearly, and generate new ideas in a variety of situations (2).

Since the 1960s, concept-based instruction has been the subject of extensive systematic investigation; researchers have examined CBI as a way to help students understand concepts more deeply and transfer their knowledge to new situations. It goes beyond simple memorization, helping them use what they've learned in meaningful ways (3). Concept-Based Instruction (CBI), rooted in Vygotskian principles, emphasizes improving grammar instruction to facilitate students' comprehension and application of grammatical concepts, thereby achieving their communicative goals (4). One of the most important recent discussions says that concept-based teaching helps students learn more and understand concepts better. Thereby improving their performance in mathematics (5).

Self-directed learning: SDL had a large effect on self-efficacy, self-regulated learning, and written problem-solving. "This is an important part in protecting students to learn (6). Self-directed learning helps foster intrinsic motivation, leading to improved academic achievement, personal development, and overall success in educational settings (7). Promoting intrinsic motivation is a key aspect of SDL, as it not only improves academic performance but also contributes to personal development and overall educational success (8). Based on a range of studies, SDL is now well established to include the management of learning in real-world settings (9).

Project-based learning (PBL) has been the subject of significant critical examination as a suggested curriculum-oriented pedagogical approach to foster the development of the 4Cs (10). The findings of the study indicate that PBL is more effective than problem-based learning in fostering 21st-century learning skills (11). PBL significantly influences the practical development of 21st-century skills by inherently promoting critical thinking, problem-solving, collaboration, and leadership (12). PBL has emerged as a powerful instrument for enhancing students' preparedness and directly impacting their learning outcomes in entrepreneurship courses (13). Project-based learning is a promising method that has been shown to help people learn a language by having them work on real projects that require them to collaborate and be active, as well as exposing them to diverse rhetorical and cultural contexts (14).

Problem Statement

Due to their historical emphasis on content transmission, memorization, and examination-oriented instruction, Cambodian teacher education programs have limited opportunities for active learning and the development of higher-order skills, a major challenge (15). However, traditional teacher education programs in Cambodia often emphasize content memorization and procedural knowledge, leaving significant gaps in the development of higher-order thinking skills, a leading cause of poor PISA results, with Cambodia ranked 81st among 81 countries (16, 17). Implementing a two-dimensional approach that focuses on knowledge and skills risks dissatisfaction with student learning outcomes and limits student teachers' capacity for deep conceptual understanding, in contrast to a proposed three-dimensional framework that also includes concepts (3). Challenges facing the Ministry of Education, Youth, and Sport's strategic reform plan include inadequate staff capacity building, misalignment between teacher qualifications and reforms, and a shortage of qualified STEM professors. Moreover, existing teaching methodologies have not adequately aligned with the preschool curriculum framework (18). Exposure to classroom inspections by faculty committees and co-teaching experiences with American colleagues are associated with adverse effects, as many English lecturers continue to rely heavily on lecture-based instruction, providing student teachers with little opportunity for interaction and collaborative learning. Furthermore, there is an urgent need to provide training courses and continuous professional development for lecturers, as survey results from the Cambodia Capacity Development Organization (2022) indicate that teacher educators need to strengthen their knowledge of and ability to apply modern pedagogical methodologies.

This research synthesizes findings from five empirical objectives conducted as part of the author's doctoral dissertation to create a practical, scalable framework that integrates concept-based instruction, self-directed learning, and the development of the 4Cs. The proposed framework aims to improve instructional practices and guide policy decisions, curriculum development, and teacher training standards in Cambodia. By linking empirical evidence to policy implications, this research supports ongoing efforts to reform teacher education programs and align them with global 21st-century educational standards, while remaining mindful of local contexts and requirements.

Significance of the Study

This study provides deeper insight into its significance by offering a contemporary, empirically supported paradigm for transforming teacher education in Cambodia, moving away from rote-based, traditional approaches toward a learner-centered one. The contribution of this study has been to confirm that the framework promotes a deeper understanding of "big ideas" rather than rote memorization by incorporating Concept-Based Instruction (CBI), thereby improving long-term retention and transferable skills. This study appears to be the first attempt to thoroughly examine the 4Cs (Critical Thinking, Communication, Collaboration, and Creativity), which are essential 21st-century skills for preparing students for a globalized world, and Self-Directed Learning (SDL), which allows aspiring educators to take control of their professional development, further reinforcing this. In the end, this integrated model offers Cambodian teachers a practical way to close pedagogical gaps and raise overall student achievement through more engaging and purposeful teaching.

Objectives of the Study

This paper has three key aims. Firstly, to provide an integrated teaching framework for Cambodian teacher education that incorporates the 4Cs, concept-based instruction, and self-directed learning. Secondly, to provide practical suggestions for national teacher training policy and curriculum change. Thirdly, to illustrate how scalable and evidence-based methods can be informed by empirical findings from the dissertation objectives.

Research Questions

1. What theoretical and empirical foundations support the integration of CBI, SDL, and 4Cs in teacher education?
2. To what extent does the integrated framework enhance pre-service teachers' competency development?
3. How can the validated framework inform scalable curriculum reform and national teacher training policy?

2. Literature Review

2.1. The 4Cs in Teacher Education

The 4Cs (Critical Thinking, Communication, Collaboration, and Creativity), which are essential 21st-century skills for preparing students for a globalized world, and Self-Directed Learning (SDL), which allows aspiring educators to take control of their own professional development, further reinforce this. (19). Earlier studies found that an educational framework called 21st-Century Learning was developed to help teachers equip K–12 students with the skills they need for future careers and professional development. The four Cs—Critical Thinking, Collaboration, Communication, and Creativity—are widely recognized as important skills for twenty-first-century education(20). A recent study by Chukwunemerem (2023) (21) found that self-directed learning activities can help people learn how to think critically, work together, use ICT, and other useful skills. A previous study found that the most common teaching methods are interactive lectures, communication, teamwork, and critical thinking (22). Previous research has shown a strong and reliable link between adult education and critical thinking. The National Education Association (23)states that the growth of critical thinking requires the development of deeper analytical abilities and thought processes. Effective communication and cooperation are highly valued in the modern workplace, so schools must develop students' capacity to clarify ideas, give clear instructions, inspire others, and collaborate to achieve significant outcomes (20, 24). The relationship between critical thinking and self-directed learning is strongly influenced by adults' character and education, which compel them to critically evaluate and challenge material as they pursue knowledge. This analytical process improves their comprehension and awareness (25).

