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Developing an active learning model using problem-based learning to enhance the 21st century skills

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ABSTRACT

This research aimed to develop and implement the Problem-Based Learning (PBL) model for 21st-century skills and evaluate the outcomes. The model went through three phases of research and development and was conducted with two groups of 55 third-year students selected using a clustered random sampling method. The research instruments used included a structured interview form, the PBL model, the 21st-century skill scales, and the satisfaction questionnaire. The instruments had quality and were assessed with the content validity and reliability. The data analysis involved the use of descriptive statistics, dependent t-tests, and content analysis. The results showed that the PBL model developed consisted of four components and was highly appropriate. Process of the PBL instruction included six steps: problem statement, problem analysis, research, synthesis, summary and evaluation, and presentation and discussion; students' critical thinking skills, collaboration, teamwork, and leadership skills significantly improved after the implementation of the model, and students expressed high satisfaction. This model can help foster learners to achieve and should also be used with other groups.

Contribution/Originality: This study provides new evidence on the PBL model that favors enhancing the vital skills of student teachers according to the policy of education management in Thailand. This has positively impacted their career paths. Student teachers can carry over these important skills to their students.

1. INTRODUCTION

Twenty-first-century skills are crucial for learners to thrive in life and work. According to the Partnership for 21st Century Learning (2016) education must equip students with the necessary knowledge and skills to succeed in a globally connected and digitally driven world. However, the 2022 PISA assessment revealed that Thai students scored below average in all tested skills, marking a significant decline compared to previous years (OECD, 2023). This underlines the urgent need to enhance Thai students' competencies, particularly their 21st-century skills. The Thai Ministry of Education (Office of the Education Council, 2017) emphasizes essential skills for teachers, such as critical thinking, collaboration, teamwork, and leadership, which align with the broader framework of 21st-century learning. According to the education management in Thailand 2022 (Office of the Education Council, 2023) to promote learning and skill development of people at all ages, we should focus on school development in parallel with teacher development. One of the government policies pertains specifically to higher education. The vision states that it is "to prepare citizens of Thailand for the 21st century." Moreover, the government policies emphasize

the importance of active learning. Among active learning methods, problem-based learning (PBL) stands out as a powerful approach that encourages students to integrate theory with practice and apply their knowledge to solve real-world problems (Savery, 2006). Studying the situation and needs to develop a PBL model that is appropriate for the learner group, including applying the PBL model to students and evaluating the results of using the PBL model, are therefore important in promoting 21st century skills.

Likewise, educators from different countries have disclosed the usefulness and effectiveness of PBL (Saputro, Atun, Wilujeng, Ariyanto, & Arifin, 2020). PBL works as an active, learner-centered model for teaching, especially in medicine (Carrió, Baños, & Rodríguez, 2022; Foo, Cheung, & Chu, 2021; Saputro et al., 2020) mathematics and engineering (Hsu, 2021), and in learning subjects, areas in basic education (Phungsuk, Viriyavejakul, & Ratanaolarn, 2017; Srikan, Pimdee, Leekitchwatana, & Narabin, 2021). There is a need to develop a model to support how to use PBL effectively to develop critical thinking, collaboration, teamwork, and leadership skills that appear in both Partnership for 21st Century Learning (2016) and the ones in education management in Thailand. Therefore, investigating and developing a model for managing PBL learning among undergraduate Thai student teachers in the research and innovation for learning subject when online learning became necessary due to the pandemic. This implementation resulted in adapting PBL methods for online distance learning and promoted students' critical thinking abilities (Chan et al., 2022). In addition, Hidayati, Zubaidah, Suarsini, and Praherdhiono (2020) discovered that online tools such as digital mind maps can facilitate critical thinking and improve knowledge dissemination. Students should be directly trained and mentored to develop their professional, personal, and social abilities.

For that reason, this study has developed a PBL model to enhance students' critical thinking, collaboration, teamwork, and leadership skills; develop guidelines for appropriate learning that present the problem, provide information resources and cognitive tools, and promote collaboration in problem-solving. This research and development is expected to improve student teachers skills and help them adjust and prepare for future careers. Moreover, the developed model can be used in teaching and learning with other groups of students and can be adapted to other subjects, both online and on-site learning.

2. LITERATURE REVIEW

2.1. Twenty- First Century Skills of Students Teachers

Twenty-first century skills are essential for students' success in life and work, including the 3Rs (Reading, Writing, Arithmetic) and 8Cs: Critical Thinking, Creativity, Cross-Cultural Understanding, Collaboration, Communication, Information and Communication Technology (ICT) Literacy, Career Skills, and Compassion (Partnership for 21st Century Learning, 2016). Research indicates that student teachers often find it challenging to develop critical 21st-century skills. Ali, Rosli, Sujadi, Usodo, and Perdana (2017) highlight the need for training programs that prepare student teachers for diverse workplace environments. Vega and Brown (2013) emphasize collaborative learning's role in fostering these skills, while Redecker et al. (2011) stress the importance of integrating them into teacher education programs to meet the evolving demands of modern education.

