

A Development of Online Problem-Based Learning Model to Promote Self-Regulated Learning among Undergraduates

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Abstract

This research aimed to develop and evaluate an online problem-based learning (PBL) model to enhance undergraduates' self-regulated learning (SRL). The Research and Development method was used in two phases: the first was to develop and validate the model. It began with a literature review to identify core features of effective PBL and SRL within an online environment, then set a concept framework and create the model manually. Seven experts were reviewed following the model, and it was piloted for further optimization. Second, the model will be implemented and evaluated with a sample of 52 students at Thailand National Sports University, Chumphon Campus. The main instruments used were the developed model, the model quality questionnaire, SRL assessments (pre- and post-), and after-action review forms. The results showed that (1) a developed model consisting of four sections: orientation of the model, the model of instruction, application, and student outcomes. Six core components: authentic problems, online collaborative learning, self-regulated learning, instructional scaffolding, online learning resources, and authentic assessments, which are organized through three main processes: preparation, implementation of SRL strategies, and summative assessment, and all activities using an iterative learning three stages: meeting the problem and planning, doing and checking, and presenting the result and reflecting. Experts agreed on the quality of this model, which was excellent. ($M=4.61$, $SD=0.52$). (2) Average SRL score was significantly higher after learning with this model compared to prior us ($p<0.01$, large effect size; $d=1.03$). The findings of this study support the developed model that can improve the students' SRL effectiveness. Overall, the students agreed that an instructor plays a critical role in developing their SRL and problem-solving skills. The students demonstrated more self-assurance and were apt to use this method to learn other subjects.

Keywords: online learning, problem-based learning, self-regulation learning, technology-enhanced learning

1. Introduction

Digital technologies are transforming the face of the undergraduate college landscape—successful or unsuccessful leader or follower, profitable or non-profitable. The digital revolution is not simply about new tools; it reflects a greater change in how education is created and consumed across the planet (Selwyn, 2016, p. 31). The widespread availability of digital tools, online platforms, and new teaching methods can establish a more flexible, personalized, and motivating learning environment that questions traditional education concepts (Hollands & Tirthali, 2014; Díaz-García, Montero-Navarro, Rodríguez-Sánchez, & Gallego-Losada, 2022). A handful of factors drive the digital transformation in undergraduate education. The Internet has also democratized access to information, paving the way for students from varied geographic and socioeconomic backgrounds to obtain top-tier educational resources (Morris, 2016). Another course where the digital economy calls for a different skillset is teaching students to prepare for future workforce needs since workers must manage another one of the above shifts (OECD, 2019). The COVID-19 pandemic has accelerated the rapid transformation of traditional higher education (Natalia, Pratama & Fitriyanti, 2021), which requires effective pedagogical approaches that attract students and promote self-regulated learning (SRL) in digital environments (Aroonsrimarakot, Laiphrakpam, Chathiphot, Saengsai, & Prasri, 2022).

Welcome to the age of everything digital, the era in which even those at the undergraduate level are embracing online learning — but do not think that all of this moving toward being completely digital will automatically yield better results. Moreover, studies indicate that integrating different teaching modes endows blended learning

online or face-to-face, rendering this quasi-experimental design potentially more effective (Bernard, Borokhovski, Schmid, Tamim & Abrami, 2014; Rodniam, 2015). The flip side is that numerous undergraduate students find self-regulation, time management, and motivation challenging in less structured online environments (Coman, Țiru, Meseșan-Schmitz, Stanciu & Bularca 2020). With online platforms, students can tap into digital assets otherwise unreachable, collaborate across cities/continents effortlessly, and study on a schedule of their choosing.

In order to raise the quality and efficiency of undergraduate education, actualizing limits of learning using resources should be removed or transformed into learning innovations that support a higher rate of student learning. The ongoing reorganization of the higher education system puts pressure on signaling theory by focusing on learning and lifelong learning effectiveness. The Internet and many digital communication devices like computers, tablets, and smartphones have made online learning more convenient. Existing studies have shown that online learning structures offer many advantages for students, such as student-centeredness, flexibility, and interaction level support using the tools used in both asynchronous (email/forum) and synchronous form chats/virtual classrooms/video conferences (Anwar & Adnan, 2020; Dhawan, 2020; Marinoni et al., 2020).

In addition to this, Internet technologies also allow the concurrent delivery of content to multiple users, which is a key benefit that online platforms offer students within their teaching space, including power over what material they browse and how long they spend studying them, offering self-directed learning in terms of pace and goal achievement (Suresh, Priya & Gayathri, 2018). Several online learning platforms, including Google Classroom, Microsoft Teams, and Canva, help the instructor guide through it all. Also, e-learning platforms provide free resources and certification for anyone, which an instructor can leverage to increase course participation.

ThaiMooc provides courses from colleges and educational institutions in Thailand for everyone who wants to learn wherever and whenever. The platform also facilitates both formal and informal learning interaction using a wide range of technologies, enabling the creation of learning cycles (Thai Cyber University Project, 2020). These examples demonstrate ways online learning could drive increased productivity for undergraduates. However, effective 21st-century learning involves studying students' knowledge and collaborative learning. In this increasingly complex and dense subject knowledge and information environment, problem-based learning (PBL) has become one of the most popular teaching methods. The current knowledge can be outdated and misplaced. The community of students—the approach: Students need to know how to learn, i.e., get at learning materials independently, learn to justify ideas, and reach solutions (alongside the ability obviously to seek information). These learning processes and abilities are the targets of improvement students can benefit from PBL.

PBL is a type of instruction in which students connect with complex and real-world problems, parallel to Dewey's idea about experiential learning (Tan, 2003). Students are also required to engage in collaborative group work, self-directed learning, and problem-solving based on new knowledge (Graaff et al., 2003; Vygotsky, 1978) using the student-centered approach. PBL facilitates providing the student with the chance to improve problem-solving skills, metacognitive capabilities, critical thinking, and intrinsic motivation (Barrows, 1996; Jonassen, 2000; Duch et al., 2001). PBL activities enhance student engagement and motivation in online learning by involving students with tasks that mimic real life.

Even though PBL has its upsides, there are multiple challenges, such as technical issues and unequal contribution, and it is time-consuming for assessment and feedback (Alves et al., 2016; Tawanwongsri & Phenwan, 2018). Furthermore, there is evidence that students in PBL settings perform better on standardized tests than their counterparts in traditional environments. Nonetheless, entwining SRL with PBL can help develop lifelong students who take charge of their learning processes (Graaff, 2003).

