

**THE EFFECTS OF ONLINE PROBLEM-BASED
LEARNING IN CLOUD COMPUTING
ENVIRONMENT ON PERFORMANCE AND
CRITICAL THINKING OF STUDENTS WITH
DIFFERENT SELF-REGULATED LEARNING
LEVELS IN LEARNING PROGRAMMING**

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UNIVERSITI SAINS MALAYSIA

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LEVELS IN LEARNING PROGRAMMING**

by

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LIST OF ABBREVIATIONS

PBL	Problem Based Learning
DI	Direct Instruction
CC	Cloud Computing
PP	Programming Performance
CT	Critical Thinking
SRL	Self-Regulated Learning
HSRL	High Self-Regulated Learning
LSRL	Low Self-Regulated Learning
OSLQ	Online Self-Regulated Learning Questionnaire
YCTD	Yoon's Critical Thinking Disposition
CPPT	Computer Programming Performance Test

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**KESAN PEMBELAJARAN BERASASKAN MASALAH SECARA
DALAM TALIAN DALAM PERSEKITARAN KOMPUTERAN AWAN
TERHADAP PRESTASI DAN PEMIKIRAN KRITIS PELAJAR PELBAGAI
TAHAP PEMBELAJARAN REGULASI KENDIRI DALAM
PEMBELAJARAN PENGATURCARAAN**

ABSTRAK

Pelbagai cabaran berkaitan pembelajaran pengaturcaraan dihadapi oleh pelajar novis pendidikan tinggi di Yaman. Selain itu, pendekatan konvensional dalam pendidikan - yang masih digunakan secara meluas di Yaman - sering kali gagal membantu mereka menjadi pelajar yang aktif dalam proses pembelajaran. Pembelajaran Berasaskan Masalah (PBL) menawarkan penyelesaian alternatif bagi mengatasi masalah ini. Kajian ini bertujuan menyelidik kesan PBL dalam talian dalam persekitaran komputeran awan terhadap prestasi dan pemikiran kritis 120 pelajar ijazah sarjana muda di sebuah universiti awam di Yaman. Kajian ini melibatkan satu pemboleh ubah bebas membabitkan dua kaedah pengajaran, iaitu (a) Pembelajaran Berasaskan Masalah (PBL) dan (b) Pengajaran Langsung (DI), dua pemboleh ubah bersandar iaitu prestasi dan pemikiran kritis, serta tahap pembelajaran sendiri pelajar (SRL) sebagai pemboleh ubah moderator. Kajian ini menggunakan reka bentuk kaedah campuran berturutan (QUAN + QUAL) yang melibatkan fasa kuantitatif dan kualitatif. Bagi fasa kuantitatif, kajian kuasi eksperimen dengan reka bentuk kumpulan kawalan pra-ujian dan pasca-ujian 2 x 2 telah digunakan. Prestasi pengaturcaraan pelajar diukur melalui Ujian Prestasi Pengaturcaraan Komputer (CPPT), pemikiran kritis pelajar diukur melalui Disposisi Pemikiran Kritis Yoon (YCTD), manakala tahap SRL mereka diukur menggunakan instrumen Soal Selidik Pembelajaran Kendiri Dalam Talian

(OSLQ). Selain itu, sesi temu bual dijalankan untuk mengumpul data kualitatif daripada lapan orang responden. Dapatan menunjukkan Kumpulan PBL memperoleh skor prestasi dan pemikiran kritis yang lebih tinggi secara signifikan berbanding Kumpulan DI. Tambahan pula, pelajar SRL tahap tinggi juga menunjukkan skor prestasi dan pemikiran kritis yang lebih tinggi dan secara signifikan berbanding pelajar SRL rendah. Namun begitu, tidak terdapat kesan interaksi yang signifikan antara tahap SRL (tinggi dan rendah) dengan kaedah pengajaran (PBL dan DI) bagi kedua-dua pemboleh ubah bersandar tersebut. Semua dapatan ini menunjukkan bahawa aplikasi PBL dengan SRL memainkan peranan penting dalam pembelajaran. Kajian ini menyediakan bukti yang diperlukan kepada sektor pendidikan tinggi di Yaman mengenai penggunaan PBL dalam talian. Akhirnya, kajian ini mengesyorkan aplikasi PBL dalam talian dalam persekitaran perkomputeran awan dalam pengajaran dan pembelajaran pengaturcaraan.

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ABSTRACT

Many challenges related to learning programming for novice learners in Yemeni higher education. In addition, the conventional approach of education – which is still being widely used in Yemen - often fail to assist them to become active learners during the learning process. Problem-Based Learning (PBL) might offer alternative solution to these problems. The current study attempted to investigate the effects of online PBL in a cloud computing environment on performance and critical thinking of 120 undergraduate students from a public university in Yemen. This study involved an independent variable that consisted of the two learning methods, i.e. (a) Problem-Based Learning (PBL) and (b) Direct Instruction (DI), two dependent variables, i.e., the students' performance and critical thinking, and self-regulated learning (SRL) as the moderating variable. This study employed the sequential mixed methods design (QUAN and QUAL) which involved quantitative and qualitative phases. For the quantitative phase, a 2 x 2 factorial design quasi experimental study with pre-test and post-test control group design was applied. The students' programming performance was measured through the Computer Programming Performance Test (CPPT), their critical thinking was measured through the Yoon's Critical Thinking Disposition (YCTD), while their SRL level was measured by applying the Online Self-Regulated Learning Questionnaire (OSLQ). In addition, an interview session was conducted to collect the qualitative data from eight interviewees. The findings indicated that the