2.2. Active Learning Approach and Problem-Based Learning (PBL)

Active learning, grounded in constructivist theory, posits that students build their understanding through interactions with their environment and experiences (Rusbult, 2007). This student-centered approach prioritizes active student participation, focusing on their unique needs and interests (Weimer, 2013). It also recognizes the diversity of student backgrounds, experiences, and learning styles. Fink (2003) identifies three core elements of active learning: access to information, experiential learning (both direct and indirect), and reflection. These elements are crucial in promoting meaningful learning and shaping curriculum design. Through active learning, students engage with various information sources and participate in real or simulated experiences, leading to deeper

understanding when coupled with reflection. This approach has significantly influenced curriculum development by integrating experience, action, and reflection to foster meaningful learning (Rusbult, 2007).

PBL is a type of active learning that focuses on helping students develop essential skills. According to Tan (2003) its primary goals include mastering subject content, developing discipline-specific strategies, and improving problem-solving abilities. It aligns with lifelong learning goals, such as acquiring information, fostering collaboration, promoting self-directed learning, and encouraging reflective thinking. Hmelo-Silver (2004) describes PBL as an experiential approach in which students work in small groups to investigate, explain, and solve meaningful problems. By engaging in PBL, students not only develop independent thinking but also gain 21st-century skills, including creativity, communication, and critical thinking (Strimel, 2014). This approach fosters key life and career skills like collaboration (Vega & Brown, 2013) and teamwork (Allert, Dellkvist, Hjelm, & Andersson, 2022; Prettyman, Ward, Jauk, & Awad, 2012) which are crucial for modern success. The PBL process involves several stages, as articulated by various scholars. Wood (2003) outlines a seven-step PBL tutorial process, while Tan (2003) suggests a five-step process, and Hmelo-Silver (2004) describes a six-step cycle beginning with problem presentation and concluding with student reflection. Despite differences in the number of steps, these processes generally include problem presentation, problem definition, brainstorming, systematic inquiry, synthesis and application, and evaluation. These stages emphasize self-directed learning, collaboration, research, and reflection, equipping students with the skills necessary to tackle complex, real-world problems.

2.3. The Development the Problem- Based Learning Model

The PBL methodology is instrumental in developing cognitive, intrapersonal, interpersonal, and technical skills, which are vital for 21st-century competencies. Integrating, developing, and assessing these skills within higher education curricula is crucial (Geisinger, 2016). Creating an effective teaching model involves several essential elements, including learning objectives, instructional strategies, content, learning activities, assessment and evaluation, feedback mechanisms, and technology integration, as outlined by educational theories and practices (Anderson et al., 2001; Joyce, Weil, & Calhoun, 2015). This study incorporates these components to develop a structured PBL model. The success of PBL in achieving desired learning outcomes largely depends on its integration into curricula and educational environments. Researchers have utilized various PBL models, which differ in self-directedness, learning processes, and problem structure (Barrows, 1996). Factors such as student and tutor behaviors, group dynamics, resources, and workload also influence outcomes. Therefore, selecting a PBL model that aligns with learners' characteristics and instructional needs is essential (Hung, 2011).

This study integrated PBL into an online research and innovative course for student teachers. Despite the new standards emerging post-COVID-19, PBL remains crucial in bridging the gap between theory and practice by engaging students in problem-solving within simulated real-world environments. The development of this model will involve studying the PBL components and process and assessing its effectiveness by measuring learners' skills during implementation.

2.4. Theoretical Framework

The research framework on the development of the PBL model to enhance the 21st-century skills of critical thinking, collaboration, teamwork, and leadership is shown in Figure 1.

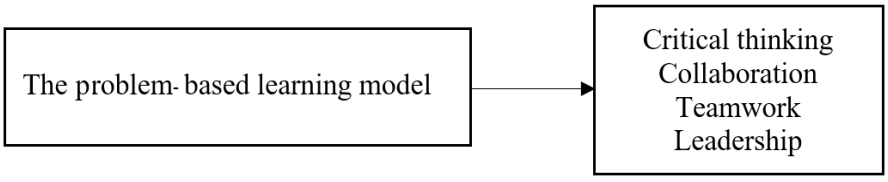

Figure 1. Conceptual framework.

2.5. Hypothesis Development

The effectiveness of the developed PBL model will be evaluated by assessing students' skills in critical thinking, collaboration, teamwork, and leadership. Surveys and interviews will also be conducted with a sample group of students. If the model is effective, it is expected to significantly enhance students' 21st-century skills compared to their pre-implementation levels, with a statistical significance level of .05. Additionally, student satisfaction with the PBL activities is anticipated to be high. The study will test the following hypotheses:

H_1: After implementing the PBL model, students' critical thinking skills will significantly improve. Critical thinking, a crucial 21st-century skill, involves evaluating the reliability of sources, deductive and inductive reasoning, and identifying connections (Joynes, Rossignoli, & Amonoo-Kuofi, 2019; Redecker et al., 2011; Scott, 2015). *Interactions with others shape it, and we can teach and refine it* (Ennis, 1985).