The purpose of this narrative review is to analyze previous accumulator reviews and subsequent meta-analyses or systematic reviews published from 1992 to 2019 regarding PBL to shed light on their educational efficacies. Waves in PBL research (Hung, Dolmans, & Van Merriënboer, 2019). Wave period Focus Key findings Polarization 1990s to mid-2000 Effectiveness research and integration Inconclusive results of effectiveness; Polarized views among researchers Integration Mid-2000s to present Content and Curriculum Integration Efforts: productive/meaningful? 2) From outcomes to process (mid-2000s–mid-2010s): generation of research focusing on how or why PBL is working (e.g., factors influencing implementation, cognitive processes involved). Specialization (mid-2010s onwards) — Examined PBL in various contexts: online platforms, disciplines, and cultures. The authors underscored further research on interdisciplinary PBL and utilized a combination of theoretical perspectives to understand this pedagogy better. This reflects trends in the literature and the status of

current research on expert PBL development in online environments. It states that using online learning to supplement PBL can provide a rich, engaging learning experience and meet the demands of students. Nevertheless, issues around technology's inherent limitations and good instructional design still need to be solved (Donnelly, 2008).

Reflecting on Gijbels and Dochy's (2006) model, the authors suggest that PBL is conducive to authentic learning opportunities where learning is centered around real-world problem-solving and technology tools used for reflection and critical thinking in a digital age can support the creation of engagement learning contexts by combining with technological tools such as blogs or e-portfolios (Portimojärvi & Donnelly, 2010).

Research into e-learning challenges in Thailand indicates three major factors contributing to its adoption's effectiveness: a tech-savvy instructor, student-instructor interactivity, and internet connectivity. The most common challenges were unstable internet access, lack of self-motivation, poor time management, and inadequate quiet spaces for learning (Aroonsrimarakot et al., 2022). Tawanwongsri and Phenwan (2018) have placed these in the category of technical issues, such as unstable Internet and ineffective digital tools, which prevent PBL from being well-supported in virtual learning environments. Indeed, a study by W. Nuankaew, P. Nuankaew, Teeraputon, Phanniphong, & Bussmann (2019) shows that Thai higher education students strongly realize the value of SRL but resort to formal learning over SRL activities, in effect contradicting the very nature of the digital learning environment. This, in turn, exposes the incongruence between their beliefs and their actions. Therefore, another challenge is to encourage the SRL in formal and informal flexible environments that can generate equilibrium with the sustainability of lifelong learning.

However, the efficacy of online learning in cultivating SRL is an issue that still requires further exploration (Bernard et al., 2014; Broadbent & Poon, 2015; Wandler & Imbriale, 2017; Chitra et al., 2022). Self-regulated students plan how they will approach a learning task in ways that allow them to monitor their cognition, metacognition, and motivation and appraise and adjust their strategies following task completion (Azevedo & Hadwin, 2005). Students' SRL involves metacognitive, motivational, and behavioral processes to get help with learning and performance targets (Zimmerman, 2000). However, if the learning environments for undergraduates' online format provide adequate structure and frequent feedback, they may harm the development of self-regulated learning skills (Cho & Cho, 2017).

Research has been conducted on the relationship between PBL and SRL in several studies regarding the capability of PBL to increase SRL skills. For example, a meta-analysis by Dochy, Segers, Van den Bossche, and Gijbels (2003) found that PBL environments are more effective in teaching students to self-regulate their learning than traditional instructional methods. For example, Sungur and Tekkaya identified that PBL positively affects SRL behaviors such as goal setting, strategic planning, and self-monitoring (Sungur & Tekkaya, 2006). Also, English and Kitsantas (2013) suggested a theoretical model that articulates the interdependent relationship between PBL and SRL. It has been put forward that these PBL tasks inherently elicit SRL processes (forethought, performance, and self-reflection), which are important for good student outcomes. In addition, their findings highlighted the importance of PBL environment design in facilitating SRL. They suggested educators integrate scaffolding and formative assessments to nurture SRL aptitudes throughout PBL.

The above shifts happening in the undergraduate learning context have demanded a combination of online PBL with SRL, which was one of these ways to support students' learning. With technology reshaping school workflow, it is time to explore innovative ways to ensure our youngsters are adequately groomed to handle the obstacles prevalent in this century. Therefore, the researchers strive to create learning innovations such as online learning with the PBL model and SRL strategies as an approach for student regulation in learning. Therefore, the main objectives of this study were to develop an online PBL learning model—how to motivate undergraduates' SRL and what its quality—as well as products realized to implement tested models through comparison between pre- and post-course SRL scores for students on the implemented model and investigation of students' opinions with Online PBL learning.

2. Literature Review

The following literature review outlines the conceptual pillars that frame our understanding of online learning models, problem-based learning (PBL), and self-regulated learning (SRL).

2.1 Online Learning Models During the COVID-19 Pandemic

The advent of online learning in the educational realm has been a game-changer by offering students learning opportunities that are both flexible and easily accessible compared to traditional classroom scenarios. COVID-19 forced many educational institutes to move online and teach synchronous as well as asynchronous learning,

encouraging engagement, self-directed learning, etc. Some factors of successful formulas for online learning:

1) Synchronous and A-synchronous Learning: the combination of lesson life along with a pre-recorded platform that increases student interaction as well as active learning (Almusharraf & Khahro, 2020; Stojan et al., 2021; Lapitan, Tiangco, Sumalinog, Sabarillo, & Diaz, 2021).

2) Synchronous and Asynchronous Learning: The blend of live and pre-recorded sessions enhances student engagement and promotes flexible learning (Stojan et al., 2021; Almusharraf & Khahro, 2020; Lapitan et al., 2021).

3) Online Platforms and Tools: The implementation of online platforms such as Zoom, Google Hangouts, and Learning Management Systems (LMS); for example, Moodle or Google Classroom) facilitated the distribution of lectures and course control, resulting in better student satisfaction (Coman et al., 2020; Bao, 2020).

3) Instructional Strategies and Support: Unlike traditional instruction, in online education, instructional strategies must be high-quality, like good quality instructional design, delivery of teaching is effective at the student end, and enough support from the faculty lines to meet learning expectations (Bao, 2020).

Regarding online learning, we can summarize the process into three (3) main stages based on Vayo, Charoennukul, Kanayan, and Kanya (2020).

1) Before online teaching, faculty members must evaluate the preparedness and organize learning management strategies that will work in situations where students find themselves.

2) Teaching & Learning: Here, the instructors have to keep things in check during teaching, as well as methods plus tools of choice for student engagement.

3) Post-Online Teaching: Assessment and de-briefings of student outcomes are essential to elevate teaching performance.

It is very important to plan appropriate instructional activities in these phases at the right place for online learning efforts.

2.2 Problem-Based Learning

Problem-based learning (PBL) is a teaching method (Yusof, Hassan, & Tasir, 2007) that helps learners develop the ability to think critically and solve problems in a team. PBL is a teaching principle in which complex, work-related problems engage students in an inquiry-based learning process (Boud & Feletti, 2013; Pengelly, 2010). Critical Elements of PBL:

1) Triggering Complexity via Problems: PBL starts with presenting ill-structured problems to rouse in-depth cognitive engagement (Hmelo-Silver, 2004; Yadav, Subedi, Lundeberg, & Bunting, 2011).