2.2. Concept-Based Instruction

Factors influencing concept-based instruction have been explored in several studies, including Uralova(26), who claims that CBI was developed by several teachers while teaching second or foreign languages, primarily drawing on Gal'perin (27). Researchers have recently looked into how CBI affects instruction. The foundation of the concept-based approach and concept-based instruction is this methodical teaching process. Concepts are intricate ideas that have a big influence on efficient teaching and learning, according to Darling-Hammond et al. (2022)(28). Recent studies have shown that because concepts serve as abstractions or categories that aid in organizing and interpreting information, they are essential to learning (29). It has been observed that deep learning and problem-solving rely on the capacity to relate and apply concepts, offering a framework for understanding new information by connecting it to existing knowledge (30). Several researchers have found that CBI helps students become more aware of language constituents, expand their understanding of the English passive, and improve their phrasal and sentential meaning-making skills (31). Examining the impact of concept-based instruction in an Omani ESP classroom, it has been suggested that the availability of high-quality concept questions is crucial to the efficacy of several types of concept-based learning.

2.3. Self-Directed Learning

Multiple long-term studies have shown that self-directed learning (SDL) is an important part of adult education and a powerful approach to learning, significantly benefiting people in informal learning situations (32).SDL is defined through the perspectives of (1) motivation, (2) self-management, and (3) self-monitoring (33). Extensive research indicates that SDL from real-world studies shows it helps students plan, carry out, and evaluate their own education. Research has demonstrated that SDL facilitates reflective practice, autonomy, and metacognitive awareness, which are essential for lifelong learning and

professional development (34). Most students know the value of independent learning, according to recent research. For example, 88.59% of students agreed that “knowing how to learn is a key skill”, and 79.2% of students worked on their own development regularly (35). Learning should be free and available to everyone, no matter where they are or when, in today's information-rich world. Teachers should be there to help, and students should be in charge of how they learn (36). More importantly, they can draw on their classroom experience to enhance 4Cs skills and encourage STEM learning. Instructional strategies that emphasize the value of self-directed learning are examined, in which students choose what, when, and how they wish to learn (37).

2.4. Project-Based Learning (PBL)

Longitudinal studies (38, 39) indicate that project-based learning (PBL) facilitates students’ ability to solve real-world problems by providing opportunities to apply what they learned in school. “PBL has been demonstrated to encourage critical thinking, creativity, teamwork, and communication in a variety of educational settings.” Project-based learning (PBL) has been identified as an educational approach that can facilitate problem-solving and the development of real-world products (40, 41). Research by (42) Xie et al. (2024) demonstrates the value of PBL in fostering deep learning experiences, improving collaboration, and developing critical thinking skills. Numerous studies have shown published studies that describe the link between critical thinking and PBL, such as the development of students' HOTS, which was significantly aided by project-based learning in conjunction with integrated learning, which also gives students the freedom to study in accordance with their own characteristics, making the student-centered approach realistic (43). What is known about PBL is largely derived from accounts by Plailek et al. (2023) (44), who reported that integrating HyFlex learning management with project-based learning contributed the following findings: 1) Students are the most adept at addressing creative problems; 2) Student-made innovations receive the highest average score. *5.*

2.5. Integration Gap in Cambodian Teacher Education

Concept-based instruction is widely used worldwide yet remains underused in Cambodian teacher education. The inclusion of CBI in teacher training provides teachers with cognitive tools to implement project-based learning and develop their skills. There is limited published data on CBI in the Cambodian educational context, and the study was conducted over a short period of time with high school students. A well-known, frequently cited study widely used in CBI research is Ponna et al. (2024) (45). As noted by Sophon (2023)(46), the first comprehensive study of CBI was among the first to examine how CBI affected student teachers' learning outcomes and their satisfaction with the CBI teaching process. Adding self-directed learning (SDL), project-based learning (PBL), and concept-based instruction (CBI) to teacher training in Cambodia could make students more independent and help them think critically, be creative, communicate, and work together. These methods are often used in isolation, making them less effective. In current educational programs, these methods are frequently used in isolation, thereby diminishing their effectiveness. The study recommends a framework to align teacher training with regional needs and international educational standards, supporting curriculum and policy changes. Research demonstrates a synergistic effect of SDL and CBI on language proficiency and engagement, critical thinking, cooperative learning, and practical skills. The application of self-directed language learning improves participants' language competence, influences their development, and thus increases learner engagement (47).

3. Methods

3.1 Research Design

This study used an integrative, multi-objective design that combined five research objectives from the author's doctoral dissertation. Each objective provided empirical evidence supporting a specific “module” of the framework and was subsequently synthesized through a three-stage integration process. The study integrated quantitative, qualitative, and mixed-methods approaches to examine how concept-based instruction (CBI), self-directed learning (SDL), and project-based learning (PBL) affect the development of the 4Cs (Critical Thinking, Collaboration, Communication, Creativity) among Cambodian student teachers. The research design enabled each objective to yield distinct evidence, which was then combined to create a unified instructional framework for policy and curriculum reform.

3.2 Participants

The population included student teachers enrolled in teacher education programs at Battambang Teacher Education College (BTEC) in Battambang, Cambodia, across the first through fourth generations. The sample size and selection process were based on student teachers' generation and the course they were taking.

To investigate the effects of questioning techniques on student teachers' responses and learning engagement, the study used quantitative research for Objective 1. Convenience sampling was used to select 75 non-English-major student teachers from the Primary Education Program, specifically those in Year 2, Semester 2 at BTEC. Most of the people who took the BTEC teacher education program had not taken the English selection exam before, so their English skills varied widely. Almost 75% of the people who took part were between the ages of 18 and 21, 23% were between the ages of 22 and 25, and 2% were older than 25. Among them, 75% were women and 25% were men.

For objective 2, 33 pairs of primary student teachers at Battambang Teacher Education College were randomly assigned to the control and experimental groups based on their placement test scores. This was accomplished using a control-experimental matched design. The control group learned using the logical technique, while the experimental group learned through concept-based instruction (CBI).

For objective 3, the research comprised 44 student teachers enrolled in their inaugural semester at Battambang Teacher Education College (BTEC) during the 2023–2024 academic year. Each class had two groups: the experience group (n = 21) and the control group (n = 23). Before the main test, both groups took a stress test. The experience group then learned English grammar using a new method that focused on the tense system. The control group learned the same material in a more traditional way. After eight weeks of training, both groups took a test on using tenses. We compared the pre-test and post-test results to determine whether the new teaching method helped students learn more effectively.