H_2: After implementing the PBL model, students' collaboration skills will significantly improve. Future work environments will require extensive remote collaboration, making this skill vital (Joynes et al., 2019). *PBL fosters collaboration by encouraging group work, peer tutoring, and mentoring, which are essential for developing respectful and effective teamwork* (Loveland & Dunn, 2014; Thanudca, 2021; Vega & Brown, 2013).

H_3: After implementing the PBL model, students' teamwork skills will significantly improve. The importance of teamwork in a globalized world necessitates training students to excel in diverse group settings (Ali et al., 2017; Prada, Mareque, & Pino-Juste, 2022). *PBL helps students apply their knowledge in group contexts, working together to achieve common goals* (Prettyman et al., 2012).

H_4: After implementing the PBL model, students' leadership skills will significantly improve. Leadership is one of the ten essential skills for workplace success identified by the Apollo Education Group (Barry, 2012, as cited in Scott (2015)*). PBL assignments employ activities like group brainstorming, project planning, conflict resolution, and role-playing to foster leadership development* (Bridges, 1992; Bridges & Hallinger, 1995).

3. METHODOLOGY

3.1 Research Design

The study employs a research and development (R&D) methodology that involves the stages of analysis, design, development, and implementation of the PBL model.

The research process was divided into three phases as follows.

The First Phase: This study examined the current educational landscape and the need to implement the research and innovation for learning subjects to improve the learning skills (R1). The results of this analysis will inform the adaptations to the model of PBL (D1).

Participants in first phase are five experts (group 1) who are participants as interviewees were selected using a purposive sampling method at a public autonomous university in Thailand, specifically five experienced lecturers who have taught research subjects for more than five years and have experience in the PBL instruction.

Instrument: The semi-structured interviews consisted of open-ended questions about teaching activities, teaching methods, media use, assignments, worksheets, learner and teacher roles, evaluation methods, and the appropriateness of problem-based learning in the program. Instrument quality check by five experts (group 2) assessed the Index of Item Objective Congruence (IOC) values ranging from 0.80 to 1.00.

Data was collected from five experts (group 1) through semi-structured interviews. Each interview lasted between 40 to 60 minutes per person. Data analysis was conducted using content analysis, carefully examining and interpreting the information collected. The result of this analysis will guide the modifications to the problem-based learning model in the next phase of the study. The Second Phase: Develop a problem-based learning model to promote 21st-century skills (R2). The result of this development is the PBL model that has quality (D2).

Participants in second phase are five experts (group 2) for checking content validity who were selected using a purposive sampling method at a public autonomous university in Thailand. They have experience in the field of educational measurement and evaluation and have experience in the PBL instruction.

The instruments were as follows:

1. The PBL model consisted of the purpose of the model, principles of the model, process of the model, and measurement and evaluation.

2. An assessment form totaling 40 items used a five-point rating scale for experts to access the appropriateness and consistency of the PBL model.

3. The 21st-century skill scales include.

A critical thinking test based on the concept of Dressel and Mayhew (1957); Ennis (1985) and Kneedler (1985). The items consisted of 40 items, each offering four choices: 1) defining the problem; 2) identifying information; 3) identifying the hypothesis; and 4) summarizing references.

Questionnaire: contained 50 items; used a five-point rating scale to measure collaboration skills (14 items), teamwork (19 items), and leadership (17 items).

4. The satisfaction questionnaire on the PBL model contained 16 items.

3.2. Instruments Quality Check

1. Five experts check content validity of an assessment form, the 21stcentury skill scales, and the satisfaction questionnaire. The Index of Item Objective Congruence (IOC) values range from 0.80 to 1.00.

2. To ensure the reliability of the 21stcentury skill scales, a tryout was conducted with a sample group of 30 students. Critical thinking skills were analyzed for discrimination index, which ranged from .20 to .45. Reliability using the KR-20 coefficient. The reliability value was .71. Collaboration, teamwork, and leadership skills were assessed by using Cronbach's alpha coefficient, and the reliability values of each instrument are .94.

Data was collected from the experts for checking quality of the PBL model by using an assessment form for evaluating the appropriateness and consistency of the PBL model. Analyzed data from assessment forms using descriptive statistics: mean *(M)* and standard deviation (*SD*).

The Third Phase: The PBL model was implemented (R3). The results of the PBL model effectiveness were assessed at critical thinking, collaboration, teamwork, and leadership of students. In addition, assess the satisfaction of students on the PBL model (D3).

The participants were the two groups of third-year students, totaling 55 persons, form Srinakharinwirot University, Bangkok, Thailand, using clustered random sampling. The instruments consist of the PBL model, the 21stcentury skill scales, and satisfaction questionnaire.

Data was collected from 55 third-year students via online learning in the teaching of the Research and Learning Innovation subjects in the second semester of academic year 2021 (January 2022 - April 2022). This course implemented the PBL model for six weeks, providing three hours of instruction per week, as part of a 15-week curriculum.

Data were analyzed to compare the outcomes before and after implementing the PBL model using dependent t-tests, means, and standard deviations.

4. RESULTS

The research divides its results into three phases:

Phase 1: The research conducted in this study involved examining the existing situation and the necessity of problem-based teaching and learning in improving 21st-century skills. To gather data, in-depth interviews were conducted to gather suggestions and recommendations to enhance the developed the PBL model. For example, the mindfulness content is helpful for this kind of learning.