2) Work in collaborative learning groups of 3-4 students to identify learning gaps and problem-solve, thereby improving teamwork and communication skills (Hmelo-Silver, 2004; Ahern et al., 2011).

3) Self-Directed Learning: Students learn to find relevant information independently, developing lifelong learning strategies and internal motivation (Hmelo-Silver, 2004).

4) Instructors as Facilitators: Instructors facilitate and assist students by focusing on learning strategies (Hmelo-Silver, 2004).

5) Theory and Practice Integration: PBL links theory to practical content, which improves comprehension (Williams & Beattie, 2008).

6) Reflective Practice: Promotes reflection to enhance learning and metacognitive skills (Hmelo-Silver, 2004).

2.3 Self-Regulated Learning

Self-regulated learning (SRL) models consist of three phases: forethought, performance, and self-reflection. Goal-setting, planning, monitoring, and evaluation are critical to SRL and academic success — even more so in an online setting where students have to function without outside support. These processes include motivational beliefs and learning strategies (e.g., cognitive and metacognitive strategies and behavioral regulation). This study divided self-regulated learning into two subdimensions primarily based on the three theories above: 1) motivational beliefs and 2) learning strategies. Built from a synthesis of main constructs extracted from SRL by Wonglorsaichon (2012), Broadbent & Poon (2015), Ratanavaraha (2016), Lee, S. Watson, & W. Watson (2019), Broadbent, Panadero, Lodge, & Fuller-Tyszkiewicz (2022), Higgins, Frankland, & Rathner (2021) and Anthonysamy, Ah-Choo & Hew (2021). This research examines the major aspects of self-regulated learning, including the following:

Motivation Beliefs Dimension:

- 1) Self-Efficacy: Students feel that they can achieve the requirements for a given course, which may elicit desire within students using intrinsic motivation.
- 2) Task Value: This is, in essence, the degree to which students feel they are capable of doing well at a particular kind of work—their belief they can be successful, along with how interesting, important, and enjoyable they find working on that type of task (which can provide active engagement).

Learning Strategy Dimensions:

- 3) Critical Thinking: Teaching students how to evaluate information critically means they understand it better and are less likely to forget what they have learned.
- 4) Metacognition: At the end of our learning, students know how they learned and use strategies to manage their studying (planning and monitoring study), the capacity that students have to plan, monitor, and reflect on their practices in the study.
- 5) Plan and Time Management: It would help students with scheduling their long-term as well as short-term time for the learning activities or can suggest the exact time slot for each of them.
- 6) Regulation of Effort: A defended low power capacity of substitution applied in the face of a lack of interest in tasks and perseverance, they can remain focused on goals and cope with distractions or more attractive activities, controlling efforts and materials for their development.
- 7) Social Support Seeking: As they might not be accessible to the instructors or peer learning activities, which makes them feel lonely, so in the context of knowledge exchange or peer-supported facilities and discussions, social support seeking by way of building their confidence and understanding does help.
- 8) Online Study Environments: Students have the power to be quiet and not noisy during their studies.

2.4 Conceptual Framework of An Online PBL Model to Promote SRL among Undergraduates

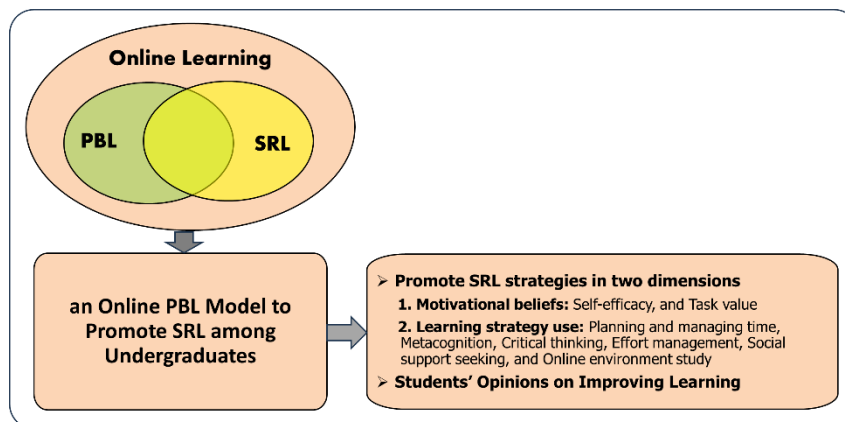


Figure 1. A Conceptual Framework for an Online PBL Model to Promote SRL among Undergraduates

In summary, integrating online learning models, problem-based learning, and self-regulated learning prepares undergraduates for success in an evolving educational landscape.

3. Research Method

The study used a two-phase mixed-methods research design based on the Research and Development (R&D) methodology approach.

Phase 1: Model Development and Validation

- 1) Literature Review: The study starts with a generalizing review of the equivalent and related work on online learning models, problem-based learning (PBL), and self-regulated learning (SRL) and explores specific components of these difficult parts captured in earlier studies at distinctive levels of the education system.
- 2) Conceptual Framework: We utilized the data from this initial phase to construct a conceptual framework that will guide the development of the online PBL+SRL model.
- 3) Model development and expert validation: The online PBL+SRL model was developed along with the user

manual and sent to seven experts for validation or comments. Purposive: We used a random selection method to select experts in online learning, problem-based learning (PBL), and self-regulated learning (SRL). The experts were asked to fill out questionnaires and respond to extensive interviews. Results: Data were analyzed descriptively using mean values and content analysis. The researchers used the results to improve both the model and the user manual.

4) A pilot test: Pilot trial of the revised model and student manual involving second-year undergraduate students enrolled in the "Digital Technology for Learning Innovation Development" course during 2022 semester one at the Faculty of Education, National Sports University, Chumphon. This included observed experiences, interviews, assessed information based on learning tracking from the Learning Management System (LMS), and ideas generated from the after-action review (AAR) activity. The qualitative research used content analysis to summarize and analyze the indicator-level data to inform the rest of this manual.

Phase 2: Implementation and Evaluation of the model

1) Implementation: An online PBL+SRL model, with 52 undergraduate students, was implemented in the course "Digital Technology for Life" for the second semester of the academic year 2022 at Thailand National Sports University, Chumphon Campus.

2) Research Design: The study used the one-group pretest and posttest research design (Cohen, Manion, & Morrison, 2000). Most often, this design is used to evaluate the effect of an intervention within one group of participants. 15 weeks in, and they all graduated from the online PBL+SRL model. We used data from SRL measures in the pre-and post-test stages as the target variable, obtained from participants before and after engaging in online PBL+ SRL.

