Journal of Information Technology Education: Research

An Official Publication of the Informing Science Institute
InformingScience.org

JITEResearch.org

Volume 24, 2025

ONLINE PBL AND CRITICAL THINKING: EFFECTS OF SELF-REGULATED LEARNING LEVELS IN COMPUTER SCIENCE

Amira Saif	Universiti Sains Malaysia (USM), Penang, Malaysia	Amirsaif77@yahoo.com
Hanan Aldowah*	Universiti Sains Malaysia (USM), Penang, Malaysia	hanan@usm.my

* Corresponding author

ABSTRACT

Aim/Purpose	The purpose of this study is to investigate the effectiveness of online problem-based learning (PBL) in enhancing critical thinking among novice programmers with varying levels of self-regulated learning (SRL). While PBL has been widely studied in traditional settings, this study uniquely examines the integration of online PBL with SRL to enhance critical thinking. This area remains underexplored in the field of programming education.
Background	Problem-based learning (PBL) emphasizes learning behaviors that lead to critical thinking, problem-solving, communication, and collaborative skills, preparing students for professional academic skills.
Methodology	A quasi-experimental design involving pre-test and post-test on the experimental and control groups was used in this study. The experimental group used online PBL, while the control group followed direct instruction. The sample comprised 120 second-year Bachelor of Computer Science students from two different higher education institutions. The participants were evenly divided between the experimental group (n = 60) and the control group (n = 60). Critical thinking was measured using Yoon's Critical Thinking Disposition instrument, which evaluates students' critical thinking.
Contribution	This study contributes to the growing body of knowledge by highlighting the effectiveness of online PBL in learning and its potential to enhance the critical thinking of students with diverse SRL levels.

Accepting Editor Vishal Shah │ Received: April 28, 2025 │ Revised: July 21, September 17, 2025 │ Accepted: October 12, 2025.

Cite as: Saif,. A., & Aldowah, H. (2025). Online PBL and critical thinking: effects of self-regulated learning levels in computer science. *Journal of Information Technology Education: Research, 24,* Article 36. https://doi.org/10.28945/5642

Findings	The results revealed that students in the experimental group scored significantly better on the critical thinking test compared to the control group ($F = 5.87$, $p < .05$), with mean scores of 101.98 and 97.85, respectively. These findings revealed that the integration of online PBL with SRL fostered positive improvements in students' critical thinking.
Recommendations for Practitioners	Provide professional development for practitioners to effectively design, implement, and facilitate online PBL experiences.
Recommendations for Researchers	The findings may encourage other researchers to apply the online problem-based learning approach in different courses and provide evidence that online PBL can serve as a viable alternative to traditional direct instruction.
Impact on Society	Our study emphasized the importance of encouraging interdisciplinary collaboration to create PBL tasks that mirror real-world challenges and prepare students for professional practice.
Future Research	Future work can experiment with online PBL to explore its potential in other disciplines and educational contexts.

Keywords	online problem-based learning, critical thinking, self-regulated learning

INTRODUCTION

Problem-based learning (PBL) is a widely adopted educational approach that enhances student engagement by integrating theoretical knowledge into real-world problem solving. Rooted in collaborative learning principles, PBL places students in small groups where they actively explore and solve authentic problems under the guidance of a facilitator (Barrows, 1996). This student-centered method encourages deeper understanding by promoting self-directed learning, critical thinking, and teamwork. Over the years, PBL has been implemented across various disciplines, including medicine, business, nursing, programming, and law (Choi et al., 2014; Hidayatullah & Setiawan, 2024; Wijnen et al., 2017).

Self-directed learning encourages students to take ownership of their educational journey by planning, monitoring, and evaluating their progress, thereby fostering lifelong learning habits. Collaborative learning in a contextualized setting fosters interaction among students as they work towards shared goals, exchanging ideas and providing feedback to deepen their understanding of the subject matter. PBL has been shown to boost students' self-confidence and develop crucial skills such as critical thinking, problem-solving, and collaboration. By fostering constructive, self-directed, collaborative, and contextual learning, PBL empowers students to connect prior knowledge with new concepts, develop problem-solving skills, and take ownership of their learning process. Given its effectiveness in enhancing academic and professional competencies, understanding its impact on student learning remains an essential area of research (Hidayatullah & Setiawan, 2024).

In science learning, students' critical thinking skills are reflected in their ability to analyze and respond to real-world problems. Critical thinkers tend to be more proactive in problem-solving (Sri Handoyo et al., 2019) and demonstrate greater emotional regulation and self-awareness (Yao et al., 2018). They actively clarify issues by asking insightful questions, considering multiple perspectives, extracting key information, and formulating rational solutions. Additionally, they have the confidence to express their ideas, critique different viewpoints, and draw well-reasoned conclusions. Critical thinking is an ongoing process of logical reasoning that involves systematically analyzing concepts, evaluating complex situations, and effectively utilizing information while assessing its sources (Thomas & Lok, 2015). This skill is essential for learners as it enables them to deal with problems effectively and evaluate solutions critically based on their abilities and real-life experiences (Yusuf et al., 2024). Furthermore, the ability to think critically is crucial for learners because it is considered a distinguishing characteristic of an educated person and a requirement for being an active and involved employee and citizen of the world (Facione, 2010).

Recently, the integration of PBL into online learning environments has gained momentum, particularly in response to global educational shifts (Saif & Umar, 2021). Online PBL enhanced students' ability to navigate personalized learning paths, allowing them to manage their time and engage in structured learning activities effectively (Alshaye et al., 2023; Hidayatullah & Setiawan, 2024). Online platforms facilitate self-regulated learning by providing guidance that encourages students to follow an organized study plan, leading to improved academic performance. As an essential learning strategy, self-regulated learning enables students to take control of their learning process, fostering deeper engagement and knowledge acquisition (Hwang et al., 2021). The combination of PBL and self-regulated learning supports independent problem-solving, enhances reasoning skills, and strengthens motivation by allowing students to construct knowledge through real-world applications actively (Rosdiana et al., 2018). In developing contexts, where access to quality face-to-face instruction can be limited, online PBL offers a scalable and flexible alternative for improving student outcomes, particularly in programming education.

While the impact of online PBL on critical thinking has been widely explored, limited attention has been paid to how students' self-regulated learning levels interact with instructional methods in shaping learning outcomes. This gap may hinder educators' ability to design effective strategies that engage students in managing real-world programming challenges. To address this, our study investigates the influence of online PBL on students' critical thinking and examines how SRL levels affect their learning outcomes in this environment. Accordingly, the following research questions are investigated in this study:

RQ1: Is there any significant difference in students' critical thinking who received online PBL and those who received Direct Instruction?

RQ2: Is there any interaction effect between SRL levels and learning methods (PBL and DI) in students' critical thinking?

RQ3: Is there any significant difference in students' critical thinking between high SRL and low SRL students in Online PBL?

RQ4: What skills do students develop through online PBL, and how effectively does it enhance their critical thinking in problem-solving?

To answer these questions, this study employed a sequential mixed-methods design, beginning with a quantitative phase, followed by a qualitative phase. By integrating both approaches, the research provides a comprehensive perspective on the effectiveness of online PBL in learning environments (Figure 1). This design contributes to a deeper understanding of how online PBL enhances students' critical thinking skills, particularly in relation to varying levels of self-regulated learning (SRL).

This study offers two key contributions. First, it examines the interplay between online PBL and SRL in the context of programming education, a connection that has received limited empirical attention. Second, it extends theoretical insights from constructivism and self-regulated learning by applying them in an online, problem-based instructional context, offering practical implications for curriculum designers and educators.