Carefully design the objectives to align with the measurement and assessment process. Learning activities associated with social awareness and social responsibility for soft skills in the workplace. Learning outcomes should be able to be identified through students' behavioral indicators.

Additionally, the five experts (E1, E2, E3, E4, and E5) provided valuable suggestions on how to enhance the overall implementation of the PBL model.

They agreed that problem-based learning management is the most suitable approach for content units. The interview results presented below reflect their consistent insights:

"Content unit is suitable for problem-based learning is researcher's code of ethics, human research ethics (E1, E2, E3, E4, E5), research problem (E1, E2, E3, E4, E5), research design (E2, E3, E5), innovative design for learning development (E1, E2, E3, E4, E5), creating and verifying the quality of research tools (E3, E4, E5), and research writing (E1, E2, E3, E4, E5)."

Below are the recommendations from the five experts' for PBL-appropriate instructional activities, media assignments, and worksheet in this course:

"Instructional activities that are suitable for PBL in this course should be setting up problems, dividing into groups, and presenting work." (E1, E2, E3, E4, E5).

"Since students lack research experience, they won't understand PBL. Instructor must teach the concept of PBL before learning." (E1,E3).

Experts recommend the following teaching method for this course's problem-based learning management:

"The teaching method should involve dividing students into groups, posing a research problem, and practicing analytical thinking." (E2).

"Learners must associate PBL with their work."(E4).

The five experts provided insights on evaluation methods, emphasizing the importance of using real-life assessment approaches considering the learner's work and performance based on assignments. They expressed that this approach is appropriate and effective.

Additionally, they suggested considering the following alternative evaluation methods:

"Use the other methods such as participation and segmentation." (E5).

"The method that is best for evaluation of a PBL activity is peer assessment."(E1, E4).

Regarding the problem situation that the researcher designed with PBL in this course, an expert said:

"The instructor must set a situation related to the research subjects; PBL can help learners understand both the content and practice." (E2).

Furthermore, the experts provided additional recommendations, which are displayed below:

"Students do not have background knowledge in research. Studying PBL will improve their understanding." (E1).

"The teacher should organize appropriate PBL for some units, as students are overburdened with work." (E1,E3,E4).

Phase 2: Researchers use data from interviews to adjust the PBL model. The development of the PBL model yielded four components: purpose, principles, process, and measurement and evaluation. Five experts assessed the appropriateness and consistency of this model at the highest level (M = 4.75, SD = 0.20). Therefore, the components of PBL model after assessing quality are shown in Figure 2.

The final step will involve implementing this model.

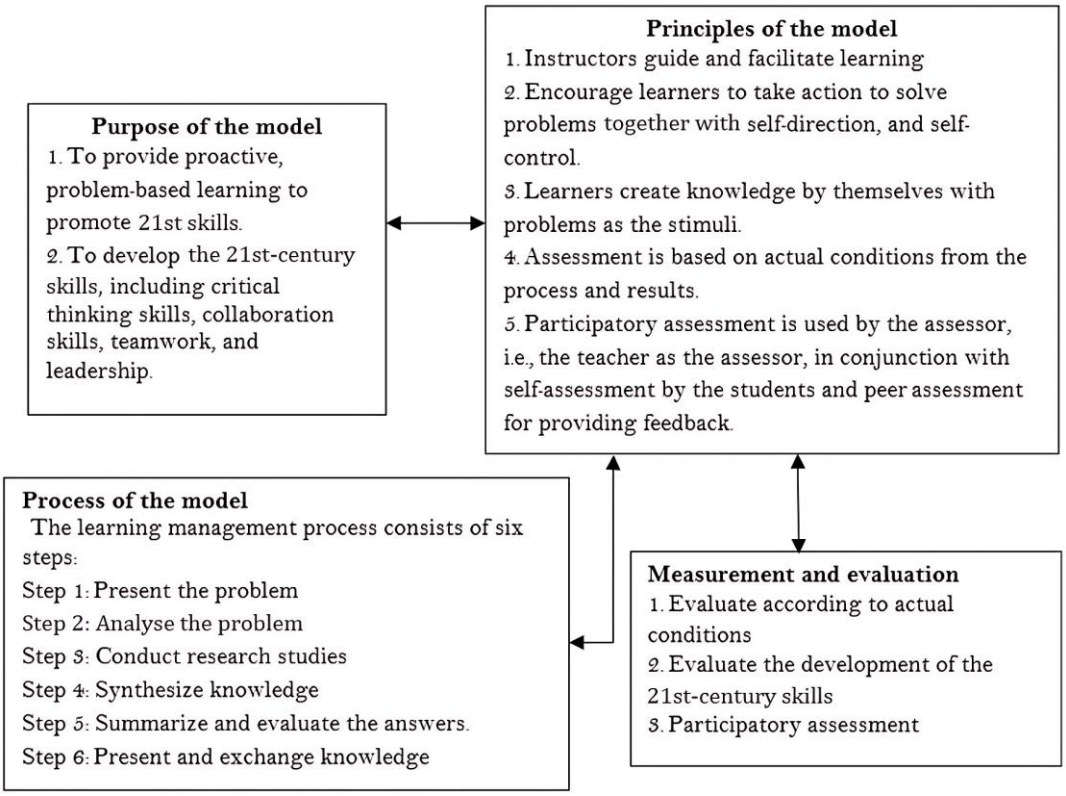

Figure 2. A proactive problem-based learning management model to promote 21st-century skills.