PBL group scored significantly higher in both performance and critical thinking as compared to the DI group. Moreover, the high SRL students significantly outperformed their low SRL colleagues in both performance and critical thinking. However, the findings indicated no significant interaction effect between the levels of SRL (high and low) and learning methods (PBL and DI) in both dependent variables. These findings revealed that the application of PBL with SRL plays an important role in learning. This study provides the higher education sector in Yemen with necessary evidence on the use of online PBL. Finally, the study recommended applying online PBL in the cloud computing environment in teaching and learning programming.

CHAPTER 1

INTRODUCTION

1.1 Introduction

In the rapid technological and social changes, the growing importance of computer programming education is becoming a crucial skill across various disciplines and areas. Furthermore, education is the power to improve the potential of a student through the process of learning to create a better life, it is important that education be able to hook up learners in new ways so that they are ready for the future.

The substance of learning is learning how to think and how to learn to face the challenges of the 21st century. Therefore, learners must be ready to work in several environments with many complex requirements such as a cloud computing environment. A cloud computing environment refers to the set of infrastructure and resources in which cloud services and applications operate (Zondi, 2023). It involves both physical data centers and underlying software and networking components (Bala, 2022).

Learning programming is a main challenge in computer science education, and some students - especially novice programmers - face difficulties in their first programming task (Ezeamuzie, 2023; Robins et al., 2010; Tsai, 2019). Today's programming languages are vastly dynamic and change at a fast pace. Consequently, the students must be active and intelligent in design programs that are needed in the job market; thus, they always need to update their knowledge and skills. This requires improving the methodologies of learning for the programming field.

1.2 Background of Study

Previous studies have indicated that programming students encounter difficulties and misconceptions when learning the basic concepts (Denny et al., 2022; Hou et al., 2024; Kaleliog, 2015; Ouahbi et al., 2015; Saez-Lopez et al., 2016; Tsai, 2019). They have little interest in programming learning because of the belief that programming languages require complex skills and concepts (Chao, 2016; Tsai, 2019), due to insufficient knowledge to understand the basic programming concepts and poor ability to write code. The performance of students in programming languages has remained low in many countries, and thus, much of the failure in school computer science is associated with a traditional instructional delivery approach that is inappropriate to the way most students learn (Alturki, 2016; Mehmood et al., 2020).

Conventional approaches of education often fail to assist the students to become active learners and encourage them in the learning process (Duch et al., 2001). However, these traditional methods are still being commonly used today in higher education. There is a concern among faculty members that students are less successful in learning programming skills than they have expected (Mcgettrick et al., 2005). Studies by Mccracken et al., (2001) and Denny et al., (2022) revealed that, by the conclusion of the first year, the learners struggled with the complexities of building programs, attributing the challenge to the inherent difficulty in learning the programming language. In any teaching and learning process, an optimum interaction between the teachers and their learners is needed to ensure effective learning. Therefore, the participation of students in the teaching and learning process is crucial to create an active, interesting, and meaningful learning to achieve the learning outcomes. Recently, the integration of cloud computing environment into educational practices has emerged as a powerful tool (Alam, 2022; Naved et al., 2022). This tool

provides a scalable and accessible platform for collaborative learning, enabling students to engage with course materials and access resources from anywhere with an internet connection. This fosters a more dynamic and interactive learning environment (Hong et al., 2023). Consequently, online learning allows easy storage and sharing of information without boundaries, and the availability of online learning activities, such as quizzes, lectures, bulletin boards, and online discussion forums vary (Al-Adwan et al., 2021; Beadle & Santy, 2008; Shimizu et al., 2019), and therefore, students can access to wealth of information and apply it in different ways (Kauffman, 2004). For example, Bickle et al., (2019) argued that the online discussion board can facilitate interaction between the instructor and students, and between the students themselves, this way would create an interesting and active learning. In addition, according to George (2020), online quizzes provide the students with the experience in attempting exams online, and allow the instructor to insert his/her comments and feedback on the students' attempts so they can improve their outcomes and learn from the mistakes.

Lecturers and students are commonly aware of the advantages of online learning environments, particularly cloud computing environment (Shamshirband et al., 2020), including its flexibility, approachability and portability (Ghahramani et al., 2022). Moreover, cloud computing environment allows students to study at their own pace and on their preferred devices. The cloud enables collaboration among students and educators. Shared documents, real-time communication, and collaborative tools improve the learning experience (Zondi, 2023). There are an abundance of learning resources and educational materials available online. In addition, teachers can apply various teaching and learning methods in learning programming, including problem-based learning (PBL), context-based learning (Omeh et al., 2022), and game-design (Akcaoglu & Koehler, 2014), pair programming (Wei et., 2021, Nagaria et., 2020),

gamification (Zhan et., 2022) according to their needs, and these methods assisted to enhance the programming languages. Recently, PBL is becoming increasingly important in computing education, and in a variety of disciplines in higher education. PBL is defined as an active and flexible method, which utilizes one or more problems as learning tools (Komala et al., 2021; Santos et al. (2019); Srikan et al., 2021). In addition, Bashir (2016) explained that integrating PBL with online learning promotes the programming skills.