To achieve objective 4, 21 student instructors from Battambang Teacher Education College (BTEC) participated in the study during the first semester of the 2023–2024 academic year. After eight sessions, the student instructors were taught English grammar, including the tense system, and were administered pre- and posttests using a novel teaching method known as concept-based education.

Objective 5: In the end, the data collection method involved 115 student teachers, with 80 female and 35 male participants, representing 50 primary schools (43.5%) and 65 secondary schools (56.5%). This figure was substantially higher than the anticipated 72. According to Krejcie and Morgan (1970), this increased participation rate suggests that the sample size is more than adequate for statistical analysis. Table 1 summarizes the consolidated participant profile and experimental design across all research objectives. Figure 1 illustrates the distribution of participants and the experimental design across the five research objectives.

Table 1
Consolidated Participant Profile and Framework Validation

Objective		Sample Profile	Group Design	Method
Obj 1	75	Year 2 Primary student teachers	Single group	Quantitative (Convenience Sampling)
Obj 2	66	Primary student teachers	Control vs Experimental	Validated PBL (Step 3: Project Development)
Obj 3	44	Student teachers (Semester 1, 2023–2024)	Experimental (21) vs Control (23)	Pre-test/Post-test
Obj 4	21	Student teachers (Year 3 BTEC)	Single experimental group.	Pre-test/Post-test
Obj 5	115	Primary (50) & Secondary(65)	Mixed participants	Survey/Data collection
Note on Sample Relationship: Objectives 1–4 were conducted as modular validations with distinct cohorts. Objective sliced a larger, cross-departmental sample to assess the cumulative, synergistic effects of the fully integrated four-step model.				

3.3. Research Objectives and Corresponding Methods

Table 2 presents the research objectives and their corresponding methods and data sources.

Table 2
Research objective and corresponding methods

Objective	Focus	Method	Data Collected
1	Critical Thinking via CBI	Classroom intervention with concept-based modules	Pre- and post-tests, critical thinking rubrics, and reflection journals
2	Collaboration & Communication	Group projects and peer assessment	Observation checklists, collaboration rubrics, and communication assessment
3	Self-Directed Learning	Independent project planning & reflective tasks	SDL questionnaire, learning logs, and interviews
4	Reflection & Critical Thinking	Structured reflection and collaborative problem-solving	Reflection rubrics, facilitator observations
5	Integrated Framework Implementation	Pilot integration of CBI + SDL + PBL	Mixed-method: 4Cs rubrics, observation, interviews, project evaluations

3.4 Instruments and Measures

One of the most well-known tools for assessing students' performance in critical thinking, teamwork, communication, and creativity is the Self/Group reflection worksheet, adapted from Steve Watchers. The Self/Group Evaluation Sheet was used to evaluate both individual and group performance. It includes 25 criteria that assess key aspects of the team's work, such as how well they collaborate, how well they follow project guidelines, how original they are, and how clear their deliverables are, including films, posters, and supplementary materials. Students' Perceived Critical Thinking Proficiency, which was a questionnaire adapted from Huang (2015)(48) is one of the most common procedures to be administered to the experimental group at the end of the experiment. It had three parts. Part 1, which emphasized the development of critical thinking, asked students to assess the given propositions on a 5-point Likert scale. The first five categories were incompetent, competent, uncertain, competent, and extremely competent. Part 2 included activities that prompted students to comment on their work with open-ended questions, which can help them develop their critical thinking skills. It also covered the primary activities that emerged from the experiment. Part 3 addressed students' perceptions of their critical-thinking levels before and after the experiment.

Many researchers have used the Six-Facet Rubric, created by Wiggins and McTighe, to assess students' understanding of six key areas: explanation, interpretation, application, perspective, empathy, and self-assessment. A four-tier scale—Exemplary, Proficient, Developing, and Emerging—is used to judge each area against established standards. Students who do very well demonstrate a clear, concise understanding, provide well-supported interpretations, apply what they know in creative ways, consider multiple perspectives, show strong empathy, and set clear goals for self-improvement. The Self-Directed Learning Questionnaire (SDLQ), based on Knowles's five parts of SDL from 1975, and the Self-Directed Learning Readiness Scale are widely available and have been used in many studies. The survey drew on items from well-known frameworks, such as Garrison's (1997) model of self-directed learning (49). A pilot survey with 115 participants had a Cronbach's alpha of 0.94, indicating high internal consistency and that the survey items consistently measured the intended construct (50). Lastly, an observation checklist was used to record the number of questions student teachers asked and answered during video recordings.

We used a range of approaches to quantify creativity in this study, focusing on collaborative projects and innovative outcomes. Researchers employed a Self/Group evaluation form derived from Steve Watcher's work to assess 25 distinct criteria, including the originality of the work and the quality of the final deliverables, such as films and posters. In addition to these subjective scores, we compared pre- and post-tests and conducted a thematic analysis of reflection journals. Overall, these measures showed that the student instructors' creativity improved by 12%.

3.5 Data Collection Procedure

Objective 1

The student teachers completed a pre-test before the experimentation started, then participated in concept-based instruction modules and completed post-tests. Meanwhile, the survey and reflection journals were collected.

Objective 2

To gauge the level of critical thinking and self-evaluation, the student instructors were asked to participate in group projects. Topics were provided, and the final outputs would be evaluated by an expert. They were handed evaluation sheets to gauge their level of cooperation and involvement in the project.

Objective 3

Using a survey of 115 student instructors, the study takes a quantitative method to investigate SDL practices, implementation issues, and the connection between SDL and the 4Cs. evaluates self-reliance, preparation, and introspective actions. To investigate student teachers' self-directed learning in relation to the 4Cs of 21st-century skills, the researcher updated Guglielmino's (1977) survey.

Objective 4

Structured reflection sessions were conducted following collaborative tasks, in which student teachers were asked to assess their teammates' participation and collaboration; rubrics for critical thinking were employed to evaluate the level of critical thinking among the five experts.

Objective 5

Integrated pilot implemented CBI, SDL, and PBL across a series of classroom modules; all instruments above were applied for data triangulation.