3) Data Collection and Data Analysis: The data were collected from the participants using a version of the SRL measure adapted by the researcher based on the works created by Broadbent, Panadero, & Fuller - Tyszkiewicz (2020) and Wonglorsaichon (2012) with 5-point Likert-type rating scale-questionnaire format, which contained a total number of 36 items and was divided into two dimensions supported each other by eight components, which has a reliability of $\alpha = 0.83-0.94$. Besides that, student opinions on the online PBL+SRL model were collected through AAR activities and interviews. After the intervention, the difference in SRL scores is tested quantitatively by t-test for dependent samples. Furthermore, effect size analysis was naturalized to test the disparity among pre-post experimental groups in terms of standard deviation units, and the mean scores were calculated by dividing the difference between the mean scores between compared pairs of samples against the total dispersion. Effect Size: To determine the extent to which there is a difference in SRL scores between the groups, we calculated the effect size. Effect sizes were interpreted as small, medium, and large under Cohen's $d=0.2, 0.50, \text{ and } 0.80$ (Furr & Cohen et al., 2008; Cohen et al., 2000). This study analyzes qualitative data through content analysis of student feedback to capture emerging themes.

4) Ethical Considerations: Ethics approval was obtained from the Thailand National Sports University Research Ethics Committee (Project No. EDU 046/2022). We adhered to respecting and protecting subjects' rights during the research period.

4. Results

As for the research, its results can be divided into two to be as follows:

4.1 Results of Model-Developed and Quality Analysis

The online PBL+SRL model that was developed is illustrated in Figure 2. It consists of four sections: 1) orientation to the model, 2) the model of instruction, 3) application, and 4) student outcomes. The quality of the model was rated excellent ($M=4.61, SD=0.52$). In the field trial, the pilot test results showed that PBL in the classroom was more interesting to students in conjunction with a blended online environment. Students applied SRL strategies in motivational dimensions like the perception of self-efficacy and task value to facilitate cooperation with same-interested students in group formation. The discipline of learning strategy use (for which the quality of work was rated) produced better results with critical and reflective thinking. They also found that scheduling and making time for work was important because many students had other commitments, such as competing in sporting tournaments, which meant they needed to manage their time effectively, utilize online resources for studying, and fall back on asking instructors or peers for help. In conclusion, the students thought that learning was flexible and could be planned, using online tools and communication with some practice, which turned learning into a more effective means to gain knowledge, work on solving problems, and lifelong continuous learning.

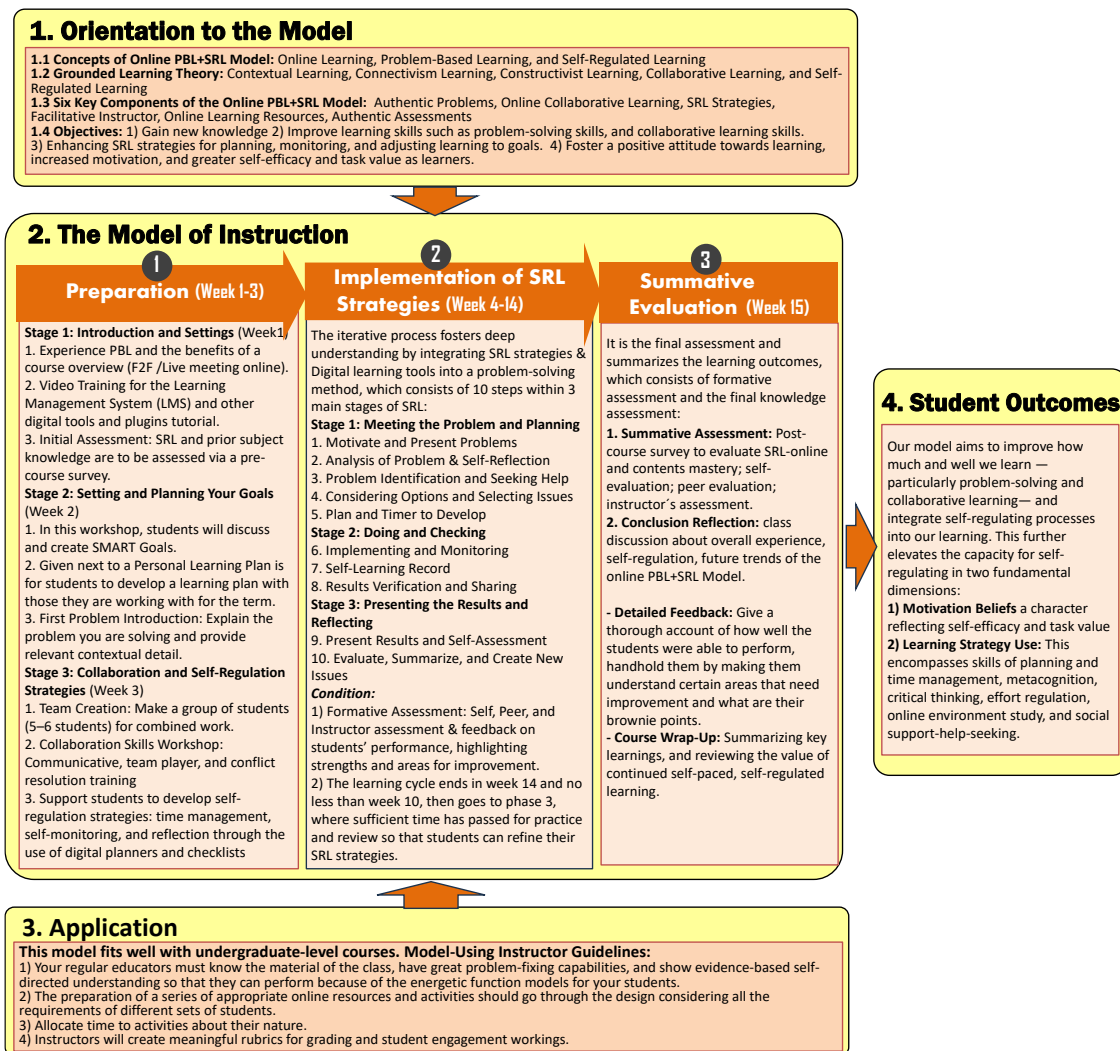


Figure 2. An Online PBL+SRL model for promoting SRL among undergraduates

The implementation of the online PBL+SRL model is given below.

Section 1) Orientation of the Model

State the origin of the model's theoretical concept, principles, and objectives.

1.1 This model integrates three key concepts:

- 1) Online learning— utilizes the flexibility and anywhere/anytime convenience of online environments to offer a broader range of resources that enable students to engage in multimedia, multi-sensory instruction and interaction;
- 2) Problem-Based Learning (PBL)— This same philosophy is at the center of PBL, which centers on real problems and requires students to apply knowledge as a group to work towards solving these problems.
- 3) Self-Regulated Learning (SRL)—Assisting students in managing and controlling their behavior, emotions, thoughts, and strategies involved in self-directed learning.

1.2 The Model is fully based on the following major learning theories:

- 1) Contextual Learning—The learning process begins with a driving-ill-structured real-world problem that drives the learning process, providing relevance and context.
- 2) Constructive Learning—Students learn by doing; this includes engaging in creative approaches to solving problems, generating hypotheses, and investing themselves in building or developing solutions through continued inquiry.