The PBL aims to improve the abilities to think critically; to solve and analyze complex real problems; to evaluate, search for, use learning resources; to work collaboratively; and to communicate effectively (Cosgun & Atay, 2021), and the students who learn in collaborative ways would think critically to acquire their learning goals (Mulyanto & Indriayu, 2018). Consequently, the students' critical thinking can be improved during learning by using the PBL model (Fitriani et al., 2021; Ibrahim et al., 2021; Satwika et al., 2018).

Lately, there has been a growing interest in acquiring programming skills. However, learning programming goes beyond understanding the programming language, to include aspects such as syntax and data types, but also includes developing multiple other skills, such as analyzing problems, developing algorithms, writing code, debugging, and fixing errors. The programming activities, like coding, can develop the aspects of critical thinking, and it must encourage students to test, evaluate and update code to develop their critical thinking skills (Popat & Starkey, 2019). The Chaffee (2012)'s theory proposed that the critical thinking is the process of thinking to illustrate an individual's understanding of something that results in an intelligent decision (Mulyanto & Indriayu, 2018). Critical thinking is a constructive

analysis process used to define and analyze the problems (Anggriani & Atmojo, 2022), while PBL process is a method to offer guidance for solving problems. These problems require learners to think deeply and carefully in order to analyze and design the problems. Therefore, critical thinking is an important skill to effective programming, particularly at the higher levels of design and analysis (Sun & Li, 2019).

Additionally, the student who is interested in learning would have a good self-regulated learning (Zalli et al., 2020). Self-Regulated Learning (SRL) is an active process that enables the students to control and set their learning activities, cognition, behaviour and motivation. SRL refers to self-generated thoughts, behaviour and feelings that are oriented to acquire the academic goals. It becomes essential when attempting to learn computer programming (Jairo et al., 2018).

The Yemeni Ministry of Education and scientific research reported that the traditional teaching and learning methods such as lecturing, note-taking, memorizing, and reciting are still the dominant means of instruction in most of the Yemeni universities (Ministry of Education, 2008). Yemen therefore needs to thoroughly improve the current techniques for teaching and learning to allow exchanging information between students (Muthanna & Karaman, 2014). Moreover, the number of Yemeni online users is increasing rapidly, and online learning has become an effective solution because of its potential to enhance the quality of education with the least minimum of resources and infrastructure (Aldholay & Isaac, 2018). Isaac and Mutahar (2020)'s results supported the higher education in Yemen to create an interesting and active environment in which students are using online learning, thus, improving their performance and the quality of their education. Despite the difficulties that Yemen's public universities face in online learning, students at these universities

are enthusiastic about the use of electronic learning in their education (Alrajawy et al., 2016; Isaac et al., 2019).

Although there are some studies focusing on the use of the Information and Communication Technology (ICT) on learning that employs technology in teaching language learning in Yemen (Ahmed, et al., 2020; Ahmed, Salem, et al., 2020), very few studies have focused on programming learning. For example, Alturki (2016)'s study explained that the reduction of programming course complexity such as the syntax of programming or the code structure (use of functions/classes, use of language libraries, variable scoping, etc.) has a positive effect on students' performance, so focusing on the fundamental concepts in programming can reduce such complexity.

Thus, the current study attempts to investigate the effects of online problem-based learning in a cloud computing environment on Yemeni students' performance and critical thinking in learning programming, and it uses self-regulated learning as a moderating effect of this relationship.

1.3 Problem Statement

Programming languages are known for its complexity and difficulty, therefore, many novice programmers face difficulties in acquiring the necessary skills while designing and writing the program (Cheah, 2020). Consequently, learning programming is a difficult task for many students (Sonsoles et al., 2021), especially among the novice learners. The main challenge in learning programming for novice programming students is to acquire various sets of skills at the same time such as semantics, syntax, problem solving, and critical thinking (Aissa et al., 2020; Malik et al., 2019).

Learning programming shapes the basic programming concepts (Ouahbi et al., 2015; Pessoa et al., 2018; Saez-Lopez et al., 2016), and students are required to learn theoretical concepts of programming and then practice these concepts in coding and designing the given problem statement (Sonsoles et al., 2021). In addition, it requires them to learn the sufficient understanding of basic concepts in order to gain a large number of new concepts (Nuutila et al., 2005). Several researchers have defined many basic programming concepts, including sequences, loops, functions, variables, and conditions (Lin et al., 2016; Panoutsopoulos, 2011; Saez-Lopez et al., 2016). Previous research has indicated that one of the reasons that contribute to learners' low performance and achievement in programming languages is a lack of understanding of concepts (Cheah, 2020; Leinonen et al., 2019; Mathrani et al., 2016), they experience difficulties when learning fundamental concepts such as loop, sequence, variables, conditions (Chao, 2016; Piwek & Savage, 2020; Saez-Lopez et al., 2016).