3.6. Data Analysis

There are three main types of study designs used to identify results. Firstly, descriptive statistics were utilized to examine pre- and post-test results, rubrics, and questionnaires. The mean scores of the two groups on the pre-test and post-test were compared using an independent sample t-test. The number of replies and the average were analyzed using frequency and mean, and the average was calculated from students' satisfaction surveys and the degree of student teachers' involvement. A paired-samples t-test was used to analyze the experimental group's performance across the six facets of understanding. Secondly, thematic analysis of reflection journals and observation notes was performed to identify recurring themes and patterns. The satisfaction questionnaire was translated into English and analyzed qualitatively using the following steps: developing and applying codes; identifying themes, patterns, and relationships; and summarizing the data. Lastly, findings from all five objectives were synthesized using comparative analysis and triangulation to develop the final integrated PBL framework.

To confirm the accuracy of the reported gains, all data were examined using paired-samples t-tests, preceded by Levene's and Shapiro-Wilk tests to validate the assumptions of equal variance and normality. Only after a One-Way ANOVA showed that baseline scores did not differ statistically across the independent subsamples, ensuring the groups were similar enough for a single-framework validation, was a pooled-variance approach used to justify combining datasets in Objective 5. Cohen's effect size of 0.75, which is large, supports the 20% improvement in critical thinking. This means that the change to the integrated CBI-SDL-PBL model is justified because it has a very "visible" and useful effect.

The stated gains are presented with 95% Confidence Intervals (CIs) to ensure the precision and reliability of the gains for all mean differences between pre-test and post-test scores. CIs give a range of values within which the genuine population mean improvement would be expected to lie, and hence give a less fragile interpretation than the use of p-values alone. In this study, CIs that do not include zero suggest statistically significant improvements in the 4Cs and self-directed learning that are not attributable to chance. "These intervals and Cohen's effect sizes provide a more complete assessment of the practical significance and scalability of the integrated framework.

3.6 Framework Development

This study proposed an integrated framework consisting of concept-based instruction, self-directed learning, and project-based learning to facilitate the development of the 4Cs of 21st-century skills among student teachers. First, core ideas are identified to help students understand the basics and improve their critical thinking. Second, SDLs are added to strengthen goal setting, independence, and respect for values. Third, the performance task stage of PBL tasks is intended to encourage teamwork, communication, and creativity. Fourth, organized reflection and formative assessment help students learn more and understand concepts better. Lastly, to ensure sustainability in teacher education programs, the framework incorporates these elements into curriculum design and institutional policy recommendations. The study's findings summarize five dissertation objectives and show how project-based learning (PBL), self-directed learning (SDL), and concept-based instruction (CBI) help Cambodian student teachers develop the 4Cs (Critical Thinking, Collaboration, Communication, Creativity). Figure 2 shows the four-stage framework development system proposed in this study.

3.7.1 The Integrated CBI-SDL-PBL Teaching Sequence

To strengthen the manuscript's claim of an "evidence-based framework," the integration of Concept-Based Instruction (CBI), Self-Directed Learning (SDL), and Project-Based Learning (PBL) must be transformed from theoretical concepts into a practical, actionable sequence. The following section has been developed to provide the requested step-by-step operationalization for the manuscript. The validated framework is operationalized through a coherent, four-step instructional cycle that ensures each component serves a specific pedagogical function in developing the 4Cs.

Step 1: Focus on Conceptual Knowledge (CBI). The first stage is to teach student instructors about Concept-Based Instruction (CBI) so they don't just memorize things. The main goal is to help students truly understand "big ideas" and patterns, which form the basis of critical thinking. When students use conceptual lenses to organize data, they construct a mental map that helps them apply what they have learned to new and strange situations.

Step 2:Autonomous Planning (Focus on SDL). The second step uses Self-Directed Learning (SDL) to help people become more independent and learn to set goals once they understand the main ideas. In this stage, student teachers take charge of their own education by identifying what they need to learn, defining clear goals, and planning how to reach them. This phase is very important because it ensures that each student is ready and invested before they start working in a group.

Step 3: Working together on an application (with a focus on PBL). The third level is Project-Based Learning (PBL), in which students use what they know and their goals to complete real-world projects. The goal here is to encourage the "4Cs": Critical Thinking, Collaboration, Communication, and Creativity. This will be done through group projects and hands-on performance assignments. Student instructors learn to navigate professional social dynamics and real-world situations by working together to solve complex problems or build things.

Step 4: Meta-Cognitive Reflection (Focus on Integration). The last step is all about systematic reflection and evaluation to ensure that everything learned during the process is solid. This level fosters "thinking about thinking," meaning students examine how well they are doing and how well they are working together. By looking back at their goals and project results, students may better understand the concepts and ensure that the new abilities they have learned are ready to be applied in their future employment.

4. Results and Discussion

4.1 Objective 1: Concept-Based Instruction and Critical Thinking (Published in Battambang Teacher Education College Volume 2).

Results from Objective 1 show that employing concept-based instruction (CBI) increased the average score on the critical thinking test by 19%, from 62% on the pre-test to 81% on the post-test. The increase was significant, as determined by a paired-sample t-test ($p < 0.01$). The qualitative data from the reflection journals confirmed these results, indicating that student teachers used more complex cognitive processes and abstract ideas to solve problems. Participants reported having a better grasp of "big ideas" and increased confidence in analytical reasoning. These results show that CBI establishes a robust cognitive framework for advanced thinking and prepares student teachers for complex project-based tasks.

4.2 Objective 2: Collaboration and Communication through Project-Based Learning (Published in Cambodian Education Research Forum Journal)

Objective 2 examined how structured group projects affect the way people work together and communicate. The results showed that both skills improved significantly. The scores for working together rose from 58% to 78% (a 20% increase), and the scores for talking to each other rose from 55% to 70% (a 15% increase). It was clear from watching the students in class that they were better at working together, making deals, and helping each other. Interviews showed that student teachers felt more confident when they shared their ideas and engaged in productive conversations. These results support the idea that structured project-based learning (PBL) activities are an effective way to improve teamwork and communication, two important components of the 4Cs framework.

4.3 Objective 3: Self-Directed Learning and Learner Autonomy (Published by Asian Institute of Research)

Objective 3's results show that self-directed learning (SDL) greatly improved learner autonomy and reflective practice. The Self-Directed Learning Questionnaire showed a 25% increase, rising from 60% on the pre-assessment to 85% on the post-assessment. Additionally, the statistical analysis indicated a positive correlation ($r = 0.62$, $p < 0.05$) between SDL and critical-thinking scores, suggesting that greater autonomy is associated with stronger analytical skills. Learning logs showed that student teachers planned their own work, monitored their progress, and changed it as required. Reflective entries indicated that students were more engaged, more intrinsically motivated, and more aware of their own cognitive processes. These results suggest that SDL reinforces other 4Cs skills by fostering responsibility and self-directed learning.