Phase 3: The results of implementing the PBL model to promote 21st-century skills were shown in Table 1 to Table 3.

Table 1. Comparison of the mean scores of critical thinking skills before and after implementing the PBL model. (n=55).

Test	Score	*M*	*SD*	df	*t*	*p*
Pre-test	40	17.13	3.85	54	9.63*	0.00
Post-test	40	22.49	3.37			

Note: *P<0.05.

From Table 1, it was found that the students who received the PBL model to promote 21st-century skills before and after implementing the model had mean scores and standard deviations of critical thinking skills that were *M*= 17.13, *SD*=3.85, and *M*= 22.49, *SD*=3.37, respectively. When comparing the mean scores, it was found that after implementing, the mean scores of critical thinking skills were significantly higher than before the implementing the model at the level of .05 (t=9.63; p=.00). Table 2 displays the other skills the students possess.

Table 2. Comparison of the mean scores of collaboration, teamwork, and leadership skills before and after the trial of the PBL model. (n=55).

Skills	Pre-test		Post -test		t	df	p
	M	SD	M	SD			
Collaborative	3.93	0.33	4.69	0.33	11.20*	54	0.00
Teamwork	3.93	0.28	4.68	0.30	14.12*	54	0.00
Leadership	3.80	0.27	4.67	0.30	14.52*	54	0.00

Note: *P< 0.05.

From Table 2, it was found that the students who received the PBL model to promote skills for the 21st century before implementing the model had the mean scores and standard deviations of collaborative skills, teamwork, and leadership of *M* = 3.39, *SD* = 0.33; *M* = 3.93, *SD* = 0.28; *M* = 3.80, *SD* =0.27, respectively. After implementing the

model, the mean scores and standard deviations were $M = 4.69$, $SD = 0.33$; $M = 4.68$, $SD = 0.30$; $M = 4.67$, $SD = 0.30$, respectively. The mean of scores for each aspect was significantly different at the .05 level.

After implementing the PBL model, the questionnaire data revealed mean scores, standard deviations, and student satisfaction levels with problem-based learning, as shown in Table 3. Overall, participants expressed a very high level of satisfaction (M = 4.37, SD = 0.77). They were particularly satisfied with the advantages of the PBL model and the instructional media, with mean scores of 4.39 (SD = 0.77) and 4.30 (SD = 0.80), respectively.

Table 3. Mean scores, standard deviations, and levels of satisfaction with problem-based learning of students.

Items	Statement	*M*	*SD*	level
Benefits of the teaching and learning approach:				
1	Enhances deep understanding of the subject matter.	4.26	0.83	Highest
2	Helps students consider reasoning to reach conclusions.	4.40	0.76	Highest
3	Trains students to build knowledge through the problem-solving process.	4.44	0.73	Highest
4	Develops problem-solving skills based on reasoning.	4.50	0.65	Highest
5	Encourages rational thinking.	4.38	0.75	Highest
6	Helps analyze and understand problem situations.	4.34	0.89	Highest
7	Stimulates learning.	4.36	0.96	Highest
8	Develops self-directed learning capabilities.	4.28	0.73	Highest
9	Trains students to engage in discussions on various interesting topics.	4.42	0.76	Highest
10	Enhances analytical and critical discussion skills.	4.36	0.72	Highest
11	Promotes planning skills.	4.40	0.70	Highest
12	Develops critical thinking.	4.54	0.71	Highest
Total		4.39	0.77	Highest
Instructional media:				
13	Suitable for learning.	4.24	0.80	Highest
14	Diverse in nature.	4.22	0.93	Highest
15	Facilitates learning.	4.34	0.80	Highest
16	Problems used in learning encourage research and exploration.	4.44	0.70	Highest
Total		4.30	0.80	Highest
Grand total		4.37	0.77	Highest

Likewise, the five students (S1, S2, S3, S4, and S5) also showed a high level of satisfaction in the interview, as shown in the results below:

"PBL stimulates students to practice creating knowledge through the process of problem-solving." (S1, S5).

"Students gain more understanding of the subject content." (S3, S4, S5).

"PBL stimulates learning and promotes learning." (S1, S2).

"Learners can understand and analyze problems through PBL instruction." (S1, S2, S3, S4, S5).

"PBL helps students to develop skills for working with others." (S1, S4, S5).

"PBL trains students to have teamwork and leadership." (S2, S5).