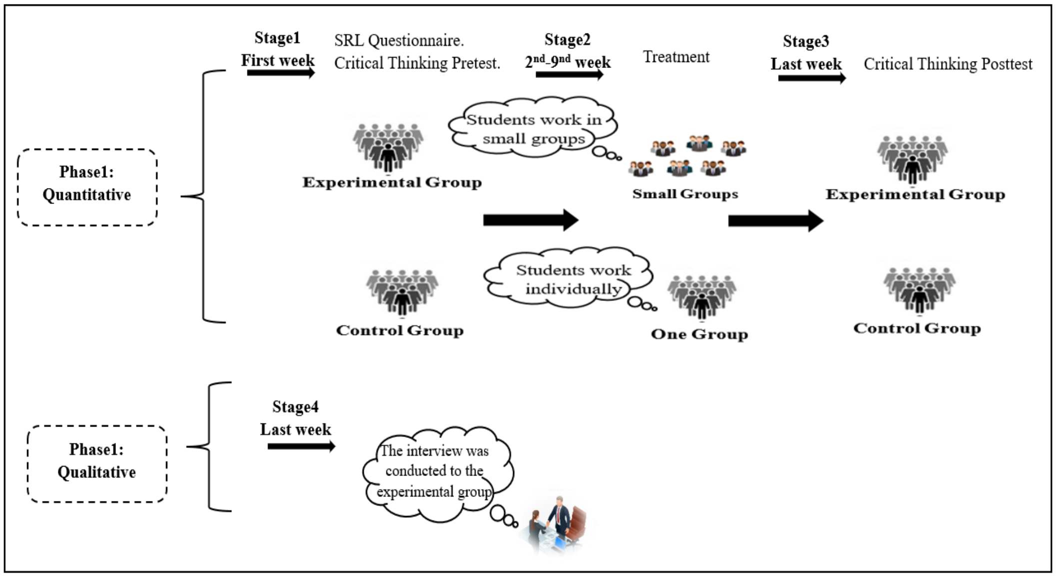


Figure 1. Overview of the study's procedural framework

THEORETICAL FOUNDATIONS AND KEY INSIGHTS

CRITICAL THINKING

Critical Thinking (CT) is an analytical process that involves evaluating one's own thoughts to arrive at rational and logical problem-solving (Rapti & Sapounidis, 2024). It requires the ability to clarify issues, focus on solutions, and critically understand, analyze, and assess assumptions. While CT includes various skills, it is also widely recognized as a complex and multifaceted concept. Several scholars have attempted to define it, including Facione (1990), Paul (1990), and Watson and Glaser (1980). Notably, El-Soufi (2019) highlighted that many academics consider critical thinking to encompass a range of dispositions, which are often regarded as more important than skills alone. One widely accepted framework for understanding critical thinking dispositions is Facione & Facione's (1992), which emphasizes the attitudinal and affective components – such as open-mindedness and persistence – that influence how individuals approach problems and make decisions. Based on this model, the California Critical Thinking Disposition Inventory (CCTDI) was developed to measure these dimensions. The CCTDI aligns closely with the conceptualization of CT dispositions and has been validated for use with undergraduate students (Facione, 1990; Yeh, 2002). Multiple studies have supported its reliability in educational contexts (El-Soufi, 2019; Facione & Facione, 2013; Jung et al., 2017; Shin, Park et al., 2015). Building on the CCTDI, Yoon (2004) developed the Yoon's Critical Thinking Disposition (YCTD) specifically for undergraduate learners. The YCTD shares similar subcategories with the CCTDI and includes seven dimensions: prudence, systematicity, objectivity, intellectual eagerness/curiosity, intellectual fairness, skepticism, and self-confidence (Shin, Park et al., 2015). Its validity and reliability have been affirmed in various studies (Kim, 2012; Yang et al., 2009; Yoon, 2004, 2008).

This study focuses on the affective disposition dimension of critical thinking. Affective dispositions – such as attitudes, habits of mind, and personal traits – play a crucial role in shaping students' engagement with problem-solving, particularly in programming education. These dispositions foster students' willingness to think critically, remain open to multiple solutions, and persist in the face of complexity (Hu, 2011). As Davies (2015) argued, a complete understanding of critical thinking must include dispositional elements. Therefore, this study emphasizes the affective aspect of CT using Yoon's Critical Thinking Disposition model.

SELF-REGULATED LEARNING

Self-Regulated Learning (SRL) involves learners actively setting goals, monitoring, and controlling their cognition, motivation, and behavior within the learning environment (Pintrich, 2000). Zimmerman (1989) explains that SRL encompasses metacognitive, motivational, and behavioral engagement, enabling students to become more aware and in control of their own learning activities. It plays a vital role in blended learning by supporting active interaction between students and learning tasks (Leong Lim et al., 2020). Traditionally, SRL has been measured using tools like the Self-Regulated Learning Interview Scale (SRLIS) and the Motivated Strategies for Learning Questionnaire (MSLQ). However, these instruments were designed for face-to-face learning and may not fully capture SRL in online settings (Barnard et al., 2009; Lynch & Dembo, 2004; McManus, 2000; Schwam et al., 2021). For example, McManus (2000) found that students with high SRL did not always perform better in online courses when measured by the MSLQ. To overcome this limitation, Barnard et al. (2009) developed the Online Self-Regulated Learning Questionnaire (OSLQ), which is a modified version of Pintrich's MSLQ made for online and blended learning environments (Handoko, 2017).

The OSLQ has been widely used in research to assess SRL in these contexts (Lee et al., 2020; Vilkova & Shcheglova, 2021). Its validity was supported by confirmatory factor analysis, showing strong construct validity (Barnard et al., 2009; Chang et al., 2015). Success in online learning depends greatly on students' ability to manage their time and regulate their own learning (Aldowah et al., 2020). Studies show that students with strong SRL skills tend to perform better than those with weaker skills (Sudia & Muhammad, 2020; Swafford, 2018; van Alten et al., 2021). Although SRL is widely recognized for its benefits, Brandmo et al. (2020) highlight that SRL models and classroom assessments are rarely integrated in practice, potentially limiting their effectiveness. Additionally, Dignath and Veenman (2021) emphasize that explicit strategy instruction by teachers is often essential, not just passive modeling, to support effective SRL development in students.

Despite the growing use of instruments like OSLQ to assess SRL in online settings, there is still limited research examining how SRL influences students' learning outcomes, especially in programming education and when combined with online PBL approaches. Moreover, the differences in SRL impact across learners with varying self-regulation levels remain underexplored in such contexts.

PROBLEM-BASED LEARNING

Problem-Based Learning (PBL) is a student-centered approach that promotes active engagement, research (Saif et al., 2024; Wijnia et al., 2024), and the integration of theory with practice to build essential 21st-century skills (Bell, 2010). First introduced at McMaster University in the 1960s, PBL encourages learners to take responsibility for their own learning by solving real-world problems (Neville & Norman, 2007; Savery, 2006). Schmidt (1983), a pioneer of PBL, explains that learning occurs when students are actively engaged in solving problems. In programming education, this means presenting students with open-ended problems that require them to explore, make hypotheses, and test programming solutions. This process helps them understand programming concepts through experience rather than through direct instruction. PBL also emphasizes collaboration. Students work in small groups to identify problems, generate hypotheses, search for relevant information, and present solutions (Saif et al., 2024). This collaborative process encourages critical thinking (Fitriani et al., 2021; Loyens et al., 2015; Şendağ & Odabaşı, 2009; Sudia & Muhammad, 2020) and helps students become more independent and responsible for their learning (Inayah et al., 2021; Surya et al., 2018; Ulger, 2018). Instructors act as facilitators, guiding the learning process rather than delivering content directly (Saif & Umar, 2019). However, recent studies have raised concerns about the variability in outcomes. For example, Erdem et al. (2025) noted that the success of PBL often depends on student readiness and the quality of the facilitator. Similarly, Lee et al. (2020) found that while online PBL enhances engagement, some students struggle with the self-direction required for this approach.

In this study, PBL was implemented in an online environment using a blended approach. Google Meet was used for live group discussions, while Google Classroom supported asynchronous activities. Students were divided into small groups to work on assignments, explore problems using online resources, and share findings. This approach allowed learners to apply programming concepts in a meaningful and collaborative way. Table 1 shows the processes of this method, which is adapted from the Seven-Step approach (Schmidt, 1983).

Table 1. Processes of problem-based learning

Step	PBL processes
1	Explanation of new words and concepts should be the first activity to resolve any problem.
2	Definition of the problem to the students.
3	Analyze the problem to produce the result; if students are not able to analyze the problem correctly, the result will not be accurate.
4	Create a structure or flowchart to allow students to understand the program so that it can be used to verify that what it displays is proper and effective.
5	Code and test the program: writing a program to determine the data, such as variables and numbers, whereas testing a program to ensure the best solution.
6	Evaluate and discuss the final solution.

However, despite the proven benefits of PBL in developing critical thinking and problem-solving skills, limited research has explored how online PBL can be effectively applied in programming education, especially in developing countries. Most existing studies focus on face-to-face PBL or general online learning, without examining how PBL can be adapted to virtual environments using common platforms like Google Meet and Google Classroom. This study aims to fill this gap by investigating the effectiveness of online PBL in helping students understand programming concepts and improve their learning outcomes.

METHODOLOGY

This study employed a sequential mixed-methods design, which proceeded with a quantitative phase and was followed by a qualitative phase (Creswell, 2013). Regarding the quantitative phase, a quasi-experimental design involving pre-tests and post-tests on the experimental and control groups was used. The research attempts to compare the effects of two learning methods, Online Problem-Based Learning (PBL) and Direct Instruction (DI) methods, on students' critical thinking with two levels of Self-Regulated Learning (SRL) as a moderator variable in the teaching and learning of basic programming concepts, as illustrated in Table 2. The students' critical thinking was measured based on the pre-test and post-test scores obtained from Yoon's Critical Thinking Disposition (YCTD).

Table 2. Pre-test and post-test experimental design

O_1	X_1	O_3
O_1	X_2	O_3
Where,		
O_1:	Pre-Test (Critical Thinking)	
O_3:	Post-Test (Critical Thinking)	
X_1:	Experimental Group (PBL method)	
X_2:	Control Group (DI method)	

Participants were divided into two groups, comprising second-year programming students from two colleges of computer science in different cities. In total, 143 students participated in this research, which employed a 2 x 2 quasi-experimental study design; a minimum of 30 subjects was expected per group. The recommended sample size in an experimental study is a minimum of 30 subjects per group to establish the existence or nonexistence of a relationship (Gay et al., 2012). However, due to student absences and incomplete responses, only 120 students were included in the final sample. Therefore, the sample size was 120 students, and they were divided into two groups: the PBL group and the DI group (60 students per group). The two colleges were randomly assigned to receive either the PBL or the DI treatments. Each of these two treatment groups involved high-SRL and low-SRL students. Thus, the final sample consisted of four subgroups (low-SRL DI, low-SRL PBL, high-SRL DI, and high-SRL PBL), each with 30 students, fulfilling the minimum requirement for experimental studies.