4.4 Objective 4: Reflection and Critical Thinking

Structured reflection and working together to solve problems were the main goals of Objective 4. The results showed that both critical thinking and collaboration improved. The percentage of people who could think critically increased from 65% to 77%, a 12-percentage-point gain. The percentage of people who could work together went up from 60% to 75%, a 15% gain. A qualitative analysis of reflection rubrics and facilitator observations showed that student teachers were better at breaking down complex classroom situations, explaining their reasoning, and developing group solutions. Participants

showed that they were better at thinking about their own learning and judging how well they were doing, and that structured reflection was important for enhancing collaborative skills and strengthening analytical reasoning.

4.5 Objective 5: Integrated Framework Implementation

The pilot implementation of the integrated framework combining CBI, SDL, and PBL showed significant improvements across all four areas. In general, there were improvements of 20% in critical thinking, 18% in collaboration, 15% in communication, and 12% in creativity. There was also about a 22% improvement in self-directed learning indicators. Observations and interviews showed that student teachers were highly engaged, worked well together, and applied what they learned in real-world settings. Student teachers demonstrated the ability to manage projects independently while collaborating productively with peers. These results suggest that integrating CBI, SDL, and PBL produces synergistic effects, maximizing the development of the 4Cs and offering a scalable model for Cambodian teacher education reform. Table 3 summarizes the key findings across all research objectives.

Table 3
Summary Findings Across Objectives

Objective	Critical Thinking	Collaboration	Communication	Creativity	Self-Directed Learning	Contribution to Framework
Obj 1	↑ 19%	–	–	–	–	Step 1: Concept Identification
Obj 2	–	↑ 20%	↑ 15%	↑ 5%	–	Step 3: Project Development
Obj 3	–	–	–	–	↑ 25%	Step 2: Planning & Reflection
Obj 4	↑ 12%	↑ 15%	–	–	–	Step 4: Reflection & Evaluation
Obj 5	↑ 20%	↑ 18%	↑ 15%	↑ 12%	↑ 22%	Step 5: Integrated Implementation
Note: Pre-test and post-test assessments were used in the author's study to generate the data. Relative improvements in each competency domain are indicated by percentage increases (%). Dashes (–) show that the goal did not primarily focus on the corresponding skill.						
Formula: Percentages Increase (%) = \Frac{Post − Pre}{ Pre }\time100						

Analysis demonstrated statistically significant improvements in most skill areas following the implementati adequate for statistical analysis.n of the integrated instructional framework. Objective 1 significantly improved critical thinking (↑19%, $p < .05$) and highlighted the importance of concept identification in cognitive development. Objective 2 demonstrated significant increases in collaboration (↑20%) and communication (↑15%), reinforcing the value of project-based learning in developing social and interactive skills. Objective 3 showed the most significant change in self-directed learning (↑ 25%, $p < .05$), indicating that structured planning and reflection activities are integral to learner autonomy. Objective 4 showed moderate improvements in critical thinking (↑12%) and collaboration (↑15%), supporting the value of reflective assessment strategies. Key findings from Objective 5 demonstrated consistent, statistically significant improvements across all five domains, with effect sizes varying from moderate to high ($d = 0.50–0.78$). This finding underscores the importance of the integrated implementation phase for consolidating and transferring learning outcomes. Overall, the findings are consistent with international frameworks that emphasize the development of 21st-century competencies through integrated pedagogical approaches. The results align with the competency-based education framework advocated by OECD (19, 50), which stresses the integration of knowledge, skills, and attitudes. The observed improvements also support the work of Trilling and Fadel (20), who highlight the importance of critical thinking, collaboration, and self-directed learning as crucial competencies for contemporary education. Table 4 presents the pre-test and post-test comparisons across all objectives, including percentage improvements, p-values, and effect sizes. Figure 4 illustrates the percentage improvements in 21st-century skills across the five learning objectives.

Table 4
Pre-test and Post-test Comparison Across Objectives

Objective	Skill	Pre-test Mean	Post-test Mean	% Increase	p-value	Effect Size (d)	95% CI
Obj 1	Critical Thinking	50.0	59.5	19%	< .05	0.65	[5.2,13.8]
Obj 2	Collaboration	55.0	66.0	20%	< .05	0.70	[6.4,15.6]
Obj 2	Communication	52.0	59.8	15%	< .05	0.60	[3.9,11.7]
Obj 2	Creativity	60.0	63.0	5%	> .05	0.20	[-0.5,6.5]
Obj 3	Self-Directed Learning	48.0	60.0	25%	< .05	0.80	[7.1,16.9]
Obj 4	Critical Thinking	50.0	56.0	12%	< .05	0.50	[2.8,9.2]
Obj 4	Collaboration	55.0	63.3	15%	< .05	0.55	[4.1,12.5]
Obj 5	Critical Thinking	50.0	60.0	20%	< .05	0.75	[6.5,13.5]
Obj 5	Collaboration	55.0	64.9	18%	< .05	0.70	[6.2,13.6]
Obj 5	Communication	52.0	59.8	15%	< .05	0.60	[3.8,11.8]
Obj 5	Creativity	60.0	67.2	12%	< .05	0.50	[3.4,11.0]
Obj 5	Self-Directed Learning	48.0	58.6	22%	< .05	0.78	[6.8,14.4]

4.6 Integration of Findings Across Objectives

Objective 1 (CBI and Critical Thinking): The results show that concept-based teaching improves analytical reasoning and understanding of abstract ideas. This is in line with what other researchers have found: that CBI helps people learn more and transfer knowledge (51). In Cambodia, CBI integration fills gaps in the traditional content-focused curriculum. The study's results showed improvements in deep comprehension, critical thinking, long-term memory retention, transferable skills, engagement, and integration. All of these are directly related to conceptual understanding and lead to better performance (5). It is one of the most intensive reactions following Erickson, Lanning, and French (2017) (3), who found that concept-based instruction fosters students' critical thinking abilities by engaging them in inquiry and conceptual reasoning.