3) Collaborative Learning—Small groups of students collaborate online, sharing ideas, co-constructing knowledge, and providing feedback.

4) Connectivism Learning—Instructors develop digital learning environments that enable students to acquire the skill of navigating the information landscape, establish connections, and learn how to self-regulate their knowledge in collaboration with a learning community.

5) Self-Regulated Learning—Accountability of the learning process: Students are accountable for their learning in group work and individual tasks through a cycle of planning, monitoring, strategy use, and evaluating-reflection leading to self-improvement.

1.3 Core Components of Online PBL+SRL Model:—as shown in Figure 3.

1) Authentic Problems— The model starts with real problem situations that are complex and ill-structured, related to students' lives or careers, setting the stage for inquiry and learning.

2) Online Collaborative Learning— Students are placed in small online teams to investigate problems, propose hypotheses, recognize learning gaps, and create solutions through recursive inquiry and discussion.

3) Self-Regulated Learning— Students are independent producers who can regulate their learning and produce knowledge through self-regulatory strategies, such as motivational beliefs. They also use creative thinking skills to establish goals, set plans, and manage time with their self-motivation goal setting/targets.

4) Instructional Scaffolding—Instructors scaffold essential SRL processes by giving prompts, feedback, modeling, coaching, and/or facilitating online discussions.

5) Online Learning Resources—A digital learning environment supports formal and informal learning anytime. Content and tools for active collaboration and SRL are contained in Thai MOOCs, Google Classroom, self-paced courses, discussion, and resource sharing.

6) Authentic Problems—Assessment is linked directly to student performance (tests), involves students in authentic applications and situations, and is embedded within the learning process—both formative and summative assessment processes are highly reflective of how well the students can use their knowledge and skills in real-world contexts; frequent feedback used as a tool for monitoring progress, identifying problems early.

1.4 Learning Objectives:

1) Acquire new knowledge,

2) Enhance learning skills (filtration between problem-solving and collaborative learning)

3) Disseminating the behavior of SRL across two parts: a) motivational beliefs (i.e., self-efficacy, task value); and b) learning strategy use (i.e., planning and time management, metacognition, critical thinking; effort management; studying in online environments; seeking social support online).

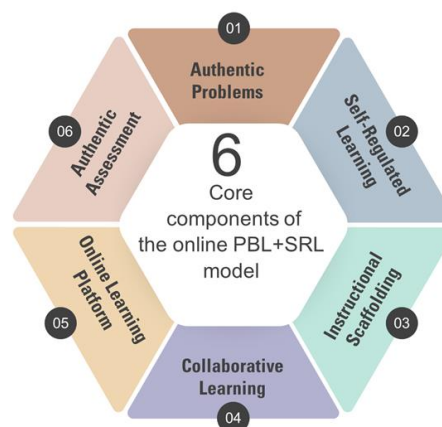


Figure 3. Six Core Components of an Online PBL+SRL Model

Section 2) The Model of Instruction

The learning process is divided into 3 main phases, each with respective learning activities.

Phase 1: Preparation (Weeks 1-3)

Provides examples of activities focused on instructors organizing basic activities for students engaged in online learning, problem-solving, and using self-regulated learning strategies (practice), as shown in Table 1.

Table 1. Describe stages, objectives, and methods & tools of organizing event activities in phase

Stages	Objectives	Activities	Methods & Tools
Introduction and Settings (Week 1)	Introduce students to the PBL model and an online learning environment.t.	<ol style="list-style-type: none"> 1. Experience PBL and the benefits of a course overview (F2F classroom/Live meeting online). 2. Video Training for the Learning Management System (LMS) and other digital tools and plugins tutorial. 3. Initial Assessment: SRL and prior subject knowledge are to be assessed via a pre-course survey. 	<ol style="list-style-type: none"> 1. The teaching mode: Interaction helps build good relations in a positive surrounding. 2. LMS: For self-paced learning activities; Thai MOOCs Google Classroom For problem-based learning activities
Setting and Planning Goals (Week 2)	Equip students with goal-setting and planning skills.	<ol style="list-style-type: none"> 1. In this workshop, students will discuss and create SMART Goals. 2. Given next to a Personal Learning Plan is for students to develop a learning plan with those they are working with for the term. 3. First Problem Introduction: Explain the problem you are solving and provide relevant contextual detail. 	<ol style="list-style-type: none"> 3) Social Communication Tools: i.e., Line, Facebook. 4. Google Hangouts, Canva, and Slack 5. digital SMART teaching/learning environment supports (mind maps, visual organizers); cognitive support group discussions; collaborative planning COCA with peers; metacognitive aids digital planners — i.e., Google Calendar, checklists.
Collaboration and Self-Regulation Strategies (Week 3)	Implement collaboration and self-regulation strategies.	<ol style="list-style-type: none"> 1. Team Creation: Make a group of students (5–6 students) for combined work. 2. Collaboration Skills Workshop: Communicative, team player, and conflict resolution training 3. Support students to develop self-regulation strategies: time management, self-monitoring, and reflection through the use of digital planners and checklists 	

Phase 2: Practice and Application of SRL strategies

An iterative process ensues to develop conceptual understanding, using the learning cycle integration of concepts learned into solving actual problems via both SRL strategies and digital tools. The stage has been divided into three distinct sub-stages, as shown in Table 2, and digital tools to support SRL are shown in Table 3.

Table 2. Shows the stages and sub-stages, objectives, activities, and SRL strategies of organizing in phase 2

Stages and Sub-Stages	Objectives	Activities	SRL Strategies
Stage 1: Meeting the problem and planning — student slot; a week as scheduled; student can extend to resolve issues and plan outside class.			
1. Motivate and Present Problems:	Introduce meaningful and challenging real-world problems that get students thinking.	Digital Tools for Multimedia Presentations, Case Studies, and Interactive Simulations.	Directly ask students how they will address the problem.
2. Analysis of Problem & Self-Reflection	Guide students in deconstructing questions and thinking critically about their understanding.	Run brainstorming and use concept maps.	Encourage reflections upon prior knowledge and identify map snapshots of background information.
3. Problem Identification and Seeking Help	Understanding the whole problem and being given guidance to seek help.	With discussion forums and Q&A sessions	Develop help-seeking behaviors utilizing peer and instructor support.
4. Considering Options and Selecting Issues	To lead to consideration of alternative strategies and focal points	Decision-making apparatuses and joint group talk.	Develop critical thinking and decision-making.
5. Plan and Timer to Develop	Teach students a structured method used for problem-solving.	Plans and Timelines TEMPLATES	Help in goal setting and managing time.
Stage 2: Doing and Checking — Students will work on exercises independently after class.			
6. Implementing and Monitoring	Carry out the plan but trace the progress continuously.	Project management tools and progress-tracking software can be used.	Foster self-regulation and adaptive learning strategies.
7. Self-Learning Record	Keep a learning log of topics covered and thoughts about them	Engage in peer reviews and use collaboration tools.	Practice self-assessment and peer feedback.
8. Results Verification and Sharing	The goal is to confirm and receive feedback on the findings.	Conduct peer review sessions and utilize collaborative platforms.	Develop self-evaluation and peer feedback skills.
Stage 3: Presenting the result and reflecting — This phase is a time for students to present their work and reflect on what they learned from it and self-assessment results.			
9. Present Results and Self-Assessment	Report results and evaluate performance.	Include presentation tools and self-assessment rubrics.	Develop self-reflection and public speaking skills.
10. Evaluate, Summarize, and Create New Issues	Assess one's study experience and pick up on patterns where improvements could be made.	Group Discussions & Summary Reports	Encourage self-reflective practice and set new learning benchmarks.