Data Collection

The assessment of critical thinking disposition before and after the experiment was carried out using YCTD, according to which it is expressed in seven components: prudence, systematicity, objectivity, intellectual eagerness/curiosity, intellectual fairness, skepticism, and self-confidence (Jung et al., 2017; Shin, Ma et al., 2015; Shin, Park et al., 2015). The questionnaire included 27 items on a 5-point rating scale (from 1 – strongly disagree to 5 – strongly agree), such as "When I am questioned, I think twice before giving my answer" and "I am handling complicated problems by my criteria." The Cronbach's alpha values for the questionnaire in this study were: YCTD Pre-Test, 0.96, and YCTD Post-Test, 0.86.

The questionnaire on self-regulated learning was carried out before the experiment to evaluate the students' level of SRL. This questionnaire has six subscale constructs including "environment structuring," "goal setting," "time management," "help seeking," "task strategies," and "self-evaluation" (Cobb, 2020; Tao et al., 2020), with 24 items and uses a 5-point Likert scale, which ranges from 1 (totally disagree) to 5 (totally agree). Based on the group mean score for the overall OSLQ (3.49), students' SRL levels were classified as either high or low. Participants with scores above the mean were categorized as having high SRL, while those with scores below the mean were classified as having low SRL. Accordingly, mean scores of 3.49 or higher for SRL items were considered high; otherwise, they were considered low. Cronbach's alpha value for this questionnaire is 0.92, indicating that it is a highly reliable questionnaire.

Experimental Procedure

This research was conducted over a period of 10 weeks. The experimental group received the online PBL method, while the control group was treated with the direct instruction method. Cloud computing tools, such as Google Meet and Google Classroom, were used in this research to support online learning. The research procedures were implemented through three stages.

First stage: The questionnaires were sent via email and WhatsApp group to increase attention in the first week. The OSLQ was sent to the students to categorize them as either low SRL (LSRL) or high SRL (HSRL) learners, and the YCTD pre-test was sent to the students. In the experimental group, the students were divided into small groups, with each group consisting of 3 to 4 LSRL students and 3 to 4 HSRL students. Meanwhile, the 60 students in the control group worked individually. Topics related to web programming were delivered to both the control and experimental groups. The lecturers explained the main topics of the course (HTML and JavaScript) by using Google Meet, and they introduced the learning methods.

Second stage: The intervention was conducted from week 2 until week 9; the experimental group received the PBL method, whereas the control group was treated with the direct instruction method.

Third stage: The YCTD post-test was administered in week 10.

Concerning the experimental group, the students were organized into eight smaller groups, each comprising a mix of high- and low-self-regulated students. Each of these groups is composed of four high-SRL students and three low-SRL students. The lecturer then gave an introductory lecture about the main topics of the course, the study environment, and explained the processes of the PBL model using Google Meet. This group was allocated four hours of sessions per week (Figure 2).

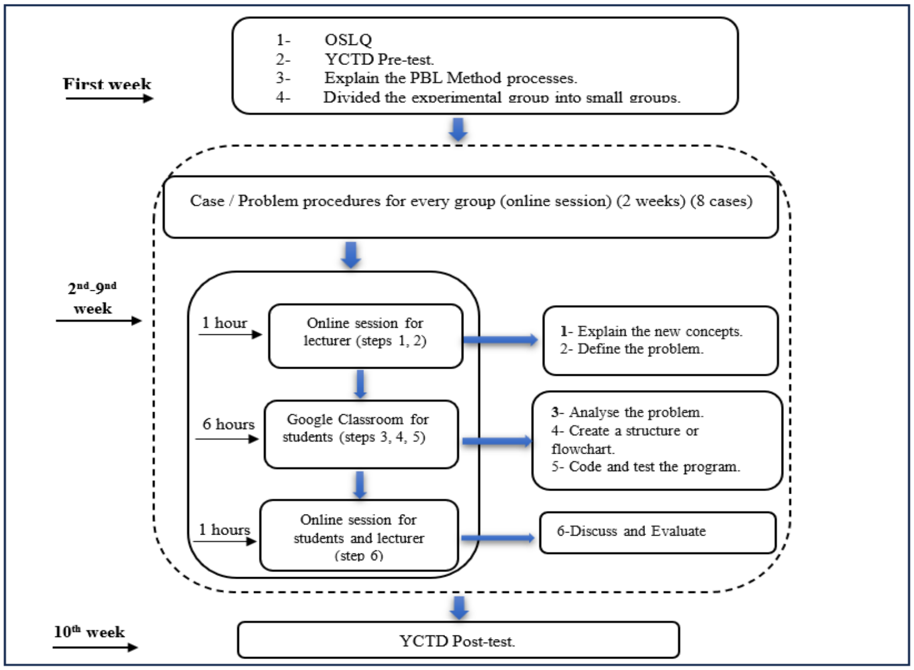


Figure 2. Experimental group procedures

For two weeks (8 hours), the lecturer provided a brief introduction to the topics and explained new concepts and terms on the Google Meet platform. Then, the lecturer defined and analyzed the problem. He also explained the main concepts and some of the terms related to the problem, for example, the concept of tags in HTML and how they are used to display content on a webpage, such as the <img> tag. The lecturer then gave each group a class code to access Google Classroom (steps 1 and 2 from the PBL processes). In Google Classroom, the lecturer distributed tasks among the group and assigned roles to each student (for example, a task for the Leader, a task for the Checker, a task for the Recorder, etc.). This has provided the students with an opportunity to contribute to their learning. The lecturer posted the problem as a shareable file in each group (step 2). In Google Classroom, each student wrote the solution as a flowchart, note, diagram, or shared a link, as illustrated, and the lecturer monitored the students' discussions, comments, and activities. He acted as a facilitator to guide them in seeking information and developing an understanding of themselves through: (i) help students with key points; (ii) carry out mini summaries as needed; (iii) motivate the students to learn how to use and access the given resources; (iv) encourage discussion between students; and (v) do not answer their questions, but make them think more deeply to discover the solutions (see Figure 4). Additionally, the students worked collaboratively through:

i. Working in a small group discussion enables distributed thinking.
ii. Engage in group work to solve the problem.
iii. The Leader helps the lecturer to distribute the tasks and produces a short report explaining how the work is divided.
iv. The Checker monitors the solutions and contributions.
v. The Recorder checks if there is consensus and writes the final version.

vi. The Members provide alternative suggestions, keeping all of them from jumping to premature solutions.

These collaborative steps not only supported the learning process but also encouraged reflective thinking, problem analysis, and decision making, thus greatly enhancing students' critical thinking abilities.

Finally, the group members chose the final solution, which was tested by the Recorder (steps 4 and 5). On Google Meet, each group presented a solution, and the lecturer discussed and evaluated their solutions. Then, he provided a summary for the topic (step 6).

Before the intervention, the researchers provided the lecturers with lecturer protocols to guide their teaching in the experimental study. Before this, permission to collect data was obtained from the appropriate institutional authorities, and the lecturers agreed to participate in the study. A lecturer's protocol is a document that provides specific information about how and what to teach the course. It includes details such as the course theme, learning resources, learning objectives, problems, exercises, and the concepts students are expected to master. Additionally, it outlines the roles of both the lecturer and the students in the learning process. These protocols were designed to assist lecturers in effectively applying the relevant learning methods – online PBL and DI – in teaching the course. Lecturers received thorough training on the use of the protocols. This training emphasized the proper application of online PBL and DI methodologies. To ensure fidelity in the experimental study, the researchers used checklists to verify that both groups adhered to the provided protocols.

Furthermore, the interviews were conducted at the end of the course, after the treatment had been completed, and the interviewers were then selected randomly from the PBL group. Before conducting the interviews, all participants provided their informed consent. Additionally, the researcher contacted all participants a few days in advance to schedule a convenient time for the personal interview. It was made clear to the participants that any sensitive or potentially harmful remarks they made would be discussed anonymously in the text.

The researcher prepared the necessary support materials for the interview process, including a voice recorder (which the researcher used on her mobile phone), a pen, and a notebook. Each interview session was conducted between 20 and 30 minutes, allowing sufficient time for in-depth discussions while maintaining participant focus (Ayton et al., 2023). The interview process was spread over four days to accommodate participants' schedules. This duration also allowed for flexibility, giving the interviewer time to reflect on each session and make any necessary adjustments for subsequent interviews. After collecting data from the open-ended questions, the researcher transcribed the interview results and ensured the validity of the gathered data. Each transcribed interview was saved in a separate MS Word document. Two cycles of qualitative coding were initiated. In the first cycle, NVivo coding was used, followed by thematic analysis in the second cycle. The qualitative findings observed from the interview were used to support the quantitative data obtained from the experimental study.