These difficulties are faced by the novice programmers due to lack of understanding of programming structures, they need to understand each instruction that is executed in the code (Robins, 2019). In addition, they have little interest in learning programming because of the belief that programming requires complex concepts and skills (Chao, 2016). Furthermore, literature has concluded that learners are unable to understand the relationship between the concepts and to understand the connection between the problems and their solutions, which embodies a lack of critical thinking (Liu et al., 2022). Critical thinking refers to the ability of learners to think about a series of interconnected critical questions, and their desire to use their ability of critical thinking to solve problems (Liu et al., 2022).

Additionally, due to the COVID-19 pandemic, cloud computing has grown stronger than ever after the pandemic (Athambawa et al., 2023). The cloud helps organizations of all sizes benefit from unlimited computing and benefit from technological developments (Singh, 2021; Theby, 2022). Consequently, higher education institutions such as colleges and universities are shifting to online learning (Al-Hajri et al., 2021; Athambawa et al., 2023; Aydin, 2021; Kumar Bhardwaj, 2021). As a result, learners were suddenly met with the unusually difficult task of self-regulating their learning activities at home (Zhang et al., 2021). Furthermore, learners face a higher barrier to seeking help, as well as having to actively monitor the amount of time they spend in class hours (Zhang et al., 2021), they face difficulties in their learning. They need to plan, manage, monitor and reflect on their own learning to achieve their learning goals.

Past studies have explored that these difficulties are due to the poor teaching methodologies, low levels of interaction in class, lack of interest in learning process (Barker et al., 2009; Coull & Duncan, 2011; Supaartagorn, 2019; Theobald, 2021), lack of collaborative learning (Alturki, 2016), and lack of motivation among learners who find learning programming boring and unexciting (Singh, 2021). Many lectures were conducted using traditional approaches involving direct teaching and practical sessions, which usually leads to passive students and less interaction between them and their lecturers (Isa, 2020; Sugeng, 2020). These methods, such as direct instruction using materials like notes, books, and slides do not seem to be effective methods in teaching programming languages (Cheah, 2020). According to Pardimin et al., (2019), the direct instruction method is appropriate for a variety of subjects. However, this method has weaknesses, such as not all students have the ability to listen well to the lecturer's explanation, and many of them feel bored and lose concentration (Pardimin

et al., 2019), so this type of conventional lecturing is not appropriate if specific objectives are to be addressed (Ersoy & Güneşli, 2016).

To overcome or reduce these difficulties, the learning process must be improved to make the classroom more active and lively (Ramadhani & Umam, 2019). Consequently, learners will be more interested and motivated in their learning process, resulting an improvement in their achievement. For instance, Supaartagorn (2019) illustrated that an improvement in the way of learning programming by using flowchart helps to reduce the complexity of the programming concepts.

Although PBL method has been used in many countries (Chang et al., 2020; Faqiroh, 2020), it is not a common method in Arab nations including Yemen. This method aims to promote knowledge, abilities, and attitudes related to collaborative learning, so as to construct collaborative knowledge and help students clarify the relationship between achieving learning outcomes and attitudes toward collaboration (Siagian et al., 2019). Furthermore, PBL also has a crucial role in motivating students to learn new concepts in programming (Loyens et al., 2015; Nuutila et al., 2005; Topalli, 2018), and improving their performance and outcomes (Merritt et al., 2017). In addition, Oliveira et al., (2013) observed that the goal of the PBL method is to learn from the problem rather than to solve it. Thus, the PBL method tries to mitigate the difficulties in learning programming by providing students a way to develop their skills and acquire knowledge (Aires et al., 2023). This method has been adopted to implement exhaustive courses in programming. For example, Santos et al., (2019) have applied PBL in teaching in the Python course, and it was found that this method was very effective, and it allowed students' engagement. Meanwhile, Yidan (2018) has also applied PBL in teaching Data Structure course, and he found that this method

has improved students' capability, developed teachers' delivery efficiency, and improved the students' competencies.

Moreover, PBL is a method that is executed in a collaborative learning environment. Students actively work in small groups, formulate problems, classify hypotheses, search for the material related to the problem, and report problem solutions (Qomariyah, 2019), which promotes their critical thinking (Fitriani et al., 2021; Loyens et al., 2015; Şendağ & Odabaşı, 2009; Sulaiman, 2011). By applying PBL, it triggers critical thinking in students, which in return will help them to solve the given problems (Sudia et al., 2020). Additionally, this method offers opportunities for students to become responsible for their own learning, where they can manage their time to achieve their learning goals, and where the instructor becomes a facilitator of the learning process (Ulger, 2018). In other words, students are able to manage the task of learning without dependence on others (Inayah et al., 2021; Surya et al., 2018). Additionally, the impact of PBL can be made stronger by integrating it with e-learning (Ioannou et al., 2016; Shimizu et al., 2019), as online PBL engages students in real-world problems that require them to apply programming concepts to solve these problems, and this process challenges students to think critically about how to design, build, and code their solutions, which promotes deep understanding (Alwehaibi, 2012), leading to increased learners' satisfaction (Al-azri & Ratnapalan, 2014; Chang et al., 2020; Cosgun & Atay, 2021) and awareness mainly in higher education (Şendağ & Odabaşı, 2009), as well as facilitated the lecturer's load (Musal et al., 2016). Thus, students' acceptance for the technology in blended PBL was higher as it allows for greater self-study (Shimizu et al., 2019), and students who are high self-study ability believed that opportunities to take on challenging tasks, practice learning, develop a deep understanding of the subject matter, and put in effort would lead to academic

success (Araka et al., 2022), they are more likely to be high achievers and successful in school as presented in many standardized tests (Puzziferro, 2008). Thus, different levels of self-regulated learning will have different impacts on the learning outcome.