Condition: 1) Formative Assessment: self, peer, and instructor assessment and feedback on students' performance, highlighting strengths and areas for improvement. 2) The learning cycle ends in week 14 and no less than week 10, then goes to phase 3, where sufficient time has passed for practice and review so that students can refine their SRL strategies.

Table 3. Digital tools to support SRL strategies at each stage of the iterative process of the model

Stages / Sub-Stages	Digital Tools
Stages 1: Problem and planning	
1. Motivate and Present Problems	- Multimedia Presentations: Tools like YouTube, PowerPoint, and Canva. - Interactive Simulations: Platforms such as virtual labs. - Case Studies: Videos from YouTube and news outlets.
2. Analysis of Problem & Self-Reflection	- Mind Mapping Software: Tools like GitMind or Lucidchart for brainstorming. - Reflection Apps: Digital journals or apps like Google Docs and Keep Notes.
3. Problem Identification and Seeking Help	- Discussion Forums: Platforms like Google Classroom for Q&A and discussions. - Collaborative Tools: Communication tools like Line and Facebook Messenger.
4. Considering Options and Selecting Issues	- Decision-Making Tools: Software like Trello for weighing options and decisions. - Collaborative Platforms: Google Workspace for shared documents and discussions.
5. Plan and Timer to Develop	- Assessment Tools: Google Forms for assessments and Seesaw for digital portfolios. - Calendar Apps: Google Calendar is used to set activity plans, deadlines, and reminders.
Stages 2: Doing and Checking	
6. Implementing and Monitoring	- Learning Analytics: Platforms like Canvas and Google Classroom that provide analytics to track student progress.
7. Self-Learning Record	- E-Portfolios: Tools like Google Sites for maintaining a learning portfolio. - Digital Journals: Apps like Evernote for recording learning experiences and reflections; voice recording apps for capturing reflections.
8. Results Verification and Sharing	- Peer Review Platforms: Services like Peergrade for structured peer review. - Collaboration Tools: Platforms like Padlet and Jamboard for sharing and discussion.
Stages 3: Presenting the Results and Reflecting	
9. Present Results and Self-Assessment	- Video Conferencing Tools: Platforms for one-on-one help from instructors. - Presentation Tools: PowerPoint, Canva, or Google Slides for presenting findings. - Self-Assessment Rubrics: Digital rubrics in LMS like Canvas or Google Forms for self-evaluation; peer and instructor feedback forms.
10. Evaluate, Summarize, and Create New Issues	- Survey Tools: Google Forms or Qualtrics for collecting feedback. - Summary Tools: Tools like Miro or MindMeister for summarizing discussions and setting future action steps.

Phase 3: Summative Evaluation (Week 15, or the final week)

1. Summative Assessment: Post-course survey to evaluate SRL-online and contents mastery; self-evaluation; peer evaluation; instructor's assessment.

2. Conclusion Reflection: Class discussion about the overall experience, self-regulation, and future trends of the Online PBL+SRL Model.

- Detailed Feedback: Give a thorough account of how well the students performed, handhold them by making them understand certain areas that need improvement and their brownie points.

- Course Wrap-Up: Summarizing key learnings and reviewing the value of continued self-paced, self-regulated learning.

Section 3) Application

This model fits well with undergraduate-level courses. Model-Using Instructor Guidelines

1) Your regular educators must know the material of the class, have great problem-fixing capabilities, and show

evidence-based self-directed understanding so that they can perform because of the energetic function models for your students.

2) The preparation of a series of appropriate online resources and activities should go through the design considering all the requirements of different sets of students.

3) Allocate time to activities about their nature.

4) Instructors will create meaningful rubrics for grading and student engagement workings.

Section 4) Student Outcomes

Our model aims to improve how much and well we learn — particularly problem-solving and collaborative learning, and integrate self-regulating processes into our learning. This further elevates the capacity for self-regulating in two fundamental dimensions:

1) Motivation Beliefs a character reflecting self-efficacy and task value

2) Learning Strategy Use: This encompasses skills of planning and time management, metacognition, critical thinking, effort regulation, online environment study, and social support-help-seeking.

4.2 Results of Implementing the OPBL+SRL Model

When the developed model was implemented, it was found that the students had significantly higher self-regulated learning scores after studying than before studying at the .01 statistical level. The effect size was at a high level, both overall (1.037) and in each aspect: motivational beliefs (0.925) and learning strategies (0.996), indicating that the application of the model can help develop the students' SRL ability. The results of the data analysis are shown in Table 4.

Table 4. The comparison of the pretest and posttest of the SRL abilities

The SRL abilities	Pretest (n=52)		Posttest(n=52)		t	df	p	SD _p	Effect size
	Mean	SD	Mean	SD					
1) <i>Motivational Beliefs</i>	3.785	0.694	4.204	0.652	6.718	51	.000**	0.438	0.925
- Self-efficacy	3.716	0.733	4.192	0.678	7.317	51	.000**	0.478	1.005
- Task-Value	3.712	0.700	4.212	0.680	5.131	51	.000**	0.497	0.665
2) <i>Learning strategies</i>	3.741	0.621	4.119	0.621	6.902	51	.000**	0.357	0.996
- Critical thinking	3.715	0.658	4.165	0.622	6.903	51	.000**	0.402	0.892
- Metacognition	3.815	0.659	4.146	0.606	5.937	51	.000**	0.402	0.756
- Plan & Time management	3.685	0.667	4.085	0.624	5.602	51	.000**	0.515	0.725
- Effort regulation	3.769	0.752	4.101	0.623	4.991	51	.000**	0.479	0.682
- Social support-help seeking	3.681	0.724	4.015	0.615	5.012	51	.000**	0.481	0.655
- Online environment study	3.782	0.636	4.199	0.595	6.718	51	.000**	0.447	0.889
<i>Overall of SRL</i>	3.752	0.627	4.140	0.571	7.873	51	.000**	0.355	1.037

Note: **p<.01

Student Opinions on the online PBL+SRL Processes

The majority of students expressed that the online PBL+SRL process was highly effective as it supported their learning journey from curiosity to comprehension through hands-on experience and collaborative group work. They specifically noted their appreciation for the instructor, who provided clear guidance and explained the significance of the learning material. Although the problems presented were often challenging, the instructor frequently introduced new techniques to facilitate learning. By maintaining individual follow-up with students and encouraging problem-solving, the instructor made the learning experience engaging rather than mundane.