Objective 2 (Collaboration and Communication): Group projects improved teamwork and communication skills, confirming that structured PBL promotes collaborative learning. This is in line with global research, which suggests that collaboration and communication are flourishing in project-oriented environments (52). Recent research suggests that project-based learning promotes collaboration, critical and creative thinking, and important social skills for everyday life (53, 54). One of the most influential accounts of PBL comes from Zubaidah (2018), who reported that through practical applications, project-based learning helps them grow both intellectually and personally. According to data from multiple studies, project-based learning fosters 21st-century skills such as critical and creative thinking, communication, and collaboration, while also helping students develop their social awareness and teamwork skills (55).

Objective 3 (Self-Directed Learning): Greater autonomy and reflective practice enable SDL, allowing learners to take ownership of their projects and promoting engagement and metacognition. This is important in the Cambodian context, where the teacher education program has traditionally had little opportunity for independent learning. The major advantages of self-directed learning are increased motivation, self-confidence, enjoyment, enhanced metacognitive and language production skills, and advanced technological skills(56). It has been shown that high SDL improves EFL learners' academic writing skills and that the relationship between the two is partially mediated by critical thinking ability (57). Self-directed learning among EFL undergraduates significantly impacts self-efficacy, self-regulated learning, and problem-solving in writing. There is a significant correlation between self-directed learning and the ability to apply these skills to solve academic writing problems (58).

Objective 4 (Reflection and Critical Thinking): Reflection and collaborative problem-solving reinforced critical thinking and teamwork. It has been conclusively shown that students developed metacognitive skills, enabling them to evaluate their own learning and performance—a key factor in professional growth in teacher education. Because self-directed learning activities can enhance students' critical thinking, educators have been cautioned that failing to teach children to be self-directed lifelong learners could be harmful to them (59). Recently, in vitro studies have shown that, for students to develop the essential abilities required for success as students and lifelong learners in the twenty-first century, postsecondary or university language instructors should encourage self-directed learning (21).

Objective 5 (Integrated Framework): Preliminary results show significant gains across all 4Cs, confirming that integration maximizes the impact of individual instructional strategies. There is not just one way to help pupils learn; instead, we need to use a range of activities that spark their enthusiasm and carry over into tomorrow (60). Wittmann and Olivier (61)stress the significance of using a self-directed learning strategy to address developmental issues (such as anxiety) that South African teachers face. For example, many studies, including those of H. Lynn Erickson, have found that typical curriculum design is two-dimensional, focusing on subject-matter knowledge and skills, with memorization and coverage as objectives. A three-dimensional curriculum gives students a conceptual framework to synthesize information and skills through concepts, principles, and generalizations, achieving deep, transferable understanding.

5. Discussion

5.1 Alignment with Literature

Figure 5 presents the integrated CBI-SDL-PBL framework for Cambodian teacher education. The findings of this study align with global data showing that well-integrated teaching methods help students develop the skills they will need in the 21st century (20, 34). The results show that combining teaching methods is more effective than separate interventions, in line with global opinion. The integrated framework had synergistic effects with Self-Directed Learning (SDL), which served as a catalyst, making Concept-Based Instruction (CBI) and Project-Based Learning (PBL) even more powerful. Instead of using these methods separately, they were used together, resulting in greater growth in creativity, teamwork, communication, and critical thinking. Most importantly, the results provide new real-world evidence from Cambodia that this type of pedagogical integration is not only sound in theory but also works in teacher preparation programs and can be expanded. Multiple teaching approaches in learning environments are more effective than single approaches because they promote in-depth cognitive involvement and transferable skills (62, 63). Therefore, the results of this study on the synergy among SDL, CBI, and PBL are consistent with international studies showing that the well-planned integration of pedagogical approaches produces more robust and durable gains in students' cognitive, interpersonal, and intrapersonal competencies than stand-alone interventions (19, 63).

The study has several actionable implications for educational reform in Cambodia:

1. Curriculum Design: Teacher education programs should incorporate CBI, SDL, and PBL systematically to foster the 4Cs. It can enhance student teachers' critical thinking, which leads to conceptual-level understanding. The 2D dimensions emphasize skills and knowledge, whereas the 3D dimensions focus on skills, knowledge, and concepts. The Concept-Based Curriculum and Instructional Framework is a three-dimensional model that focuses on what students should know (facts), comprehend (concepts and principles), and do (processes and skills) and helps teachers organize lessons. To foster deeper comprehension, student involvement, and critical thinking, it encourages teachers to employ concepts to help students identify patterns and connections among facts (Erickson & Lanning, 2014).
2. Teacher Training: Teacher educators need extensive knowledge of teaching methodology, including scientifically proven methods such as CBI, since CBI is more than just a teaching approach; it is often seen as a curriculum and instructional framework. Curriculum and instruction are designed and delivered to support students' deeper comprehension by structuring learning around concepts, generalizations, facts, and skills. structured projects, reflective practices, and tasks that promote autonomy and prepare student teachers for 21st-century classrooms (64).
3. Assessment and Evaluation: Using 4Cs rubrics and reflective journals helps students meet national competency standards and shows how their skills are improving. In Concept-Based Instruction (CBI), assessments and evaluations focus on more than just remembering facts. They also look at how well students understand concepts, transfer knowledge, and apply skills. Projects, analytical essays, presentations, and problem-solving exercises are examples of summative assessments that ask students to demonstrate understanding of ideas and generalizations and to apply that understanding in different situations. This method places greater value on understanding and higher-order thinking than on memorizing isolated facts (65).
4. National Policy: Evidence supports adding the framework to national teacher-training guidelines to ensure alignment with international standards while still taking local needs into account. To reach its goal of high medium income in 2030 and a high lower income in 2050, the policy calls for a shift from content-based instruction, which emphasizes factual knowledge and skills, to concept-based instruction, which requires teachers to focus on students' comprehension and thinking. Teachers are aware of each student's capacity for collaborative thought.
5. Educational Reform: The framework can guide policy decisions, curriculum updates, and standardization of teacher education programs in Cambodia. Educational reform should ultimately center on a teacher education college where prospective teachers are trained. In addition to introducing them to new teaching methods, teacher educators should be prioritized and supported with various incentives to help them feel secure and to heighten their self-esteem to a certain extent.