RESULTS

The findings highlight key differences between the groups. The descriptive statistics showed that the mean score of the critical thinking pre-test for the control group is 99.48 (SD: 9.19), whereas the experimental group exhibits a mean score of 89.18 (SD: 16.91). It can be concluded that the pre-knowledge of both groups regarding the current study's topic was heterogeneous, meaning that the two groups had different levels of prior knowledge related to the subject being studied (Table 3). To examine whether there is a significant statistical difference between pre-tests at $p < 0.05$, a t-test was conducted. According to Gay et al. (2003), Hittleman and Simon (2002), and Johnson and Christensen (2000), when non-equivalence exists between the experimental and control groups in the pre-test, analysis of covariance (ANCOVA) can be employed to analyze post-test scores.

Table 3. Descriptive statistics for the pre-tests and post-test

Groups	N	Pre-test		Post-test	
		Mean	SD	Mean	SD
Experimental Croup	60	89.18	16.91	98.17	16.32
Control Group	60	99.48	9.19	101.67	9.38
Total	120			99.92	13.37

Table 4 shows the overall differences in the critical thinking pre-test scores between the two groups (experimental and control). Significant differences were observed, with [F:21.41, p:0.00]. Based on this result, this means that the two groups are not equally homogeneous in their critical thinking. Thus, it is vital to use the pre-test as the covariate in controlling for the existing knowledge that differs between the groups. Because these groups may vary on several different attributes, employing ANCOVA helps to mitigate some of these differences (Pallant, 2013).

Table 4. t-test result

		F	Sig.	T	df	Sig. (2-tailed)
CT-Pre	Equal variances assumed	21.41	.000	4.15	118	.000
	Equal variances not assumed			4.15	91.04	.000

A one-way ANCOVA analysis was conducted to assess the effects of the two groups (experimental and control) on students' critical thinking. The analysis is meant to determine if there is a significant difference in the dependent variable (student critical thinking) between the two different groups (experimental and control), while controlling for the pre-test.

To answer Question 1, the analysis results in Table 5 indicate a significant difference between the two groups (experimental and control) in the students' critical thinking. The experimental group, i.e., the PBL group, scored significantly better on the critical thinking test compared to the control group, i.e., the DI group [F: 5.87, $p < 0.05$], with means of 101.98 (SD 1.17) and 97.85 (SD 1.17), respectively. The effect size (η^2: 0.05*)* indicates a small to medium effect according to Cohen's (1988) guidelines, indicating that the relationship between the learning methods and critical thinking was small to moderate in strength. The findings also suggested that the experimental group performed better than the control group in terms of the students' critical thinking post-test scores, as shown in Table 3.

Table 5. One-way ANCOVA results of the two treatment groups

Groups	N	Mean	SD	Adjusted mean	Adjusted SD	F	Partial eta squared
Control group	60	101.67	9.38	97.85	1.17	5.87	.05
Experimental group	60	98.17	16.32	101.98	1.17		

In the experimental group, the mean score for the critical thinking post-test increased to 98.17, while in the control group, it rose to 101.67. There is a difference of 8.98 for the experimental group and 2.18 for the control group. Accordingly, findings related to Research Question 1 (RQ1) are as follows: There is a significant difference in students' critical thinking between those who received online PBL and those who received Direct Instruction. This finding suggests that online PBL is more effective than traditional direct instruction in promoting students' critical thinking, emphasizing the value of active, student-centered approaches in programming education.

Question 2 aimed to examine whether there is an interaction effect between the different groups (experimental and control) and SRL levels (high and low) on students' critical thinking. Two-way ANCOVA was conducted to investigate the interaction effects between learning methods and SRL levels on the students' critical thinking using the profile plots and a formal statistical test (Table 6).

Table 6. Two-way ANCOVA results of the post-tests between learning methods and SRL levels

Groups	SRL_level	N	Mean	SD	F	Sig
Control Group	High	30	98.67	1.56	3.21	.08
	Low	30	96.69	1.55		
Experimental Group	High	32	105.65	1.55		
	Low	28	98.15	1.58		

The results of the two-way ANCOVA revealed no interaction effects on the post-test scores between learning methods and SRL levels [F: 3.21; p = 0.08]. Additionally, Figure 3, the profile plot, showed that there is no significant interaction effect in terms of critical thinking between the learning methods and the SRL levels. The profile plot displayed parallel lines for high and low SRL, indicating that there was no interaction effect between learning methods and SRL levels, despite some students with different SRL levels perceiving the learning methods differently. In addition, high SRL students in the online PBL group attained higher scores in critical thinking than their low SRL colleagues in the same group, and the same result can be observed in the DI group. Furthermore, among the high SRL students, those who received online PBL intervention scored better than their high SRL colleagues who received DI treatment, and the same result was observed among the low SRL students. It can be concluded that the high SRL students consistently achieve better results than the low SRL students. Therefore, findings related to Research Question 2 are that there is no interaction between SRL levels and learning methods (PBL and DI) on students' critical thinking. This indicates that the influence of learning method on critical thinking was consistent across SRL levels, implying that PBL may benefit both low- and high-SRL students. However, the extent of benefit may differ.

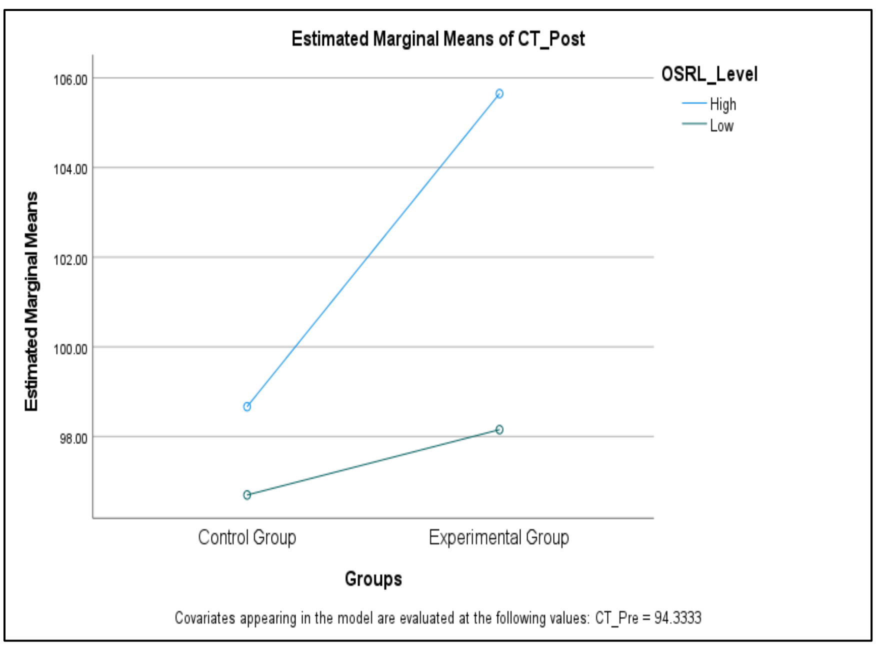


Figure 3. Interaction effect plots for critical thinking between learning methods and SRL levels

The pairwise comparisons of critical thinking were conducted, as shown in Table 7, to identify whether there is a significant difference in students' critical thinking between high SRL and low SRL students in Online PBL. The results of pairwise comparisons revealed a significant difference in scores between the LSRL students and the HSRL students in the PBL group [F: 6.07; p = 0.01]. The effect size ($\eta^2 = 0.1$) was considered a significant effect according to Cohen's (1988) guidelines, indicating that the relationship between the LSRL students and the HSRL students in the PBL group was substantial. As mentioned above, the high SRL students in the online PBL group (mean: 105.65) attained significantly higher scores than the low SRL students in the online PBL group (mean: 98.15). Thus, the findings related to Research Question 3 indicate a significant difference in students' critical thinking between high-SRL and low-SRL students within the online PBL group. This suggests that students with higher self-regulated learning (SRL) skills benefit more from online PBL in developing critical thinking, highlighting the importance of fostering SRL in technology-enhanced learning environments.

Table 7. Pairwise comparisons for critical thinking

SRL levels/ groups	SRL levels/ groups	df	Mean square	F	Sig.	Partial ETA squared
HSRL in PBL	LSRL in PBL	1	744.48	6.07	0.01	0.10
HSRL in DI	LSRL in DI	1	50.77	3.17	0.08	0.05
HSRL in PBL	HSRL in DI	1	209.59	1.96	0.16	0.03
LSRL in PBL	LSRL in DI	1	113.31	8.22	0.01	0.13

Figure 4 illustrates the students' interaction in the PBL group within the online learning environment. Students actively engage in solving problems to identify appropriate solutions. They collaborate with their peers, working together to exchange ideas, share perspectives, and build collective knowledge. Discussions play a pivotal role, as students discuss possible solutions, evaluate alternatives, and refine their understanding of the problem. These activities are facilitated by Google Classroom, which serves as a central platform for communication, resource sharing, and collaboration, thereby enabling an interactive and student-centered learning experience.