Students indicated that this learning approach empowered them to explore innovative learning methods, take risks, and be more proactive in their learning endeavors. They also recognized the flexibility of online learning concerning time management. Nevertheless, some students encountered issues with internet connectivity and device performance. Still, collaborating and sharing information within the online classroom invigorated their understanding and motivation, particularly when managing assignment deadlines.

Furthermore, students found that this learning method not only enhanced their knowledge but also enabled them to apply new insights to other subjects and their daily lives, fostering a stronger sense of responsibility and self-assurance. They emphasized the importance of self-assessment and reflection in their learning, which they could easily incorporate using online tools, thereby improving self-awareness and highlighting the utility of such

tools in streamlining the learning process. The instructor's support was vital in boosting morale and instilling the understanding that every problem has a solution. Students recommended integrating online and problem-based learning across various subjects to enhance flexibility and effectiveness.

Case Examples:

Case 1: "We appreciate this type of learning because it provides us with new perspectives. There are many ways and options available, and we can discover knowledge independently, which builds our self-assurance."

Case 2: "Collaborative learning in groups is beneficial as it simplifies our success in learning and working, especially when using convenient online collaboration tools and AI assistants to produce high-quality work."

Case 3: "This approach makes me feel free to learn, fosters better relationships with my colleagues, and enhances my understanding of myself and others. I believe self-assessment and reflection will increase my awareness, enabling me to identify shortcomings and find solutions, improving my behavioral control."

Case 4: The After Action Review (AAR) study results indicate that instructors play an essential role in promoting both self-regulation and problem-solving learning. In every learning session, instructors clarify the objectives and significance of the content and offer concise guidelines on effective learning strategies, including how to seek help. This enables us to establish clear goals and actionable plans. When challenges arise, instructors encourage us and present opportunities to brainstorm new alternatives so we do not become discouraged during the learning process.

5. Discussion

The study demonstrates that the developed model, which integrates PBL and SRL within an online framework supported by technology, significantly aids students in becoming independent students. The researchers have pinpointed several critical discussion points.

5.1 Experts Who Reviewed the Developed Model Identified it as being of Excellent Quality

The model evaluation results are close to their excellent quality, considered together with the abovementioned influencing teaching theories/frameworks — PBL (related both to the ontological approach and complete notion/the entire idea of the learning process/modality offered), SRL, and online learning. This aligns with the fundamental principles of undergraduate education in the 21st century: to make learning more effective and other competitive strategies so that students will continue to learn throughout life (Aroonsrimarakot et al., 2022). This is consistent with Tanner and Tanner's (1995) assertion that a sound educational model should correspond to the needs and prevailing social conditions. The model is presented systematically, clearly, and user-friendly, consisting of four elements: orientation, instructional model, application, and student outcomes. The researchers enhanced the model by incorporating Joyce, Weil, and Calhoun's (2004) teaching framework, known for its practical applicability in educational settings.

The model's learning steps are based on four primary learning theories: contextual learning, connectivism, constructivism, collaborative learning, and self-regulated learning (4C+1S). These theories are vital for real-world application as they place students at the center of the learning experience, leading to six essential components: 1) authentic problems, 2) online collaborative learning, 3) self-regulated learning, 4) instructional scaffolding, 5) online learning resources, and 6) authentic assessments. The learning process is structured into three distinct phases: Phase 1: Preparation (Weeks 1–3), Phase 2: Practice and Application of SRL strategies (Weeks 4–14), and Phase 3: Summative Evaluation (Week 15). This structure aligns with Zimmerman's self-regulated learning process (Zimmerman, 2000), which includes three steps: 1) the forethought phase, 2) the performance phase, and 3) the self-reflection phase. The researchers would like to present the results of the close examination of the scheduled activities in all three phases towards improving SRL as follows:

Phase 1: Preparation revealed a logical progression from building foundational knowledge to facilitating understanding and readiness. This approach helps all students comprehend the objectives of the teaching model, practice strategies for utilizing the learning management system (LMS), and engage with digital technology to bolster self-regulation in their learning process. Broadbent et al. (2020) advocate for training sessions to develop SRL skills, including workshops on metacognitive strategies and motivational techniques.

Phase 2: Implementation of SRL strategies through applications, where real-world issues spark collaborative inquiry and problem-solving among learners. This phase is organized into a learning iterative cycle of 3 steps (10 sub-steps) based on 1. meeting the problem and planning, 2. doing and checking, and 3) presenting the results and reflecting, which take place progressively during the learning activity, promoting an action-reflection-action model that should become a self-regulatory habit throughout matriculation. We use SRL strategies, including

problem-solving activities and self-regulatory processes, to guide and support learning that involves 1) motivational beliefs, such as self-efficacy and task value; 2) cognitive learning strategies, including task strategies (such as rehearsal mnemonic devices), metacognitive cognition (such as summarizing), planning and time management, monitoring learning effort, and online environmental scanning for relevance or interest topics for finding solutions to identified needs/interests — e.g., social environments with digital tools. Students are encouraged to utilize online resources to document, monitor, track, and report their results, with the option to share outcomes through network groups—stimulating peer learning and offering opportunities for observation and enhancement of the learning journey. The instructor plays an essential role in facilitating this transition through instructional scaffolding, promoting skill development in knowledge acquisition, learning strategies, and self-regulated learning.

Phase 3: Summative Evaluation employs authentic assessment measures to capture student outcomes, encompassing behaviors, self-regulation, and problem-solving abilities. This phase ultimately enables students to acquire knowledge, skills pertinent to the learning process, and positive attitudes toward their education. This investigation aims to bolster the potential for effective learning management within an online environment. Based on these principles, expert evaluations endorse the quality of the developed model.

5.2 The Implementation of the Model Resulted in a Significant Increase in Students' SRL Abilities

This improvement can be attributed to a meticulously structured and sequential learning management process, which emphasized fostering motivational beliefs regarding self-efficacy and task value. By recognizing the importance of their learning methods and goals, students understood the effort necessary to develop effective strategies for achieving those objectives. While He, Zhao, and Su (2021) noted that elevated levels of SRL might reduce efficiency within online learning environments, the developed learning model took advantage of the strengths inherent in problem-based learning (PBL). By utilizing engaging, real-world problems relevant to students' professional contexts, the model stimulated curiosity and motivated students to deepen their understanding.

As a result, implementing PBL in conjunction with SRL in online environments markedly enhanced students' self-regulatory abilities. These findings parallel those of Hanefar et al. (2021), who reported that Bangladeshi students participating in PBL exhibited heightened motivation and engagement compared to their experiences with traditional teaching methods. This increased engagement is critical for fostering sustained effort and perseverance, both of which are essential components of self-regulated learning.