Based on the above discussions, it has become necessary to develop alternative techniques and methods to the direct instruction method. Several studies have recommended the need to improve learning strategies and environment of programming learning (Aissa et al., 2020; Ouahbi et al., 2015; Saez-Lopez et al., 2016; Tsai, 2019). Thus, this study attempts to apply online PBL method in a cloud computing environment with different self-regulated learning levels that is expected to effectively reduce the difficulties in learning programming and increase students' learning interest which will positively reflect on their performance and critical thinking. In addition, the gap in the existing literature provides a limited understanding of the effectiveness and potential of online PBL in programming education in developing countries, especially for students with varying self-regulated learning abilities. The study also contributes to the growing body of research on the use of cloud computing tools to support online learning in these contexts.

1.4 Research Objectives

In accordance with the formulation of a problem that has been presented, the researcher carried out this study to find out whether the use of the PBL approach in the programming languages would have any significant effect on students' performance and critical thinking as compared to the Direct Instruction Method.

Specifically, the objectives to be achieved in this research were:

1. To investigate whether there is any significant difference in programming performance between the Problem Based Learning (PBL) and the Direct Instruction method (DI) groups.
2. To investigate if there is any significant difference in programming performance between students with high and low self-regulated learning.
3. To investigate whether there is any significant difference in critical thinking between the PBL and the DI groups.
4. To investigate if there is any significant difference in critical thinking between students with high and low self-regulated learning.
5. To examine whether there is a significant interaction effect between learning methods and self-regulated learning on programming performance.
6. To examine whether there is a significant interaction effect between learning methods and self-regulated learning on critical thinking.
7. To examine the students' perceptions of online PBL.
8. To examine skills learned in online PBL.

1.5 Research Questions

The following are the research questions involving the main and interaction effects of the interventions in this study:

The main effects:

RQ1 Is there any significant difference in terms of programming performance of students who received PBL and those who received DI in learning programming?

RQ2 Is there any significant difference in terms of programming performance between high SRL and low SRL students in learning programming?

RQ3 Is there any significant difference in terms of critical thinking of students who received PBL and those who received DI in learning programming?

RQ4 Is there any significant difference in terms of critical thinking between high SRL and low SRL students in learning programming?

The Interaction Effects

RQ5 Is there any interaction effect between SRL levels and learning methods (PBL and DI) in terms of performance in learning programming?

RQ6 Is there any interaction effect between SRL levels and learning methods (PBL and DI) in terms of critical thinking in learning programming?

Other secondary research questions include

RQ7 What are the students' perceptions of online PBL?

RQ8 What skills are learned in online PBL?

1.6 Research Hypotheses

The following hypotheses were formulated based on the main and interaction research questions. To investigate the effects of online PBL in a cloud computing environment for a programming language course, the hypotheses were employed in this study:

H₁ There is a significant difference in term of performance of students who received PBL and those who received DI in learning programming.

H₂ There is a significant difference in term of performance between high SRL and low SRL students in learning programming.

H₃ There is a significant difference in term of critical thinking of students who received PBL and those who received DI in learning programming.

H₄ There is a significant difference in term of critical thinking between high SRL and low SRL students in learning programming.

H₅ There is a significant interaction effect between SRL levels and learning methods in term of performance in learning programming.

H₆ There is a significant interaction effect between SRL levels and learning methods in term of critical thinking in learning programming.

1.7 Theoretical Framework

The theoretical framework of this study is based on constructivism theory, Piaget's theory, and Vygotsky's theory. Constructivism learning theory is the prevailing method of teaching and learning in education today. According to constructivism learning theory, learners' construction of knowledge is largely dependent on prior or current knowledge, and the role of lecturers in helping learners to acquire experiences instead of merely transferring knowledge (Piaget, 1964; Vygotsky, 1978).

Piaget's theory of Cognitive Development (1972), which describes how individuals progress through the stages of cognitive development, provides valuable insights into learning computer programming. According to Piaget (1972), learners move from concrete thinking in the earlier stages to more abstract and logical reasoning in the formal operational stage. Programming, which requires understanding abstract concepts, problem-solving, and logical reasoning, aligns with Piaget's formal operational stage. Thus, Piaget's theory suggests that as learners' cognitive abilities mature, their capacity to understand and excel in computer programming increases, highlighting the importance of age-appropriate teaching methods that align with their cognitive development stages.

Vygotsky's Theory on Social Development (1978) emphasizes the importance of social interaction and cultural context in cognitive development, which has significant implications for learning computer programming. According to Vygotsky, learning occurs through social interactions, and this theory suggests that collaborative learning environments are essential for developing programming skills. Through these interactions, learners can internalize complex programming concepts, problem-solving strategies, and best practices by working closely with more experienced programmers.

Vygotsky's theory emphasizes the role of social learning in mastering programming and highlights the value of collaborative tools and guidance in the learning process.