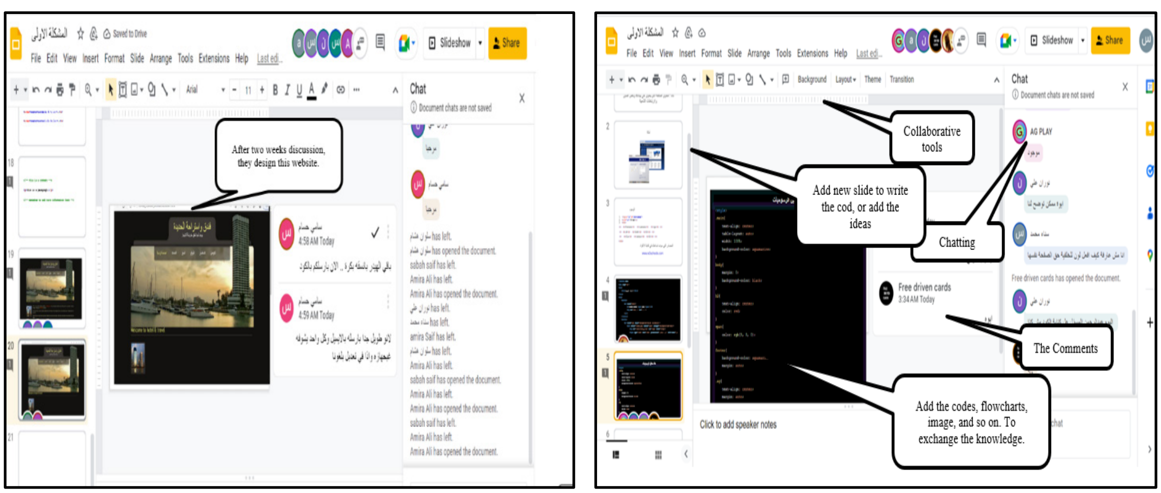


Figure 4. The interaction between students in an online PBL environment

Regarding the qualitative data, Figure 5 illustrates the thematic analysis phases employed in this study to generate theme codes (Braun & Clarke, 2006). The thematic analysis was conducted to ensure the themes are distinct and free from redundancy. This process involved several iterative phases to identify overlaps and refine the initial themes. Each theme has been carefully examined for uniqueness and relevance, and to ensure that it covers a specific aspect of the data. It provided a comprehensive representation of the data, supporting a clear and focused analysis. Figure 6 shows the final result for the analysis.

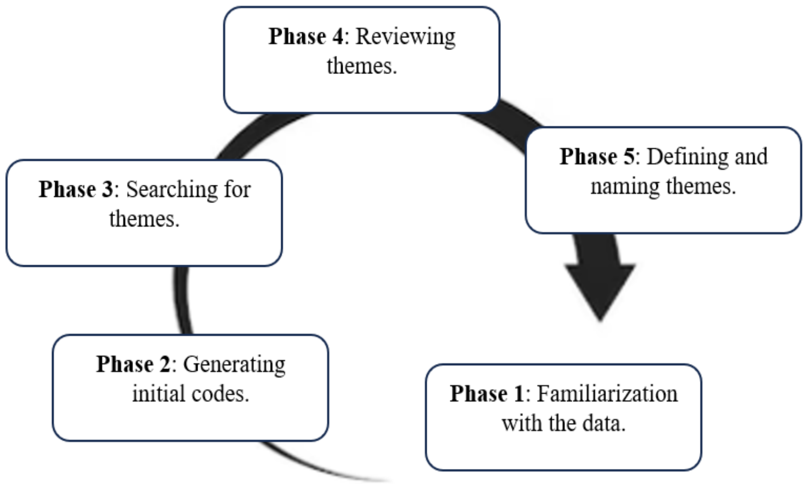


Figure 5. Thematic analysis phases

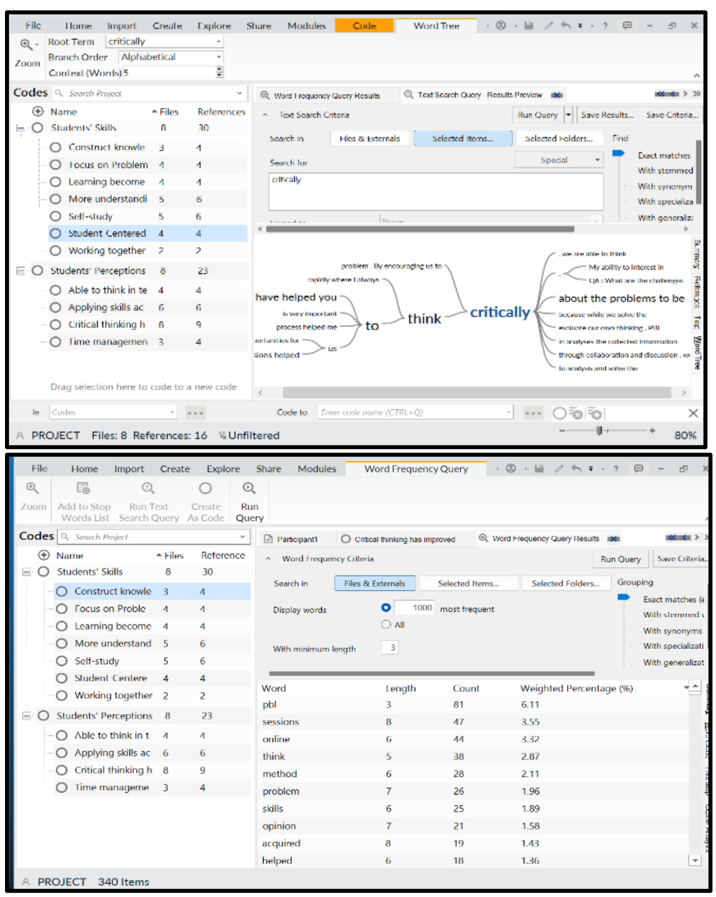


Figure 6. The results in NVivo software

The overall interview results clearly showed that the online PBL method empowers students to take charge of their time and learning. They have to search for information, analyze it, and collaborate in small groups to solve problems. Furthermore, this approach provides students with the opportunity to actively construct their own knowledge and enhance their understanding of learning. It encourages them to become critical thinkers, independent learners, and problem solvers, as stated by a participant:

> As we know, online PBL requires students to analyze and synthesize information from multiple sources and apply their knowledge and skills to solve problems, which helps them acquire critical thinking and problem-solving skills.

Another participant added:

> I worked with my classmates in small groups. We searched, analyzed, and identified until we found the solution. This helped us acquire or improve our critical thinking. During these sessions, I felt an increase in acquiring knowledge.

In online PBL, students frequently engage in reflective practices, where they assess their progress, analyze their problems, and consider what they have learned. This reflection is an integral part of the learning process, as it encourages students to refine their critical thinking. As they work on these problems, students become more independent learners. These skills gained from the PBL sessions are valuable in other courses. PBL enhances their critical thinking, research, self-study, and problem-solving abilities, which are essential in various subjects. So, it is like getting better at teamwork and solving complex problems, which can be helpful in different situations.

In addition, we employed a word cloud to support the qualitative data. These keywords indicate a positive perception towards online PBL and provide valuable insights into ways of learning through online PBL. A word cloud is a visualization tool used to display the frequency of use of keywords in interview responses. Figure 7 shows the word cloud of the participants' interview responses about online PBL.

Figure 7. World cloud of online PBL participants' interview

DISCUSSION AND CONCLUSION

Problem-based learning integrated with an online environment was used to improve students' critical thinking. This study analyzed the impact of online PBL on students' critical thinking, comparing it to direct instruction, with varying levels of self-regulated learning. The results provided clear evidence that online PBL significantly enhances critical thinking, particularly among students engaged in active and collaborative learning. The significant difference in critical thinking scores between the experimental and control groups highlights the effectiveness of PBL. This method fosters active engagement, critical analysis, and real-world problem-solving, requiring students to identify relevant information and collaborate on developing solutions. Such processes cultivate deeper thinking skills necessary in both academic and practical contexts.

Additionally, online PBL's collaborative nature encourages decision-making based on evidence and logical reasoning. Students worked in groups, sharing ideas, evaluating arguments, and refining solutions – key aspects of critical thinking development. In contrast, students in the direct instruction group worked individually, limiting opportunities for shared reflection and debate. Moreover, integrating online components with PBL appears to further enhance outcomes. The combination leverages digital tools to increase access to resources, communication, and flexible collaboration factors that optimize critical thinking beyond traditional PBL alone (Ritonga et al., 2021). This implies that educational institutions should consider integrating online PBL in programming and other technical subjects to better foster students' higher-order thinking skills. Educators may also benefit from designing online learning environments that encourage collaborative exploration, which is a key trigger for deep thinking.

