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# The use of innovative project-based learning to elevate pre-service teachers' critical and creative thinking skills

**Rahmawati Darussyamsu**[1+]
**Lufri Lufri**[2]
**Yuni Ahda**[3]
**Syakirah Samsudin**[4]
**Muhammad Kristiawan**[5]

[1]*Universitas Negeri Padang, Indonesia.*
[1]*Email: rahmabio@fmipa.unp.ac.id*
[2,3]*Biology Department, Faculty of Mathematics and Natural Science, Universitas Negeri Padang, Indonesia.*
[2]*Email: lufri@fmipa.unp.ac.id*
[3]*Email: ahdayuni@fmipa.unp.ac.id*
[4]*Biology Department, Faculty of Sciences and Mathematics, Universiti Pendidikan Sultan Idris, Malaysia.*
[4]*Email: syakirah@fsmt.upsi.edu.my*
[5]*Educational Administration Department, Faculty of Education, Universitas Bengkulu, Indonesia.*
[5]*Email: muhammadkristiawan@unib.ac.id*

*(+ Corresponding author)*

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## ABSTRACT

This study aims to develop an innovative project-based learning (PBL) that fits the purpose of fostering critical and creative thinking skills (CCTS). The innovations were made to the PBL's syntax and referred to as RAHMA which stood for (1) Recognize the problem. (2) Analyze the problem. (3) Handle a project. (4) Monitor the progress. (5) Assess the result. Attempts were made to make the model valid and practical, capable of improving pre-service biology teachers' (PSBTs') CCTS and fitting the purpose of a pedagogical course. This study used Plomp's research and development model which consisted of three stages: preliminary research, prototyping phase, and assessment phase. The results indicated that the PBL with RAHMA syntax was highly valid and practical. Furthermore, the instruments used to measure the CCTS were also highly valid. In conclusion, PBL with RAHMA syntax and its supporting tools are valid to enhance PSBTs' CCTS. The implication highlights the necessity of using this learning model in the pedagogical courses that focus on designing products in teamwork.

**Contribution/Originality:** This study contributes as a learning model that has the potential to train the critical and creative thinking skills of pre-service teachers in pedagogical lectures for materials that involve teamwork, especially in the development of learning instruments.

## 1. INTRODUCTION

It is essential that we properly train pre-service teachers (PSTs) since they will eventually teach students in the future. They serve the task of being an agent of change (Kadir, 2017) and to lead the way to achieve global competence (Zhang, Zhou, Wu, & Cheung, 2024). It is anticipated that PSTs will have to acquire more knowledge and skills to face and embrace the challenges of societal change (Valli & Buese, 2007). PSTs must be able to foresee and acquire the knowledge and skills needed for their future professional endeavors (Lungu, 2022). This also applies to pre-service biology teachers (PSBTs).

PSBTs will teach learners the ever-evolving contents of biology courses. PSBTs need to cultivate their critical thinking, reflective practice, creativity, and communication skills to be proficient and flexible in the current and future eras (Arsih, Zubaidah, Suwono, & Gofur, 2020; Nadaf & Nazir, 2022; Susilo, Sudrajat, & Rohman, 2021). These skills are essential within an educational setting as they facilitate effective problem management through innovative and analytical approaches (Serin, 2013).

Critical thinking skills involve accessing, analyzing and synthesizing information. Furthermore, people are deemed to apply critical thinking when they use their cognitive skills or strategies such as when solving problems, drawing conclusions, assessing probabilities, and making -decisions to increase the probability of desired outcomes (Ennis, 2018; Halpern, 1999). Finally, critical thinking skills involve higher-order thinking skills (HOTS) to guide individuals to solve their problems and make decisions (Facione, 2023; Moore, 2013). When PSBTs demonstrate strong critical thinking skills, they exhibit the capacity to scrutinize assumptions, thereby enhancing their comprehension of biological concepts and fostering robust knowledge development (Bahr, 2010).