Vygotsky (1978) and Piaget (1972) both emphasized that knowledge is constructed through interaction with the environment. Piaget believed that all construction takes place in the learner's mind; Vygotsky felt strongly that learning occurs when knowledge is mediated through social interaction with adult guidance or collaboration with peers. In this context, an experienced teacher or peers can play a crucial role as facilitators, helping passive learners become more active and encouraging them to construct their prior knowledge and experiences

These theories - which will be further explained in Chapter Two - are based on the principles that learners should construct knowledge while dealing with the problem, rather than waiting passively to achieve the learning objectives. This study applied most of these principles: the learning task should be embedded in the problem-solving context that requires the students to acquire relevant knowledge and explain concepts in the problem to solve it. While the students work on solving the problem, the teacher encourages and helps them to generate the hypotheses and solutions, this way makes them interested in their learning. The interaction between the members of the group helps them to exchange new information with each other and cover all the learning tasks/objectives.

Jonassen's model (1999), often referred to as the Constructivist Learning Environment Model, is based on the principles of constructivism, where learners actively construct their own understanding and knowledge through experience and reflection. Jonassen's model focuses on designing learning environments that support meaningful learning by providing opportunities for learners to engage in problem-solving, critical thinking, and knowledge construction. It also emphasizes authentic

tasks, real-world contexts, and the importance of the learner's active role in the learning process. PBL is a learning method that is consistent with the principles of the Jonassen's model. In PBL, learners are presented with real-world problems that do not have straightforward solutions. They must collaborate, research, and apply their knowledge to solve these problems. This process requires critical thinking, and the ability to integrate and apply knowledge from different fields. The Jonassen's model provides a theoretical framework that supports the implementation of PBL by emphasizing the need for learning environments that promote active problem-solving and knowledge construction. In a PBL environment, learners are engaged in authentic tasks, as Jonassen advocates, that reflect real-world challenges and require students to apply what they have learned in a meaningful way. Additionally, Jonassen's focus on providing scaffolding and guidance aligns with the PBL approach, where facilitators (teachers) guide students through the PBL processes without directly providing answers, thus encouraging deeper understanding and independent thinking.

In addition, this study will apply the Seven-Step Model introduced by Schmidt (1983). This model provides a structured framework that guides learners through the PBL process, closely aligned with the principles outlined in Jonassen's Constructivist Learning Environment. This model provides a clear, systematic approach to problem solving that helps students actively construct knowledge, as advocated by both Jonassen and the PBL approach.

Furthermore, McGill and Volet (1997)'s conceptual framework of the several components of programming knowledge will also be used in this study. The components are integrated into three forms of cognitive knowledge (declarative, procedural, and conditional) with three types of programming knowledge (syntactic, conceptual, and strategic). This framework is made of five categories of programming

knowledge which are procedural syntactic, procedural conceptual, declarative syntactic, declarative conceptual, and strategic/conditional knowledge.

Facione's model (1992) for critical thinking is a comprehensive framework that outlines both the cognitive skills and dispositions necessary for effective critical thinking. This model identifies key dispositions such as open-mindedness, inquisitiveness, systematicity, analyticity, truth-seeking, self-confidence, and maturity of judgment (Facione, 1990). These dispositions are critical in shaping how individuals' approach and engage with problems, particularly in educational settings like learning programming through PBL (Toker, 2022).

Pintrich's model (2000) of self-regulated learning is a framework that describes how students take control of their learning by regulating their cognition, motivation, behaviour, and environment. Self-regulated students are characterized by active engagement in learning through cognitive perception, motivation, and behaviour. Characteristics related to self-regulating persons are similar to the characteristics associated with high performance, high-capacity learners, as opposed to low performance or learning disabilities (Jiwani, 2018). They are also better at reflecting on their learning experiences, which enhances their critical thinking. Students' performance and critical thinking are influenced by levels of self-regulated learning, especially in a student-centered environment. Therefore, this study used low and high levels of self-regulated learning to examine their effects on students' performance and critical thinking

1.8 Conceptual Framework

In addition to the theories, the conceptual framework of this study as presented in Figure 1.1 is based on Jonassen's Model for Designing Constructivist Learning

Environments (CLE). According to Jonassen (1999, p.218) “the focus of any CLE is the question or issue, the case, the problem, or the project that learners attempt to solve or resolve”. As this model starts with a problem and solved it through its components, it is consistent with a PBL method that was used in this study. The model of this study was focusing on the problems / issues that students attempt to solve or resolve, it defined the problem through the components of problem space in CLEs Problem context, Problem presentation/simulation, and Problem manipulation space. In this study, the students are required to solve the problem in collaborative groups. They are required to analyze the problem correctly, produce the flowchart, and code and test the selected solutions. In other words, the problem is expected to be solved in a proper manner and more meaningfully in groups. Moreover, the teachers and students were given the instructions to support them through the implementation of the process, and the students were provided with the relevant information resources to support them in understanding the problem.