These results are consistent with a study conducted by Kousar and Afzal (2021), which explained the impact of PBL on critical thinking using a quasi-experimental design. The results of the study clearly demonstrate that PBL has a positive effect on critical thinking. Notably, the intervention group that experienced PBL showed significant improvement in their critical thinking. This result is equivalent to many studies that found a positive impact of PBL intervention on the development of critical thinking (Gholami et al., 2016; Martyn et al., 2014; Nargundkar et al., 2014; Son, 2020; Ulger, 2018). Furthermore, Caroni (2021) revealed that an online PBL course can help students enhance their critical thinking and integrate knowledge.

Based on the findings of the two-way ANCOVA, the analysis of the research data revealed no interaction effect between students' SRL levels and learning methods on their critical thinking. This study explained that students' SRL levels did not significantly influence the impact of learning methods on critical thinking, despite the fact that high SRL students in the PBL group obtained better scores in critical thinking than those in the DI group. Conversely, as expected, there was a notable difference in critical thinking between low SRL students in the PBL and DI groups. These results highlight that the low SRL students exposed to the PBL group attained significantly higher critical thinking scores than their counterparts in the DI group.

The explanation for this finding is that the presence of PBL with SRL may have fostered improvement in students' critical thinking. In this study, online PBL helped students construct their knowledge by engaging in problem-solving activities. As a result, it fostered positive improvement in their critical thinking (Sari & Juandi, 2023) and encouraged them to think critically in discussing issues and finding solutions (Amin et al., 2020). These discussions were also supported by the qualitative results that found an improvement in students' skills during the treatment period, as stated by the interviewees. Another explanation for this could be the use of an online PBL method in this study; the students were presented with a problem to explore in their own learning. This would benefit high SRL students, as they think critically when solving problems in a group using online learning, compared to those who study individually via direct instruction (Gokhale, 1995; Huitt, 1998). In this study, high SRL students were encouraged to share their ideas, construct their own understanding, and think critically about facts based on current knowledge to find solutions. Therefore, the reason for that could be due to this procedure. Additionally, the students in the PBL group worked collaboratively in small groups, posting their comments and input related to the solution on the platform, and then discussing them. This enhanced friendly discussion in the online environment and improved the collaboration among students. Thus, collaborative learning with peers under PBL in online learning strengthens students' critical thinking, which aligns with Gokhale's (1995) study.

Another possible explanation for this result may be the greater responsibility that high SRL students have in the learning process. The components of SRL that are present in high SRL students have further enhanced their critical thinking, including time management, goal setting, task strategies, and self-evaluation. Moreover, high SRL students – who are usually essential in thinking – had few difficulties when solving the problems. In this study, high SRL students found the learning process easy and understood the concepts well, enabling them to effectively apply these concepts in finding solutions. Based on the characteristics of the high SRL students, the result was consistent with what had been predicted. Additionally, among the low SRL students, those who received the PBL method outperformed their low SRL peers who studied via the DI method. This is due to the high SRL students in the PBL group working collaboratively in groups with low SRL. In this situation, they were able to learn from high SRL students through the exchange of ideas and constructive criticisms. These low SRL students benefited the most from participating in groups by providing reasoning and explanations on how the solutions were developed and concluding with decisions on novel problems.

Theoretically, this study extends the existing literature on self-regulated learning and problem-based learning by exploring their interaction in an online setting. While past studies have primarily examined PBL or SRL independently, this research contributes by integrating both within a cloud-based environment. The results suggest that online PBL may offer a scaffold that helps even low-SRL students improve their critical thinking skills, possibly compensating for their lack of internal regulation through external structure and collaboration. This highlights the importance of designing digital learning environments that incorporate cognitive support and promote active engagement, particularly in developing country contexts, where resources and instructor availability may be limited. This theoretical perspective aligns well with the practical design of this study, which incorporated scaffolding as outlined in Jonassen's (1999) model to support learners in the online PBL environment. In particular, Jonassen's model was employed to guide the implementation of PBL in the experimental group, emphasizing scaffolding as a key element to support student learning. Scaffolding is often customized to meet the individual needs of learners, aiming to enhance the development of critical thinking in this context. In this study, low SRL students worked in PBL groups with high SRL students, in which the high SRL students assisted the low SRL learners.

Additionally, many interviewees highlighted that online PBL is a highly effective learning approach for developing critical thinking. By presenting them with real problems and engaging them in active learning, collaboration, and guided inquiry, it encourages their ability to think critically, analyze information, and arrive at well-reasoned solutions. These qualitative findings align closely with the quantitative results, providing further support for the effectiveness of online PBL. Interviewees also offered valuable insights into the specific skills they developed through this method.

In conclusion, this study's findings demonstrate that online PBL provides a comprehensive learning experience that enhances critical thinking while fostering self-regulation and collaboration skills among students. The integration of online tools has created a seamless, interactive environment that supports both individual and team-based learning, suggesting that online PBL could serve as a sustainable model for improving critical thinking. These findings highlight the potential of online PBL to enrich students' critical thinking and prepare them for future professional roles. However, this study is not without limitations. The short duration of the intervention may have limited the depth of critical thinking and skill development that could have been observed over a longer period. Additionally, the study was conducted within a single institution in a developing country, which may affect the generalizability of the results. Potential instructor bias and the use of a non-randomized design also warrant caution when interpreting the findings.

Since no prior research has investigated the effect of online PBL with varying levels of self-regulated learning on students' critical thinking in learning programming, this study contributes new knowledge in this area. The results underscore the effectiveness of online PBL for students with diverse SRL levels, particularly in improving critical thinking. Future studies should adopt a longitudinal approach to evaluate the sustained impact of online PBL on students' critical thinking and skill development over time. In addition to extending the duration, future research might explore the application of online PBL across different disciplines or in hybrid learning contexts. As a practical next step, educators and institutions should consider offering professional development focused on designing effective online PBL environments. This includes training instructors on how to scaffold learning for low-SRL students, foster peer collaboration, and integrate appropriate digital tools to support inquiry-based learning. In summary, this study lays the foundation for further targeted research at the intersection of PBL, SRL, and technology-enhanced learning, particularly in resource-constrained educational settings.

REFERENCES

Aldowah, H., Umar, I., Ghazal, S., Bervell, B., & Saif, A. (2020). Examining the effect of lecturers' demographic variables on the challenges facing the use of e-learning in a university context. *International Journal of Business Information Systems, 35*(4), 439-458. https://doi.org/10.1504/IJBIS.2020.111650

Alshaye, I. A., Tasir, Z., & Jumaat, N. F. (2023). The effectiveness of online problem-based learning tasks on Riyadh's secondary school students' problem-solving ability and programming skills. *Open Education Studies, 5*(1), 20220208. https://doi.org/10.1515/edu-2022-0208

Amin, S., Utaya, S., Bachri, S., Sumarmi, S., & Susilo, S. (2020). Effect of problem-based learning on critical thinking skills and environmental attitude. *Journal for the Education of Gifted Young Scientists*, *8*(2), 743-755. https://doi.org/10.17478/jegys.650344.

Ayton, D., Tsindos, T., & Berkovic, D. (2023). *Qualitative research: A practical guide for health and social care researchers and practitioners*. Monash University. https://oercollective.caul.edu.au/qualitative-research/.

Barnard, L., Lan, W. Y., To, Y. M., Paton, V. O., & Lai, S.-L. (2009). Measuring self-regulation in online and blended learning environments. *The Internet and Higher Education*, *12*(1), 1-6. https://doi.org/10.1016/j.iheduc.2008.10.005

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

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House: A Journal of Educational Strategies*, *Issues and Ideas*, *83*(2), 39-43. https://doi.org/10.1080/00098650903505415

Brandmo, C., Panadero, E., & Hopfenbeck, T. N. (2020). Bridging classroom assessment and self-regulated learning. *Assessment in Education: Principles, Policy & Practice*, *27*(4), 319-331. https://doi.org/10.1080/0969594X.2020.1803589

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Caroni, A. (2021). Problem-based learning in online settings during COVID-19. *International Journal of Management*, *Knowledge and Learning*, *10*, 21-30. https://doi.org/10.53615/2232-5697.10.21-30

Chang, H., Wang, C., Lee, M., Wu, H., Liang, J., Lee, S. W., Chiou, G., Lo, H., Lin, J., Hsu, C., Wu, Y., Chen, S., Hwang, F., & Tsai, C. (2015). A review of features of technology-supported learning environments based on participants' perceptions. *Computers in Human Behavior*, *53*, 223-237. https://doi.org/10.1016/j.chb.2015.06.042

Choi, E., Lindquist, R., & Song, Y. (2014). Effects of problem-based learning vs. traditional lecture on Korean nursing students' critical thinking, problem-solving, and self-directed learning. *Nurse Education Today*, *34*(1), 52-56. https://doi.org/10.1016/j.nedt.2013.02.012

Cobb, R., Jr. (2020). Developing self-regulated learning behaviors in online learning environments - A Conceptual Framework for Inclusion. *Journal of Research Initiatives*, *5*(2), Article 5. https://digitalcommons.uncfsu.edu/jri/vol5/iss2/5

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Routledge. https://doi.org/10.4324/9780203771587

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage.