5. DISCUSSION

This study presents the discussion on two issues before and after the model was implemented:

5.1. Before the Implementation of the Model

This model followed a systematic development approach that included three phases: 1) examining the existing situation and the necessity of problem-based teaching and learning in fostering 21st century skills, 2) developing the PBL model, and 3) implementation of the PBL model. The findings were consistent with previous work by Anchunda and Kaewurai (2021) and Carrió et al. (2022) which emphasized the importance of systematically developing instructional models based on established theories. In addition, rigorous research procedures were used to develop this model, including interviews with professors. Evaluation of the instructional model's effectiveness

revealed that its components were generally considered highly appropriate and consistent (M= 4.75, SD= 0.20). This finding supported the principles proposed by Dick and Carey (1996) that the learning management model used should be quality checked, any deficiencies corrected, and subjected to pilot testing to assess its appropriateness and feasibility before it is implemented in an actual experiment to achieve the learning outcome.

5.2. PBL Process

The implementation of the PBL model in teaching enhances the development of 21st-century skills. This research on problem-based learning followed a structured six-step process: 1) Presenting the problem, 2) Analyzing the problem, 3) Conducting study and research, 4) Synthesizing knowledge, 5) Summarizing and evaluating solutions, and 6) Presenting and exchanging knowledge. This method aligns with the problem-based learning management principles outlined by the Secretariat of the Council of Education of Thailand (Office of the Education Council, 2017). Bridges and Hallinger (1995) describe the core features of PBL management, which the developed model also reflects. 1) The problems presented in the learning process reflect real-life challenges that learners are likely to face in their future careers. 2) Learners acquire knowledge by actively solving problems rather than relying on memorization of principles or rules. 3) Collaborative teamwork is emphasized. 4) Most learning occurs through small group work rather than formal classroom instruction. This is according to Tan (2003) assertion that PBL involves multiple phases of learning, including problem introduction, research, resource usage, collaboration, solution proposition, solution presentation, reflection, and learning evaluation. PBL is an instructional approach that actively engages students by presenting problems and encouraging them to learn about a specific subject energetically. This pedagogical approach places learners at the center of their learning experience and allows them to engage in open-ended problem-solving activities (Ali, 2019). Undergraduate Thai students from the Faculty of Education implemented the developed model in their research and innovation subject for online learning during the COVID-19 pandemic. Similarly, Chan et al. (2022) adapted PBL methods for online distance learning that promoted students' critical thinking abilities.

5.3. The Results of Instructional Model Implementation

Experimental implementation of the PBL model produced significant results. After the intervention, a statistically significant difference in students' critical thinking abilities was found at a significance level of .05, indicating that this PBL approach can improve students' 21st-century skills. Well-structured problems and strategic questions can improve the depth and quality of thinking. According to Carrió et al. (2022) and Office of the Education Council (2017), the essential skills for teachers consist of critical thinking, collaboration, teamwork, and leadership. This set of skills is relevant to 21st-century skills. An important learning management process that helps students develop 21st-century skills is active learning, which is a student-centered and lifelong learning process (Van de Bogart, 2009).

The findings of this study are consistent with the research of Cosgun and Atay (2021); Phungsuk et al. (2017) and Saputro et al. (2020) all of which demonstrate the positive effects of PBL on critical thinking. Duch, Groh, and Allen (2001) also support these results by highlighting that problem-based instruction stimulates problem-solving, thus enhancing learners' self-directed learning and critical thinking skills. When comparing the mean scores for collaboration skills, teamwork, and leadership skills, the means for each aspect were significantly different at the .05 level. This finding is consistent with the study by Saldo and Walag (2020) who found differences in pretest and posttest scores for collaboration in PBL methods. Likewise, Christiansen, Kuure, Mørch, and Lindström (2013) said that PBL promoted flexible knowledge, problem recognition and problem-solving skills, effective collaboration, and self-directed learning. In addition, Allert et al. (2022) found significant improvements in teamwork and collaboration skills with problem-based learning. Despite the online nature of this study and the absence of face-to-face interaction among learners, the PBL process effectively fosters these essential skills. According to the

information gained from the interview with students in this study, PBL promotes students' skills in working with others. Students are able to gain a better understanding of the subject content and engage in teamwork and leadership skills.

6. CONCLUSION

This study aims to design and develop a PBL model, which was then implemented in an undergraduate course for Thai student teachers in the subject of "Research and Innovation for Learning." The research findings indicate that the PBL model is of the highest quality. Furthermore, the implementation of the model demonstrated that problem-based learning effectively supports students in achieving learning outcomes. Groups discuss these process-related problems, motivating students to critically analyze and solve them. This model effectively promotes critical thinking, collaboration, teamwork, and leadership skill development, suggesting that it is appropriate for student growth and development.

Therefore, PBL is useful for developing these important skills. In addition, participants were very satisfied with the PBL model. The PBL Model can enhance important skills of undergraduate Thai students and help them better understand the content of research and innovation subjects.

7. RECOMMENDATIONS

According to Thai government policies, they promote active learning. The recommendations are directed to the instructors/teachers. The research results show that the PBL model can promote 21st-century skills. Therefore, the proactive learning management model developed in this study is efficient and beneficial, making it suitable for organizing learning activities in online environments or implementing them in different levels and subjects at the undergraduate level.

Moreover, the model can be extended to students in different faculties. Finally, when implementing the learning management model, it is essential to tailor it to different student groups, e.g., by adapting the problem situations to the specific course content. In addition, the role of the teacher should change to be a facilitator and stimulator to ensure effective implementation and participation. Students at other educational levels, including high school, have successfully applied this model by modifying it to meet their needs.