By following Schmidt's Seven-step Model (1983), the PBL process becomes a structured path that fully embodies the principles of Jonassen's constructivist learning environment. Each step in the Schmidt model involves systematically engaging students in active learning, critical thinking, and collaborative knowledge construction, which are core principles of both the Jonassen model and the PBL approach. Through this structured and flexible process, students are not only solving problems but also developing the cognitive and perceptual skills necessary for deep learning and knowledge transfer. This alignment demonstrates how PBL; guided by Schmidt’s model; is an effective method for applying constructivist principles in educational settings, especially in areas such as computer programming where problem solving is essential

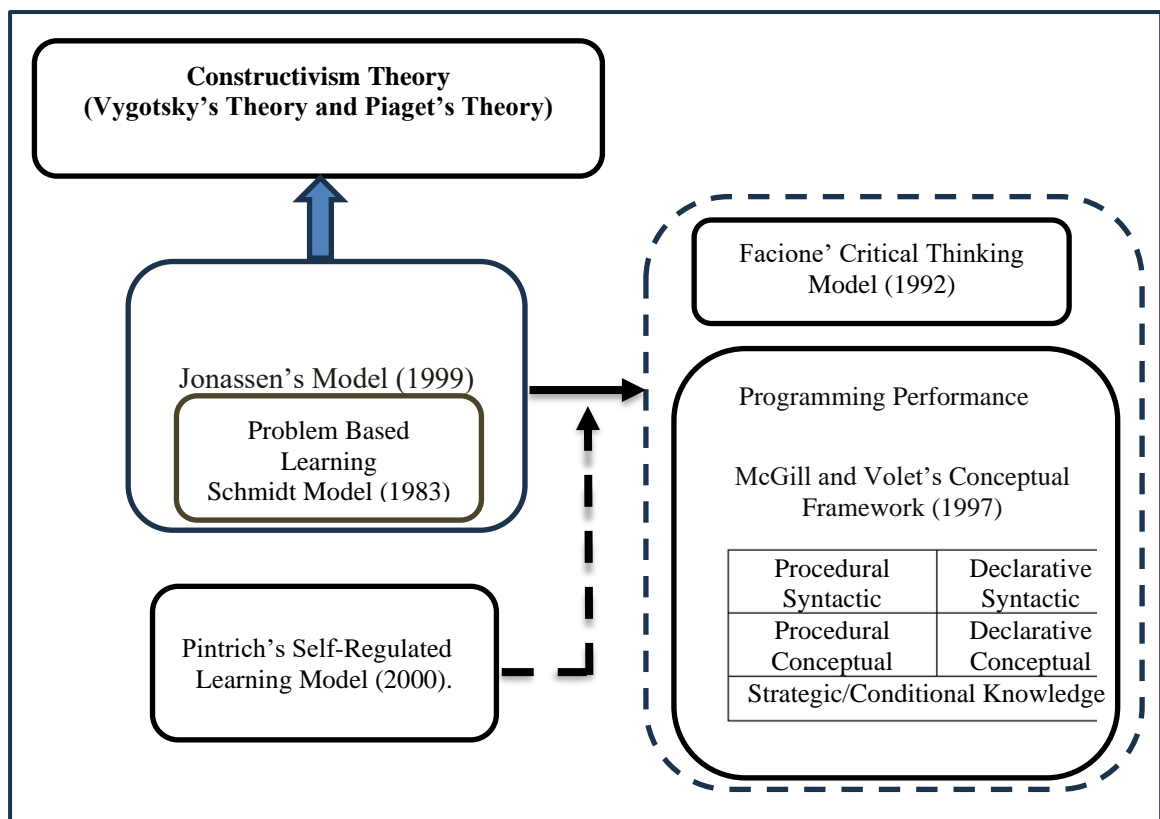


Figure 1.1 Conceptual Framework of Study

Moreover, the conceptual framework of this study is based on McGill and Volet (1997)'s conceptual framework, in which as an educational taxonomy, it classifies and organizes learning outcomes in programming education. This taxonomy is particularly effective in structuring learning objectives and assessing the development of programming skills.

This conceptual framework is also based on Facione's Critical Thinking Model (1992) and Pintrich's Self-Regulated Learning Model (2000). The Facione's model for measuring the dispositions toward critical thinking with seven scales which are truth-seeking, open-mindedness, analyticity, systematicity, Critical Thinking (CT) self-confidence, inquisitiveness, and maturity of judgment (Facione & Facione, 1992). Pintrich's model can be used for measuring student's SRL levels. This model is based on students' ability to self-study and how they progress in their learning to accomplish

planned goals. Pintrich’s model can be used to understand how students learning computer programming, particularly through online PBL, regulate their learning processes. SRL is particularly relevant in PBL environments where students must independently manage their learning, set goals, seek out resources, and evaluate their understanding—all key aspects of Pintrich’s model. This model also helps explain how students in a PBL environment set learning goals related to programming tasks and choose strategies to achieve these goals, monitor their progress.

The research framework of this study is presented in Figure 1.2, it is based on conceptual framework and outlines the relationship between the learning methods and the study variables. In this study, the independent variable, i.e., learning method will involve the PBL or DI mode, while the dependent variables involving the programming performance and critical thinking. Meanwhile, self-regulated learning will be the moderating variable.