Davies, M. (2015). A model of critical thinking in higher education. In M. Paulsen (Ed.), *Higher education: Handbook of theory and research*. Springer. https://doi.org/10.1007/978-3-319-12835-1_2

Dignath, C., & Veenman, M. V. (2021). The role of direct strategy instruction and indirect activation of self-regulated learning – Evidence from classroom observation studies. *Educational Psychology Review*, *33*(2), 489-533. https://doi.org/10.1007/s10648-020-09534-0

El-Soufi, N. (2019). *Evaluating the impact of instruction in critical thinking on the critical thinking skills of English language learners in higher education* [Doctoral dissertation, Durham University]. http://etheses.dur.ac.uk/13208/

Erdem, C., Kaya, M., Tunç Toptaş, H., & Altunbaşak, İ. (2025). Problem-based learning and student outcomes in higher education: A second-order meta-analysis. *Studies in Higher Education*, 1-22. https://doi.org/10.1080/03075079.2025.2498084

Facione, P. A. (1990). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction. Research findings and recommendations* (ED315423). ERIC. https://eric.ed.gov/?id =ED315423

Facione, P. A. (2010). *Critical thinking: What it is and why it counts: 2010 Update.* https://www.scribd.com/doc/38236691/09B456D6d01

Facione, P. A., & Facione, N. C. (1992). *The California critical thinking disposition inventory*. California Academic Press.

Facione, P. A., & Facione, N. C. (2013). Critical thinking for life: Valuing, measuring, and training critical thinking in all its forms. *Inquiry: Critical Thinking Across the Disciplines*, *28*(1), 5-25. https://doi.org/10.5840/inquiryct20132812

Fitriani, F., Nurhuda, N., & Ina, A. (2021). Improving students' activeness and critical thinking skills through problem-based learning. *Journal of Science and Education*, *2*(1), 19-29. https://doi.org/10.56003/jse.v2i1.60

Gay, L. R., Mills, G. E., & Airasian, P. W. (2003). *Educational research: Competencies for analysis and applications* (7th ed.). Pearson.

Gay, L. R., Mills, G. E., & Airasian, P. W. (2012). *Educational research: Competencies for analysis and applications* (10th ed.). Pearson.

Gholami, M., Moghadam, P. K., Mohammadipoor, F., Tarahi, M. J., Sak, M., Toulabi, T., & Pour, A. H. H. (2016). Comparing the effects of problem-based learning and the traditional lecture method on critical thinking skills and metacognitive awareness in nursing students in a critical care nursing course. *Nurse Education Today*, *45*, 16-21. https://doi.org/10.1016/j.nedt.2016.06.007

Gokhale, A. A. (1995). Collaborative learning enhances critical thinking. *Journal of Technology Education*, *7*(1), 22-30. https://doi.org/10.21061/jte.v7i1.a.2

Handoko, E. (2017). *The impact of Self-Regulated Learning (SRL) on students' completion of Massive Open Online Courses (MOOCs)* [Doctoral dissertation, University of Houston]. https://hdl.handle.net/10657/4579

Hidayatullah, & Setiawan, B. (2024). Empowering students' collaborative skills sustainability by utilizing problem-based learning as an instructional strategy in online learning. *Cogent Education*, *11*(1), Article 2362006. https://doi.org/10.1080/2331186X.2024.2362006

Hittleman, D., & Simon, A. (2002). *Interpreting educational research: An introduction for consumers of research*. Prentice Hall.

Hu, C. (2011). Computational thinking: What it might mean and what we might do about it. *Proceedings of the 16th Annual Joint Conference on Innovation and Technology in Computer Science Education* (pp. 223-227). Association for Computing Machinery. https://doi.org/10.1145/1999747.1999811

Huitt, W. (1998). Critical thinking: An overview. *Educational Psychology Interactive.* http://www.edpsycinteractive.org/topics/cognition/critthnk.html

Hwang, G. J., Wang, S. Y., & Lai, C. L. (2021). Effects of a social regulation-based online learning framework on students' learning achievements and behaviors in mathematics. *Computers & Education*, *160*, 104031. https://doi.org/10.1016/j.compedu.2020.104031

Inayah, S., Septian, A., & Ramadhanty, C. L. (2021). The development of flipped classroom model learning device based on problem-based learning to improve critical thinking ability and self-regulated learning. *Proceedings of the International Conference on Education of Suryakancana*, 200-205.

Johnson, B., & Christensen, L. (2000). Educational research: Quantitative and qualitative approaches. Allyn & Bacon. Google Scholar.

Jonassen, D. (1999). Designing constructivist learning environments. In C. M. Reigeluth (Ed.), *Instructional-Design Theories and Models: A New Paradigms of Instructional Theory* (pp. 215–239). Taylor & Francis. https://doi.org/10.4324/9781410603784

Jung, D., Lee, S. H., Kang, S. J., & Kim, J.-H. (2017). Development and evaluation of a clinical simulation for new graduate nurses: A multi-site pilot study. *Nurse Education Today*, *49*, 84-89. https://doi.org/10.1016/j.nedt.2016.11.010

Kim, D. H. (2012). Improvement in problem solving and critical thinking among Korean nursing students over an academic year. *Educational Research Journal*, *2*(8), 257-265. https://doi.org/10.7782/JKSR.2012.15.3.257

Kousar, R., & Afzal, M. (2021). The effects of problem-based learning on critical thinking and problem-solving skills among midwifery students. *Pakistan Journal of Medical & Health Sciences*, *15*(4), 722-725.

Lee, D., Watson, S. L., & Watson, W. R. (2020). The relationships between self-efficacy, task value, and self-regulated learning strategies in massive open online courses. *International Review of Research in Open and Distance Learning*, *21*(1), 23-39.

Leong Lim, C., Ab Jalil, H., Ma'rof, A. M., & Saad, W. Z. (2020). Self-regulated learning as a mediator in the relationship between peer learning and online learning satisfaction: A Study of a private university in Malaysia. *Malaysian Journal of Learning and Instruction*, *17*(1), 51-75. https://doi.org/10.32890/mjli2020.17.1.3

Loyens, S. M. M., Jones, S. H., Mikkers, J., & van Gog, T. (2015). Problem-based learning as a facilitator of conceptual change. *Learning and Instruction*, *38*, 34-42. https://doi.org/10.1016/j.learninstruc.2015.03.002

Lynch, R., & Dembo, M. (2004). The relationship between self-regulation and online learning in a blended learning context. *International Review of Research in Open and Distributed Learning*, *5*(2). https://doi.org/10.19173/irrodl.v5i2.189

Martyn, J., Terwijn, R., Kek, M. Y. C. A., & Huijser, H. (2014). Exploring the relationships between teaching, approaches to learning and critical thinking in a problem-based learning foundation nursing course. *Nurse Education Today*, *34*(5), 829-835. https://doi.org/10.1016/j.nedt.2013.04.023

McManus, T. F. (2000). Individualizing instruction in a web-based hypermedia learning environment: Nonlinearity, advance organizers, and self-regulated learners. *Journal of Interactive Learning Research*, *11*(2), 219-251. https://www.learntechlib.org/p/8486

Nargundkar, S., Samaddar, S., & Mukhopadhyay, S. (2014). A guided problem-based learning (PBL) approach: Impact on critical thinking. *Decision Sciences Journal of Innovative Education*, *12*(2), 91-108. https://doi.org/10.1111/dsji.12030

Neville, A. J., & Norman, G. R. (2007). PBL in the undergraduate MD Program at McMaster University: Three iterations in three decades. *Academic Medicine*, *82*(4), 370-374. https://doi.org/10.1097/ACM.0b013e318033385d.

Pallant, J. (2013). *SPSS Survival Manual: A step by step guide to data analysis using IBM SPSS*. McGraw-Hill Education. https://books.google.com/books?id=hes1AAAAQBAJ&newbks=0&hl=en&source=newbks_fb

Paul, R. W. (1990). *Critical thinking: What every person needs to survive in a rapidly changing world* (ED338557). ERIC. https://doi.org/10.1177/019263659107553325

Pintrich, P. R. (2000). The role of goal orientation in self-regulated learning. In M. Boekaerts, P. R. Pintrich & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 451-502). Academic Press. https://doi.org/10.1016/b978-012109890-2/50043-3

Rapti, S., & Sapounidis, T. (2024). Critical thinking, communication, collaboration, creativity in kindergarten with educational robotics: A scoping review (2012–2023). *Computers & Education*, *210*, 104968. https://doi.org/10.1016/j.compedu.2023.104968

Ritonga, S., Areeisty, K., & Zulkarnaini, Z. (2021). Enhancing students' CT skills through problem-based learning integrated with mindmapping. *Asian Journal of Science Education*, *3*(1), 63-69. https://doi.org/10.24815/ajse.v3i1.19727

Rosdiana, G. C., Yuniarsih, T., & Waspada, I. (2018). The effect of implementation problem based learning method towards students' critical thinking skills moderated by self regulated learning on basic competency analyzing international trade. *EPH - International Journal of Educational Research*, *2*(1), 57-64.