Over and above strengthening risk beliefs, the learning model that was developed enabled longitudinal engagement in learning over a complete 15 weeks. 8 factors of self-regulation strategies were implemented by students during this time, including self-efficacy, task value, planning and time management, metacognition, critical thinking, effort regulation, studying the online environment, and seeking social support. In this role, instructors functioned as conductors of motivation and human behavior; they guided, encouraged, and modeled effective behaviors for working remotely and, at a significant cost, cried out for more targeted technical and instrumental support to improve their online learning experience.

Students also had access to online mechanisms for recording their learning, which allowed them to document each experience they learned about quickly and wherever it occurred. The 15 weeks (approximately 14 weeks with the additional week) probably helped improve students' SRL. This is consistent with the results obtained by Fung, Abdullah, and Hashim (2019) investigating how personalized weekly e-Learning journals (e-LJs) affect university students' SRL. The researchers conducted the study with 54 undergraduate students who used an LMS for an uninterrupted period of 10 weeks and received personalized self-reflection prompts on course-related matters as well as assessment reflections. Findings showed an increase in students' SRL scores that were particularly notable for planning and effort regulation, demonstrating how efficacious personalized e-LJs are in promoting SRL in higher education.

Besides, consistent with Tan (2002), another important factor that contributes to this success is the flexibility of PBL, where the instructor will have the opportunity for better supervision of students and group discussions, which is reflected in improved understanding, resulting in progress at essential skills as critical thinking, problem-solving, communication, and self-regulation. This conclusion is also reinforced by previous investigations that have shown students involved in PBL on their own development of SRL skills. Akdogan, Velipasaoglu, and Musal (2021) investigated the impact of PBL on SRL competencies and found that it affects SRL competencies positively. The fact that the students with PBL instruction had higher self-efficacy and learned better themselves indicated that PBL was more effective than traditional instruction in practical courses. Van den Hurk's (2006) study on first-year psychology students revealed that students with better time planning

and self-regulation skills performed better in problem-based learning, emphasizing the significance of time management and monitoring of study activities. In addition, Yaniawati et al. (2019) found that web-based PBL could also increase SRL and ATP in mathematics problem-solving for undergraduate students. Online PBL has been found to have an additive effect on academic success through the study of Somyaron and Teeraputon (2023), which found that students who practiced SRL and critical thinking achieved higher scores in SRL changes related to academic performance.

6. Conclusion

PBL and SRL can be collaboratively integrated in the design of online learning environments to support student SRL. Study findings underscore the need for robust instructional design and continuous capacity-building for instructors to address and optimize them. Explicit knowledge for learners and a feedback-oriented learning environment are necessary) as well as the actual application of SRL strategies to problem-solving. For instance, self-efficacy and task value are significant for these types of motivation to endure in any endeavor despite being autonomous or controlled. The course is designed to give rationale and support for the development of both habits of mind, with a short refresher in study strategies—critical thinking, metacognitive regulation, planning and time management, effort regulation, social seeking for help, and study online environments—as they enable one to achieve not only their academic but also broader goals. One of the few common messages students consistently repeated in a pilot using this model was that instructors are critical to their learning experience. This is why instructors can help initiate discussions to promote critical thinking, serve feedback on assignments, and accommodate unusual learning processes to foster student motivation and engagement. Instructors will take hope into the real world as they depart from the institute. Conclusion: The evidence presented in this study validates the proficient mix of PBL and SRL in designing powerful learning environments in online platforms.

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Authors contributions

Assistant. Prof. Dr. Narumon Rodniam led this research, developed the research methodology and model, analyzed the research results, and wrote and edited the manuscript. Mr. Damp Sukswanont assisted in supporting data collection. Both authors read and approved the complete manuscript.

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Appendix

Appendix A. Self-regulation learning assessment in online PBL model for undergraduate students

Self-Regulated Learning		Items	Level of SRL				
Aspect	8 key factors		5	4	3	2	1
Motivational Beliefs	Self-efficacy	1. I am sure I have developed study habits and other self-regulatory strategies needed to do the work in this online course.					
		2. I should be able to do great in this online class, even if I think the problems assigned are hard.					
		3. I can combine similar efforts to obtain a good mark with the problem-based study and use self-regulation strategies in the online portion of this study.					
		4. I know I can do a good job of knowing what the questions of the assigned problem ask me to calculate.					
	Task-Value	5. I can gain broader knowledge from this course that might also help me in other fields.					
		6. This kind of learning, I hope, will lead me to devise a better way of learning in the digital age.					
		7. This way of learning will enable me to delve deep into new information and better work with others.					
		8. I found this to be a very useful way which helps me learn strategies to solve problems and work online fairly well.					
		9. I have learned a method to learn better and this is what that...					
Learning strategies	Critical thinking	10. I know what the problem is before I ever start solving it online.					
		11. I analyze all of it contextually and personally to find an answers.					
		12. There are few sources I rely on, the ones I trust to give me accurate and unbiased information, before forming conclusions.					
		13. Every problem-solving learning will only require me to think and read through the options, reason out on my own, and then draw a conclusion.					

		14. Even If I Validate or ascertain something, several other methods come into my mind.					
Metacognition		15. So I ended up using old learning strategies that worked out in the past, applying them on how to tackle problems and or assignments.					
		16. I attempt to break down and decode my writing so that I can figure out what it is that I need to do.					
		17. I will sometimes evaluate my performance once completed.					
		18. I go over the feedback I got in the past about how I am learning right now.					
		19. I consistently wonder: what can I do to meet the grading rubric my instructor sets for me?					
	Plan & Time management		20. I set immediate goals (daily, weekly)				
		21. I simply had realistic deadlines for my learning.					
		22. So I fragment a bit the larger goals, in smaller actions.					
		23. I go down to the nitty-gritty details of actions I have to take to get these tasks done.					
		24. I stated the problem in online learning and solved it.					
Effort regulation		25. Now, even though it is well-known that there is a great deal of other fun to have, I am prepared to put this online problem-based learning into effect as much as I can.					
		26. Even when it is difficult for me to learn online, I continue to be dedicated towards the goal of learning.					
		27. I am trying harder to focus while I engage in this online learning, which is still the very early stages of it.					
		28. Regardless of how I feel, I remain engaged in virtual learning.					
Social support-help seeking		29. I do so if other students ask online questions where I can assist.					
		30. In online classes, I ask people who know the better than me online for some help.					
		31. Study tips and how to find answers in online learning Are some of the information I ask my instructor and/or peers.					
		32. If I face any problems with online classes then I look for help from others by the way of online as well (forums, social media, email, etc.)					
		33. If you want help, reach out to your instructor or other students via email, forums, social media, etc.					
Online environment study		34. This way I can go through my online problem-based activity and not have the distractions of the endless Reddit scroll.					
		35. I spend most of my time in a quiet area that is distraction-free.					
		36. I know in which way/atmosphere I can study and problem-solve there effectively.					