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Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
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REFERENCES

Ali, A. B., Rosli, D. I., Sujadi, I., Usodo, B., & Perdana, F. A. (2017). Mastering the soft skills in the implementation of work-based learning among community college students. *Journal of Physics: Conference Series*, *795*(1), 1-12. https://doi.org/10.1088/1742-6596/795/1/012004

Ali, S. S. (2019). Problem based learning: A student-centered approach. *English Language Teaching*, *12*(5), 73-78. https://doi.org/10.5539/elt.v12n5p73

Allert, C., Dellkvist, H., Hjelm, M., & Andersson, E. K. (2022). Nursing students' experiences of applying problem-based learning to train the core competence teamwork and collaboration: An interview study. *Nursing Open*, *9*(1), 569-577. https://doi.org/10.1002/nop2.1098

Anchunda, H. Y., & Kaewurai, W. (2021). Instructional model development based on collaborative and communicative approaches to enhance lower secondary students' English-speaking skills in Thailand. *Kasetsart Journal of Social Sciences*, *42*(2), 287-292. https://doi.org/10.34044/j.kjss.2021.42.2.11

Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., . . . Wittrock, M. C. (2001). *A taxonomy for learning, teaching, and assessing: A revision of bloom's taxonomy of educational objectives*. New York: Longman.

Barrows, H., S. (1996). Problem-based learning in medicine and beyond: A brief overview. *New Directions for Teaching and Learning*, *68*, 3-12. http://dx.doi.org/10.1002/tl.37219966804

Bridges, E. M. (1992). *Problem based learning for administrators ERIC clearinghouse on educational management university of Oregon*. Retrieved from http://hdl.handle.net/1794/3287

Bridges, E. M., & Hallinger, P. (1995). *Implementing problem based learning in leadership development ERIC clearinghouse on educational management university of Oregon*. Retrieved from http://hdl.handle.net/1794/3272

Carrió, M., Baños, J., & Rodríguez, G. (2022). Comparison of the effect of two hybrid models of problem-based learning implementation on the development of transversal and research skills and the learning experience. *Frontiers in Education*, *7*, 1-9. https://doi.org/10.3389/feduc.2022.875860

Chan, C. F., An, J. L., Che Rafidah, A., Wei, H. H., Vinod, P., Cockburn, J. G., . . . Jamuna, V. (2022). Learning experiences of pre-clinical medical students in virtual problem-based learning amidst the COVID-19 pandemic. *The Asia Pacific Scholar*, *7*(1), 33-43. https://doi.org/10.29060/taps.2022-7-1/oa2493

Christiansen, E. T., Kuure, L., Mørch, A., & Lindström, B. (2013). *Problem-based learning for the 21st century new practices and learning environments*: Aalborg University Press. https://vbn.aau.dk/ws/portalfiles/portal/187818413/PROBLEM_BASED_LEARNING_FOR_THE_21st_CENTURY_WEB.pdf.

Cosgun, G., & Atay, D. (2021). Fostering critical thinking, creativity, and language skills in the EFL classroom through problem-based learning. *International Journal of Curriculum and Instruction*, *13*(3), 2360-2385.

Dick, W., & Carey, L. (1996). *The systematic design of instruction* (4th ed.). New York: Harper Collins College Publishers.

Dressel, P. L., & Mayhew, L. B. (1957). *General education: Explorations in evaluation* (2nd ed.). Washington, D.C: American Council on Education.

Duch, B. J., Groh, S. E., & Allen, D. E. (2001). The power of problem-based learning: A practical "how to" for teaching undergraduate courses in any discipline. *Stylus Pub.*

Ennis, R. H. (1985). A logical basic for measuring critical thinking skills. *Educational Leadership*, *43*(2), 45–48.

Fink, L. D. (2003). *Creating significant learning experiences: An integrated approach to designing college courses*. San Francisco: Jossey-Bass.

Foo, C. C., Cheung, B., & Chu, K. M. (2021). A comparative study regarding distance learning and the conventional face-to-face approach conducted problem-based learning tutorial during the COVID-19 pandemic. *BMC Medical Education*, *21*(1), 1-6. https://doi.org/10.1186/s12909-021-02575-1

Geisinger, K. F. (2016). 21st century skills: What are they and how do we assess them? *Applied Measurement in Education*, *29*(4), 245–249. https://doi.org/10.1080/08957347.2016.1209207

Hidayati, N., Zubaidah, S., Suarsini, E., & Praherdhiono, H. (2020). The relationship between critical thinking and knowledge acquisition: The role of digital mind maps-PBL strategies. *International Journal of Information and Education Technology*, *10*(2), 140-145. https://doi.org/10.18178/ijiet.2020.10.2.1353

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review*, *16*, 235-266. https://doi.org/10.1023/b:edpr.0000034022.16470.f3

Hsu, Y.-C. (2021). An action research in critical thinking concept designed curriculum based on collaborative learning for engineering ethics course. *Sustainability*, *13*(5), 2621. https://doi.org/10.3390/su13052621

Hung, W. (2011). Theory to reality: A few issues in implementing problem-based learning *Educational Technology Research & Development*, *59*(4), 529–552. https://doi.org/10.1007/s11423-011-9198-1

Joyce, B., Weil, M., & Calhoun, E. (2015). *Models of teaching* (9th ed.). New Jersey: Pearson.