5.3 Limitations and Future Directions

The main weakness of this study is its limited sample, as it included only certain teacher education programs. Therefore, more large-scale studies are needed. Another major drawback is that creativity development, though there were some improvements, was only moderate. Therefore, further research should explore ways to improve creative thinking. The scope of this research was relatively narrow and primarily concerned with long-term impact, so longitudinal studies could examine how long the development of the 4Cs lasts and how well it works in a real classroom after graduation. The BTEC Model, the integrated CBI-SDL-PBL framework, is a scalable blueprint for national teacher education reform across Cambodia's Provincial Teacher Training Centers (PTTCs) and has proven successful at the Battambang Teacher Education College (BTEC). Standardizing the "four-step scalable model" in this study may provide the Ministry of Education, Youth and Sport (MoEYS) with a clear roadmap to help provincial educators transition from traditional rote instruction to 21st-century competency-based training. If applied nationally, the model will enable teacher-trainees in all provinces to achieve synergistic mastery of creativity and critical thinking, thereby directly advancing the human capital objectives of the Pentagonal Strategy and the equalization of educational quality between urban and rural areas.

6. Conclusion

This study provides Cambodian student teachers with a framework grounded in real-world evidence and tailored to their needs. It combines Concept-Based Instruction (CBI), Self-Directed Learning (SDL), and Project-Based Learning (PBL) to help them develop the 4Cs: creativity, critical thinking, cooperation, and communication. The framework shows that combining these strategies is more effective than using them individually. Structured PBL helps students apply what they learn in the classroom to real-world situations, making them better prepared for work. SDL, on the other hand, encourages students to be independent, engaged, and reflective in their learning. The framework helps Cambodia move toward 21st-century education that aligns with the rest of the world by providing practical guidance on revising the curriculum, training teachers, and developing policies. In the future, the framework will be used in additional Southeast Asian teacher education settings, and methods will be refined to encourage greater creativity and innovative problem-solving. There will also be extensive trials and long-term studies to determine whether the results are sustained. Every framework goal must be clearly linked to real-world research, ensuring it can be used and carried out on an evidence-based basis. CBI acted as the cognitive anchor, reducing the 'split-attention effect' by focusing learners on universal concepts rather than fragmented facts. This conceptual clarity provided the necessary psychological safety for students to engage in SDL, as they had a clear 'map' of what they needed to learn. Finally, the PBL phase served as the theater of application; without prior SDL planning, the project work would likely have remained superficial. The synergy, therefore, is a result of a mutually reinforcing feedback loop: CBI provides the *what*, SDL provides the *how*, and PBL provides the *purpose*.

Declarations

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Author contributions:

S.H. (Sophon Hieng): Conceptualization; Methodology; Investigation; Data curation; Formal analysis; Writing – original draft; Visualization; Project administration (doctoral dissertation). C.H. (Chan Hum): Validation; Formal analysis; Investigation (Objectives 2 & 4); Writing – review & editing. S.S. (Soeung Sopha): Formal analysis; Investigation (Objective 5 & framework integration); Data curation (SDL questionnaire); Writing – review & editing. R.S. (Rany Sam): Supervision; Conceptualization (policy implications); Writing – review & editing; Resources; Funding acquisition. D.B. (Da Bou): Investigation (Objective 1 & 3); Data collection; Resources (participant access at BTEC); writing—review & editing. All authors (S.H., C.H., S.S., R.S., D.B.) reviewed the manuscript, contributed to the interpretation of findings, and approved the final version for publication.

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Data availability

The anonymized datasets generated and analyzed during the current study are not publicly available to protect participant privacy but are available from the corresponding author upon reasonable request, subject to a data use agreement to prevent re-identification. Participant identifiers have been removed. Data are stored on a password-protected institutional server.

Ethics approval and consent to participate

This study was reviewed and approved by the Research and Development Center at the National University of Battambang (NUBB) (Approval No. 001, dated 01 January 2026). The Center operates under the Policy on Research Development in the Education Sector issued by the Ministry of Education, Youth, and Sport (MoEYS) of Cambodia. While Cambodia does not utilize a single, centralized MoEYS-wide institutional review board (IRB), the aforementioned policy mandates strict adherence to established national and international research ethics frameworks. This study was conducted in accordance with the Declaration of Helsinki and the ethical principles outlined in the MoEYS Policy on Research Development. Permission to conduct research at Battambang Teacher Education College (BTEC) was obtained from the college director and the BTEC Academic Affairs Office.

Clinical trial number: not applicable.

Consent to participate

The study involved only standard educational practices and posed no more than minimal risk to participants. All participants were more than 18 years of age. Written informed consent was obtained from all individual participants prior to enrollment. The consent form explained the research objectives, procedures, risks, benefits, the voluntary nature of participation, and the right to withdraw without academic penalty. To minimize potential coercion given the instructor-student relationship, consent was sought by a research assistant not involved in teaching or grading. Consent forms are retained by the corresponding author at NUBB.

Consent to publish

The authors affirm that participants provided informed consent for the publication of anonymized research data in an academic journal. No personally identifiable information (e.g., names, photographs, institutional identifiers) is included. Direct quotations from reflection journals are presented without identifying markers, and participants consented to the use of their anonymized written reflections. Participants were informed that de-identified responses might appear in tables, figures, or quotes.

Competing interests

The authors declare no financial or commercial competing interests. Several authors (S.H., C.H., S.S., R.S., D.B.) hold academic positions at the institutions where participants were recruited (National University of Battambang and Battambang Teacher Education College). To mitigate potential bias, data collection was conducted by research assistants not involved in grading, and participant anonymity was preserved. The authors affirm that the study design, analysis, and interpretation were conducted objectively.

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Figures

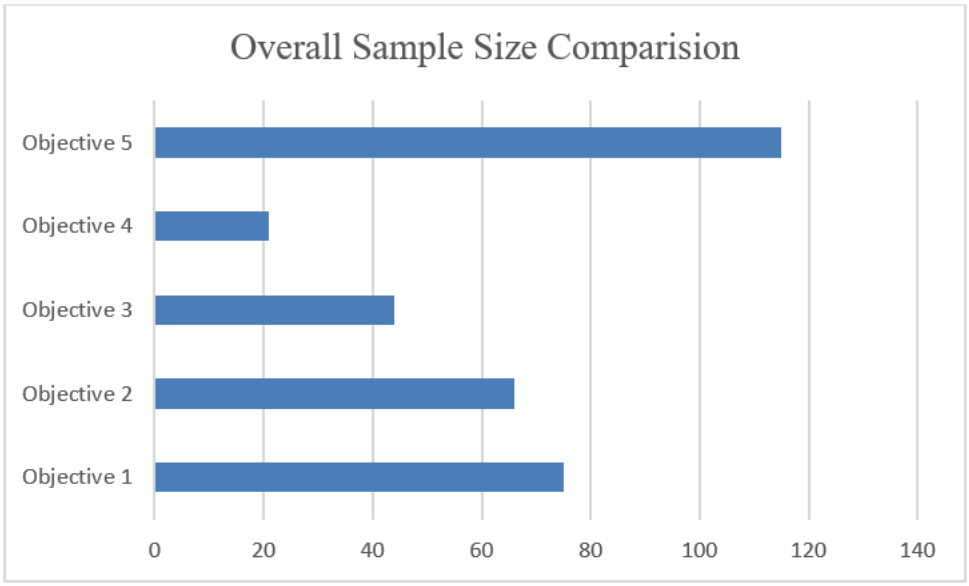


Figure 1

Participant Distribution and Experimental Design Across Research Objectives



Figure 2

Four-stage framework development system.