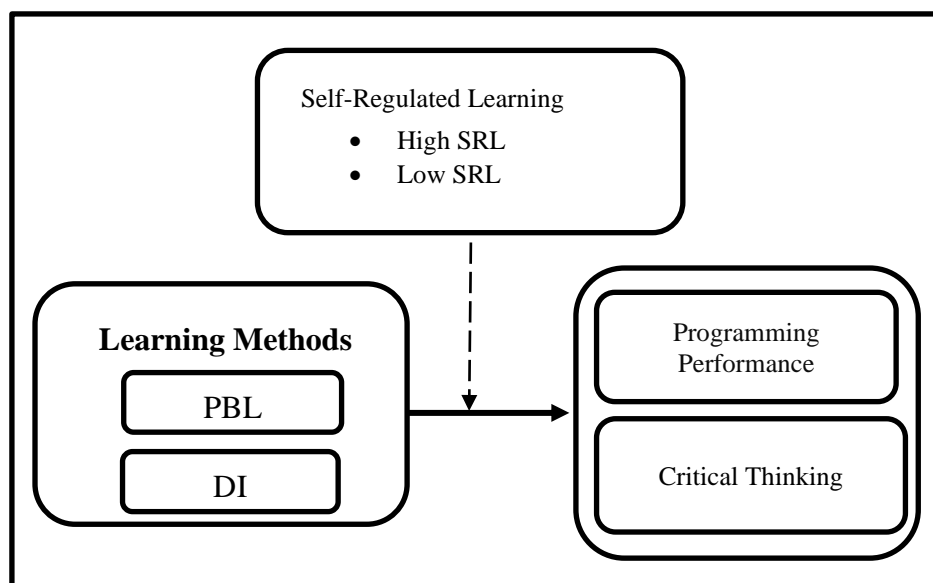


Figure 1.2 Research Framework of the Study

1.9 Significance of the Study

The significance of this study lies in its innovative approach to addressing the challenges facing programming education, especially in the context of a developing country such as Yemen. By exploring the effects of online PBL in a cloud computing environment on students' performance and critical thinking, this study has the potential to contribute to educational progress, particularly in enhancing programming education. This study highlights the potential of online PBL to develop the Yemeni students' abilities by encouraging them to actively engage with complex, real-world problems rather than passively absorbing information.

The study on online PBL strategy will possibly provide students with the opportunity to continue learning programming languages, and the effects of online PBL in this study may probably stimulate their thinking. It is hoped that the findings of this study will contribute for further understanding of the role of online PBL in enhancing the students' programming languages performance and critical thinking. The online PBL method will probably permit students to create decisions of their own and help them to improve their ability to ask and frame questions. In other words, the online PBL method will possibly make students be convinced and courageous when a solution is suitable. Thus, the findings of this study are significant to provide potential solutions in addressing the problems of students' attrition in programming languages learning. Findings from this study will also contribute to the existing literature on students' performance with online PBL specifically in online learning and potentially its impact on higher education.

Moreover, the findings of this study will provide the university with valuable insights into the cloud computing environment in assisting its administrations, further understanding of the new technology method in learning. If the use of a cloud

computing environment with PBL method proves its effectiveness in improving programming languages performance and critical thinking, lecturers will have a better alternative learning method to support the quality of learning and improve students' programming performance.

In addition, the utilization of online PBL in cloud computing environment in education will probably help the lecturers to be more creative and interested in their teaching strategies. The lecturer in PBL assists students evaluate their hypotheses and the processes they use, he acts as a guide who directs students to identify and analyze the problems, gives reward and motivation when they ask questions and find their own solutions.

Finally, this study will perhaps provide a significant contribution to the Ministry of Education in Yemen by demonstrating how online PBL can be an effective method for improving students' performance and critical thinking in programming courses. Given the challenges of poor performance in learning programming languages, especially in a developing country with limited resources, implementing PBL through online platforms provides a practical and scalable solution. By encouraging active learning, collaboration, and critical thinking, online PBL can address the root causes of poor performance and equip students with the skills needed to succeed in programming. This could lead to broader educational reforms, which could improve the quality of science education across the country.

1.10 Operational Definitions

The following are the definitions of some of variables or key terms to avoid ambiguities in this study.

1.10.1 Cloud Computing Environment

Cloud computing includes applications provided as services over the Internet, along with the hardware and systems software located in data centers that support these services (Shamshirband et al., 2020). As defined by National Institute of Standards and Technology (NIST), it is a model to provide easy network access to a set of scalable networks (Naved et al., 2022). While cloud computing services provide storage, computing power, and platforms to build and run applications, including Learning Management Systems (LMS), online learning environments often use cloud computing services to host their platforms, are specifically designed for education and are centered around learning processes and interactions (Almarashdeh et al., 2021).

Google Apps is one of the most popular cloud services that can be useful for educational institutions and other organizations (Nasser, 2020), which will be used as the context in this study. Google Apps is a suite of collaboration tools by Google for productivity and collaboration. It includes applications such as Gmail for email, Google Drive for file storage, Google Meet for video conferencing and collaboration platform for virtual meetings, and Google Classroom. The online learning platforms used in this study were Google Meet and Google Classroom. Google Meet is a free application involving Google programs such as Google Forms, Google Docs, G-mail, and Google Presentations. It is a service for online meetings, sharing the screen, presenting documents, slides, during the presentation, class meeting, conference, etc. Meanwhile, Google Classroom is a free collaboration tool for teachers and students. Teachers can create an online classroom, invite students to the class and then post a new assignment, explaining the problem scenario, main concepts, required resources and student tasks. Within Google Classroom, both the students and teachers can have