Joynes, C., Rossignoli, S., & Amonoo-Kuofi, E. F. (2019). 21st century skills: Evidence of issues in definition, demand and delivery for development contexts. *Institute of Development Studies*, *1*(1), 1-77.

Kneedler, P. E. (1985). *Assessment of critical thinking skills in history-social science*. Sacramento, CA: California State Department of Education.

Loveland, T., & Dunn, D. (2014). Teaching engineering habits of mind in technology education. *Technology and Engineering Teacher*, *73*(8), 13-19.

OECD. (2023). PISA 2022 results: The state of learning and equity in education, PISA. In (Vol. 1): OECD Publishing. https://doi.org/10.1787/53f23881-en.

Office of the Education Council. (2017). *Education in Thailand*: Prigwan Graphic Co. Ltd. https://www.bic.moe.go.th/images/stories/pdf/EDUCATION_IN_THAILAND_2017.pdf.

Office of the Education Council. (2023). *Education in Thailand 2022. Prigwhan Graphic*. Retrieved from https://backoffice.onec.go.th/uploads/Book/2057-file.pdf

Partnership for 21st Century Learning. (2016). *Framework for 21st century learning*. Retrieved from https://www.battelleforkids.org/

Phungsuk, R., Viriyavejakul, C., & Ratanaolarn, T. (2017). Development of a problem-based learning model via a virtual learning environment. *Kasetsart Journal of Social Sciences*, *38*(3), 297-306. http://dx.doi.org/10.1016/j.kjss.2017.01.001

Prada, E. D., Mareque, M., & Pino-Juste, M. (2022). Teamwork skills in higher education: Is university training contributing to their mastery? *Psicologia: Reflexao e critica*, *35*, 1-13. https://doi.org/10.1186/s41155-022-00207-1

Prettyman, S. S., Ward, C. L., Jauk, D., & Awad, G. (2012). 21st century learners: Voices of students in a one-to-one STEM environment. *Journal of Applied Learning Technology*, *2*(4), 6-15.

Redecker, C., Ala-Mutka, K., Leis, M., Leendertse, M., Punie, Y., Gijsbers, G., . . . Hoogveld, B. (2011). *The future of learning: Preparing for change*: Publications Office of the European Union.

Rusbult, C. (2007). *Active-learning theories (Constructivism)*. Retrieved from http://www.asa3.org/ASA/education/teach/active.htm#constructivism

Saldo, I. J. P., & Walag, A. M. P. (2020). Utilizing problem-based and project-based learning in developing students' communication and collaboration skills in physics. *American Journal of Educational Research*, *8*(5), 232-237.

Saputro, A. D., Atun, S., Wilujeng, I., Ariyanto, A., & Arifin, S. (2020). Enhancing preservice elementary teachers' self-efficacy and critical thinking using problem - based learning. *European Journal of Educational Research*, *9*(2), 765-773. https://doi.org/10.12973/eu-jer.9.2.765

Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. *Interdisciplinary Journal of Problem-Based Learning*, *1*(1), 9-20. https://doi.org/10.7771/1541-5015.1002

Scott, C. L. S. (2015). *The futures of learning 2: What kind of learning for the 21st century? (ERF Working Paper No. 14) UNESCO Education Research and Foresight*. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000242996

Srikan, P., Pimdee, P., Leekitchwatana, P., & Narabin, A. (2021). A problem-based learning (PBL) and teaching model using a cloud-based constructivist learning environment to enhance Thai undergraduate creative thinking and digital media skills. *International Journal of Interactive Mobile Technologies*, *15*(22), 68-83. https://doi.org/10.3991/ijim.v15i22.24963

Strimel, G. (2014). Authentic education. *Technology and Engineering Teacher*, *73*(7), 8- 18.

Tan, O. S. (2003). *Problem-based learning innovation: Using problems to power learning in the 21st century*. Singapore: Thomson Learning.

Thanudca, S. (2021). The comparisons of effects of the cooperative learning model using metacognitive moves and traditional instruction on the science for quality-of-life subject for enhancing the learning achievement and critical thinking of undergraduate students at Chaiyaphum Rajabhat University. *Kasetsart Journal of Social Sciences*, *42*(4), 894–903.

Van de Bogart, W. G. (2009). *Active learning pedagogy: A new teaching methodology for a new generation of teachers.* Retrieved from http://www.southeastasianreview.com/Active%20learning%20Pedagogy.pdf

Vega, A., & Brown, C. (2013). The implementation of project- Based learning. *National Forum of Educational Administration and Supervision Journal, 30*(2), 4-29.

Weimer, M. (2013). *Learner-centered teaching: Five key changes to practice* (2nd ed.). San Francisco: Jossey-Bass.

Wood, D. F. (2003). Problem based learning. *Bmj, 326*(7384), 328-330. https://doi.org/10.1136/bmj.326.7384.328