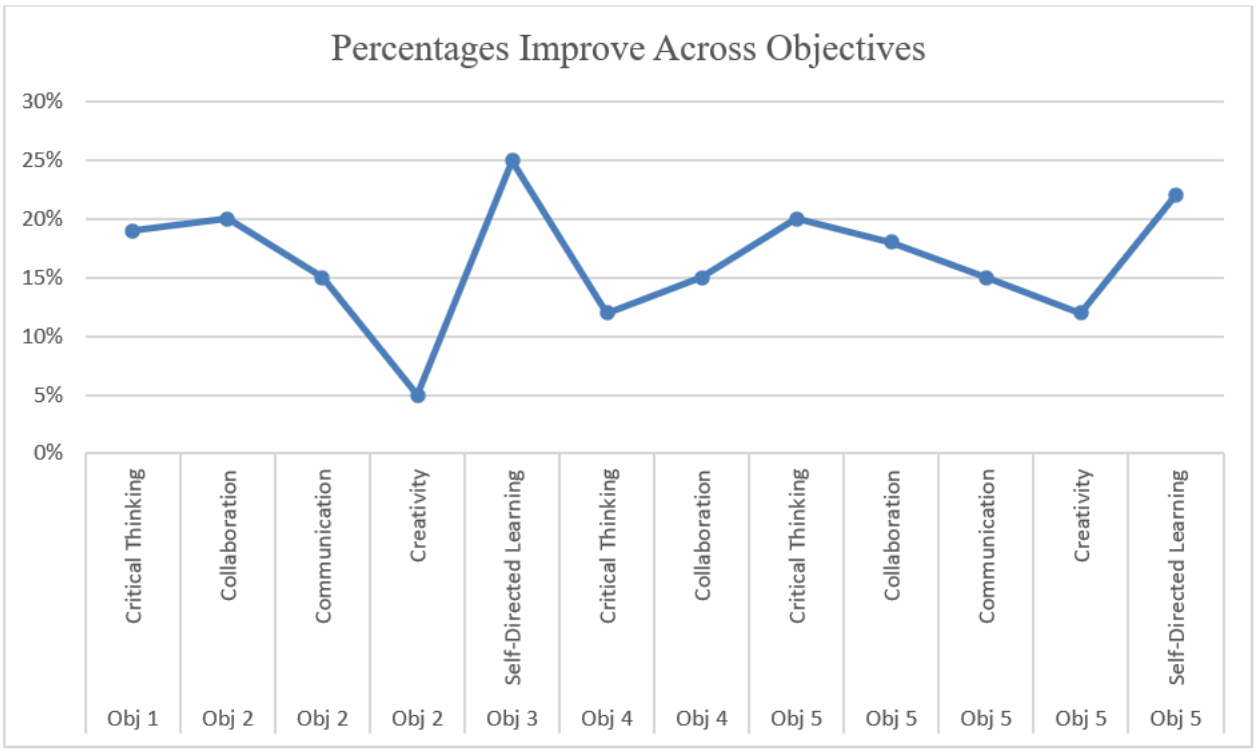


Figure 3

Figure 4. Percentage Improvement in 21st Century Skills Across Five Learning Objectives Source: Primary data collected by the author (2023/2025)

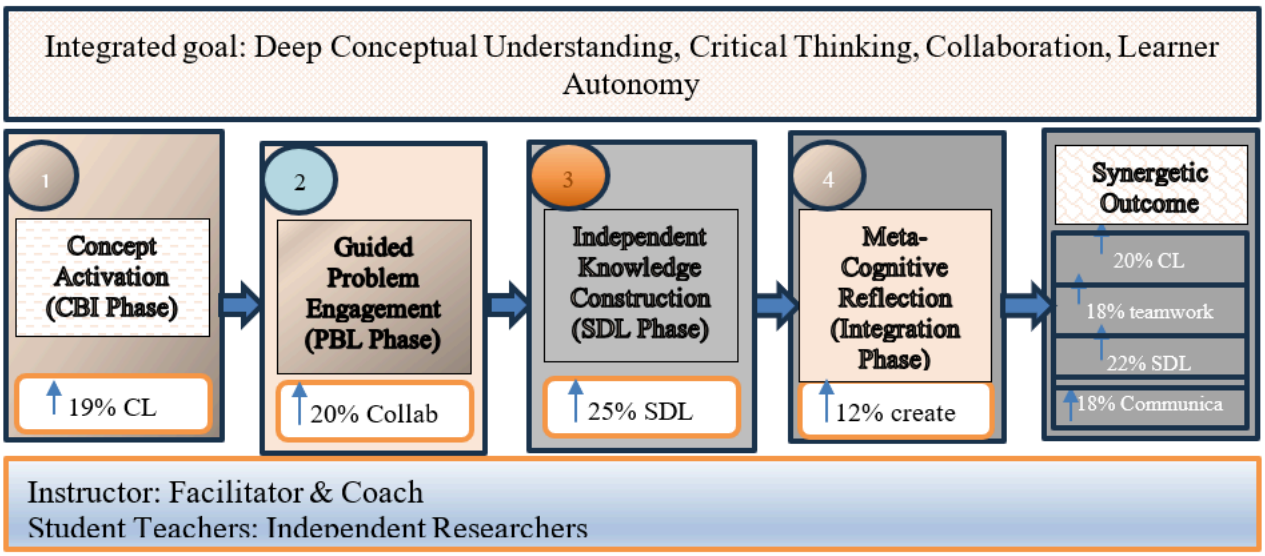


Figure 4

Figure 5. Integrated PBL Framework for Cambodian Teacher Education.