In addition to being one of the 13 essential indicators of lifelong learning (Chaiyasut, Samuttai, Phuwiphadawa, & Inthanet, 2014) critical thinking (i) is also one of the most important skills that people need to have to live in the 21st century (Tucker, 2014) (ii) helps individuals solve both educational and daily problems (Southworth, 2022) and (iii) contributes significantly to the teaching and learning activities in higher education settings (Moore, 2013; Tucker, 2014). PSBTs can develop critical thinking skills by consistently practicing them either through directed discussion or instruction facilitation (Arends, 2012).

A previous study found that PSBTs' critical thinking skills in Indonesia were still inadequate (Arsih et al., 2020). The study revealed that (a) the PSBTs' average score for critical thinking skills was at a moderate level of 60.50 and (b) only 11.92% of these PSBTs demonstrated high levels of critical thinking skills. This indicated the need for targeted improvement initiatives.

Irwanto, Saputro, Rohaeti, and Prodjosantoso (2018) reported that on average, PSTs still had insufficient critical thinking skills. Amin, Duran Corebima, Zubaidah, and Mahanal (2017) showed that PSBTs' ability to comprehend topics and skills to think critically remained low indicating that their critical thinking skills were not yet well-developed. Furthermore, several other studies conducted in recent years have also provided information on low critical thinking skills (Farcis, 2016; Jirana, Amin, Suarsini, & Lukiati, 2019; Suwono, Pratiwi, Susanto, & Susilo, 2017).

Similar issues arise with PSTs' creative thinking skills which also need improvement. Creative thinking skills involve the capacity to generate new ideas, possibilities and discoveries through originality in their conception (Daud, Omar, Turiman, & Osman, 2012). In a biology course, creative thinking is used when the teacher generates new ideas for learning including lesson planning, implementation, and evaluation. When biology teachers are creative, they will innovate in their class to foster their students' creative thinking skills (Azzahra, Arsih, & Alberida, 2023; Fitri, Lufri, Alberida, Amran, & Fachry, 2024) and this innovation is measurable when evaluated.

Knowledge and skills to evaluate the learning are important aspects in pedagogic science for PSTs (Evans, Kandiko Howson, Forsythe, & Edwards, 2021). For this reason, the biology learning evaluation course is programmed as a compulsory course for students majoring in biology education (Lecturer Team of Biology Learning Evaluation, 2023).

The biology learning evaluation course is intended to enable PSBTs to evaluate learning effectively in their future roles as teachers, specifically by formulating assessment questions. A fundamental component of this course is the expected improvement in students' capability to construct evaluation instruments that assess knowledge-related HOTS. This capability is integral to fostering critical and creative thinking skills as students are involved in critical analysis of the problems that will serve as the basis for formulating the question instruments, thereby transforming them into question units that exemplify creative thinking abilities.

One learning model to train PSBTs' critical and creative thinking skills in making evaluation instruments is project-based learning (PBL). According to Vogler et al. (2018); Almulla (2020) and Wurdinger and Qureshi (2015) the PBL learning model can enhance students' critical and creative thinking skills. Previous studies have highlighted many assets of PBL. For example, Guo, Saab, Post, and Admiraal (2020) reviewing 76 articles on PBL, state that the PBL requires learners to collaborate in identifying genuine issues while integrating knowledge, applying it, and building upon it. Teachers and members of the community often serving as guides, offer guidance and assistance to students, thus aiding their educational journey (Guo et al., 2020). Krajcik and Shin (2014) revealed additional strengths of PBL including a focus on learning goals, increased engagement in learning tasks, teamwork among students, application of digital tools, and solving authentic problems.

Another study also stated that PBL has its advantages in promoting such things as 1) critical thinking; 2) problem-solving; 3) personal communication and 4) creativity and innovation (Chu et al., 2017). Still another study showed that PBL allows students to collaborate effectively and foster greater involvement in study assist one another, explain concepts to each other, think creatively and demonstrate patience (Tsybulsky & Muchnik-Rozanov, 2023) and contemplate objects deeply (Miller & Krajcik, 2019).