Saif, A., & Umar, I. (2019, November). The current state of an information technology maintenance department in a university context: Challenges and recommendations. *Proceedings of the 9th IEEE International Conference on Control System, Computing and Engineering, Penang, Malaysia,* 11-15.. https://doi.org/10.1109/ICCSCE47578.2019.9068537

Saif, A., & Umar, I. (2021). Research on online problem-based learning among undergraduate students: A systematic review. In F. Saeed, F. Mohammed & A. Al-Nahari (Eds.), *Innovative systems for intelligent health informatics* (pp. 1187-1197). Springer. https://doi.org/10.1007/978-3-030-70713-2_105

Saif, A., Umar, I. N., Ghazal, S., & Aldowah, H. (2024). The problem-based learning revolution: A systematic review exploring its effect on student achievement and self-regulated learning. In F. Saeed, F. Mohammed & Y. Fazea, Y. (Eds.), *Advances in intelligent computing techniques and applications* (pp. 196-205). Springer. https://doi.org/10.1007/978-3-031-59711-4_18

Sari, R. N., & Juandi, D. (2023). Improving student's critical thinking skills in mathematics education: A systematic literature review. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, *7*(1), 845-861. https://doi.org/10.31004/cendekia.v7i1.2091

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/10.2307/j.ctt6wq6fh

Schmidt, H. G. (1983). Problem-based learning: Rationale and description. *Medical Education*, *17*(1), 11-16. https://doi.org/10.1111/j.1365-2923.1983.tb01086.x

Schwam, D., Greenberg, D., & Li, H. (2021). Individual differences in self-regulated learning of college students enrolled in online college courses. *American Journal of Distance Education*, *35*(2), 133-151. https://doi.org/10.1080/08923647.2020.1829255

Şendağ, S., & Odabaşı, H. F. (2009). Effects of an online problem-based learning course on content knowledge acquisition and critical thinking skills. *Computers & Education*, *53*(1), 132-141. https://doi.org/10.1016/j.compedu.2009.01.008

Shin, H., Ma, H., Park, J., Ji, E. S., & Kim, D. H. (2015). The effect of simulation courseware on critical thinking in undergraduate nursing students: Multi-site pre-post study. *Nurse Education Today*, *35*(4), 537-542. https://doi.org/10.1016/j.nedt.2014.12.004

Shin, H., Park, C. G., & Kim, H. (2015). Validation of Yoon's critical thinking disposition instrument. *Asian Nursing Research*, *9*(4), 342-348. https://doi.org/10.1016/j.anr.2015.10.004

Son, H. K. (2020). Effects of S-PBL in maternity nursing clinical practicum on learning attitude, metacognition, and critical thinking in nursing students: A quasi experimental design. *International Journal of Environmental Research and Public Health*, *17*(21), 7866. https://doi.org/10.3390/ijerph17217866

Sri Handoyo, S., Iriani, T., & Septiandini, E. (2019). Study of the analysis on the characteristics of learning style of the students of the vocational education of building construction study program, Faculty of Engineering, Jakarta State University. *KnE Social Sciences, 3*(12), 339-348. https://doi.org/10.18502/kss.v3i12.4100

Sudia, M., & Muhammad, A. P. A. (2020). A PBL model to improve students' mathematical communication abilities: Self-regulated learning. *International Journal of Innovation, Creativity and Change*, *12*(7), 537-554. https://www.ijicc.net/images/vol12/iss7/12706_Sudia_2020_E_R.pdf

Surya, E., Syahpurta, E., & Juniati, N. (2018). Effect of problem based learning toward mathematical communication ability and self-regulated learning. *Journal of Education and Practice*, *9*(6), 14-23. https://www.iiste.org/Journals/index.php/JEP/article/view/41143

Swafford, M. (2018). The relationship between motivation and online self-regulated learning. *Journal of Human Sciences and Extension*, *6*(3), Article 6. https://doi.org/10.54718/AWIJ9321

Tao, J., Zheng, C., Lu, Z., Liang, J.-C., & & Tsai, C.-C. (2020). Cluster analysis on Chinese university students' conceptions of English language learning and their online self-regulation. *Australasian Journal of Educational Technology*, *36*(2), 105-119. https://doi.org/10.14742/ajet.4844

Thomas, K., & Lok, B. (2015). Teaching critical thinking: An operational framework. In M. Davies & R. Barnett (Eds.), The Palgrave handbook of critical thinking in higher education (pp. 93-105). Palgrave Macmillan. https://doi.org/10.1057/9781137378057_6

Ulger, K. (2018). The effect of problem-based learning on the creative thinking and critical thinking disposition of students in visual arts education. *Interdisciplinary Journal of Problem-Based Learning*, *12*(1), Article 10. https://doi.org/10.7771/1541-5015.1649

van Alten, D. C. D., Phielix, C., Janssen, J., & Kester, L. (2021). Secondary students' online self-regulated learning during flipped learning: A latent profile analysis. *Computers in Human Behavior*, *118*, 106676. https://doi.org/10.1016/j.chb.2020.106676

Vilkova, K., & Shcheglova, I. (2021). Deconstructing self-regulated learning in MOOCs: In search of help-seeking mechanisms. *Education and Information Technologies*, *26*, 17-33. https://doi.org/10.1007/s10639-020-10244-x

Watson, G., & Glaser, E. (1980). *Watson Glaser critical thinking appraisal manual.* Psychological Corporation.

Wijnen, M., Loyens, S. M., Smeets, G., Kroeze, M., & van der Molen, H. (2017). Comparing problem-based learning students to students in a lecture-based curriculum: learning strategies and the relation with self-study time. *European Journal of Psychology of Education*, *32*, 431-447. https://doi.org/10.1007/s10212-016-0296-7

Wijnia, L., Noordzij, G., Arends, L. R., Rikers, R. M., & Loyens, S. M. (2024). The effects of problem-based, project-based, and case-based learning on students' motivation: A meta-analysis. *Educational Psychology Review*, *36*, Article 29. https://doi.org/10.1007/s10648-024-09864-3

Yang, S.-H., Lee, O.-C., Lee, W.-S., Yoon, J., Park, C.-S., & Lee, S.-J. (2009). Critical disposition and clinical competency in 3 nursing colleges with different education methods. *The Journal of Korean Academic Society of Nursing Education*, *15*(2), 149-158. https://doi.org/10.5977/JKASNE.2009.15.2.149

Yao, X., Yuan, S., Yang, W., Chen, Q., Wei, D., Hou, Y., Zhang, L., Qiu, J., & Yang, D. (2018). Emotional intelligence moderates the relationship between regional gray matter volume in the bilateral temporal pole and critical thinking disposition. *Brain Imaging and Behavior*, *12*, 488-498. https://doi.org/10.1007/s11682-017-9701-3

Yeh, M. L. (2002). Assessing the reliability and validity of the Chinese version of the California Critical Thinking Disposition Inventory. *International Journal of Nursing Studies*, *39*(2), 123-132. https://doi.org/10.1016/S0020-7489(01)00019-0

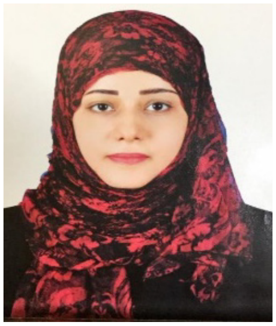
Yoon, J. (2004). *Development of an instrument for the measurement of critical thinking disposition in nursing* [Doctoral dissertation, The Catholic University, Seoul, South Korea].

Yoon, J. (2008). A study on the critical thinking disposition of nursing students – Focusing on a school applying integrated nursing curriculum. *Journal of Korean Academy of Nursing Administration*, *14*(2), 159-166.

Yusuf, A., Bello, S., Pervin, N., & Tukur, A. K. (2024). Implementing a proposed framework for enhancing critical thinking skills in synthesizing AI-generated texts. *Thinking Skills and Creativity*, *53*, 101619. https://doi.org/10.1016/j.tsc.2024.101619.

Zimmerman, B. J. (1989). A social cognitive view of self-regulated academic learning. *Journal of Educational Psychology*, *81*(3), 329-339. https://doi.org/10.1037/0022-0663.81.3.329

AUTHORS



Amira Saif, a PhD in Instructional Technology from Universiti Sains Malaysia, specializes in human-computer interaction within the field of Computer Science. She holds a Master's in IT and Management from Taiz University and Delft University of Technology. Her areas of research interest include PBL, online learning environments, critical thinking, and technology-enhanced learning in programming education. She is also interested in the application of artificial intelligence, data analytics, and technology applications for special education.

Hanan Aldowah, a senior lecturer at the School of Management, Universiti Sains Malaysia (USM), holds a PhD and a Master's in IT and Multimedia from the same university, along with a Bachelor's in Computer Science. Her extensive expertise spans diverse domains, including data analytics, data mining, machine learning, artificial intelligence, internet of things, cognitive maps, VR & augmented reality, and instructional technology. Aldowah holds a keen interest in the application of emerging technologies, such as AI, IoT, ML, and sentiment analysis, to enhance various sectors, including management, education, and computer education, as well as technology adoption, digital transformation, and organizational behavior.