Many educational experts have suggested the syntax of PBL. The most widely used one is the syntax of Lucas (2007). However, syntax has generally been studied for its implementation in sciences, engineering, and language learning (Guo et al., 2020).

Lucas's (2007) version of the PBL learning model has been implemented since 2019 in the biology educational study program at FMIPA, UNP, but the results have not been fulfilling as it has not been capable to enhance the critical and creative thinking abilities of PSBTs. Our preliminary study found that PSBTs' skills in developing evaluation instruments for HOTS-level knowledge aspects were still very low. The very low ability of these students aligns with Ramadhan, Mardapi, Prasetyo, and Utomo (2019) who suggested that developing HOTS question instruments is not easy and is a big challenge for a teacher (Jensen, McDaniel, Woodard, & Kummer, 2014).

Thus, it is acknowledged that the syntax of PBL by Lucas (2007) cannot be used directly in pedagogical courses that focus on designing, implementing, and evaluating learning based on findings in the field. Therefore, adjustments are needed to the stages of PBL to make it suitable for teaching pedagogical courses to PSTs, especially in the biology learning evaluation course.

Several adjustments need to be made to the PBL syntax by Lucas (2007) to make it more relevant for practicing critical and creative thinking skills in pre-service teacher students in pedagogy courses. These adjustments are formulated in the RAHMA syntax, an acronym for recognize the problem, analyze the problem, handle a project, monitor the progress, and assess the result. The first step was to determining the fundamental question. It was replaced by recognizing real problems in the field. This was because real problems in the field engaged students more effectively as they faced these issues first-hand (Hung, 2016).

Secondly, adjustments also needed to be made by operationalizing the phases in the project design where the development of question instruments carried out in the biology learning evaluation course required inspection and review by lecturers and peers, allowing PSBTs to be skilled enough in making question instruments properly. Therefore, adjustments are made to the handling of a project stage which was further broken down into scenario, scheduling, review, revision and trial.

The third adjustment was made by combining syntaxes five and six of Lucas (2007) as it could be implemented in a unified activity. In the PBL learning model with RAHMA syntax, it was renamed as the assess the result phase, in which PSBTs assessed the results of their projects and drew conclusions from a series of project tasks that they had done.

The importance of developing a suitable learning model to accommodate the need to improve PSBTs' critical and creative thinking skills makes this study highly crucial. In turn, it makes it equally important to develop the

PBL model with RAHMA syntax, especially for the biology learning evaluation course. The RAHMA model needs to be studied for its components, feasibility, and practicality in an effort to address the weaknesses of the currently used PBL model. Hence, this study addresses the following three key questions:

1. What are the components of PBL with RAHMA syntax that can improve PSBTs' critical and creative thinking skills?
2. How is the validity of PBL with RAHMA syntax in enhancing PSBTs' critical and creative thinking skills?
3. How practical is PBL with RAHMA syntax for enhancing PSBTs' critical and creative thinking skills?

## 2. LITERATURE REVIEW

### *2.1. Learning Model Components*

A learning model is a framework that conceptually describes the systematic procedures of learning and organizes students' learning experiences to achieve certain goals and functions. It also serves as a guideline by which teachers can plan and carry out their learning activities (Fatimah, Darmansyah, Marlina, & Zaini, 2024). The development of learning models involves developing the approach used, including the learning objectives, the stages of learning activities, the learning environment, and the classroom management (Arends, 2012).

Different features make learning models varied. Despite these variations as Joyce and Calhoun's (2024) suggest, all learning models share certain traits: (1) teaching students the way to learn and acquire new information, skills, and self-awareness; (2) having a unique style (a construction orientation) that helps develop students' knowledge, skills, and values; (3) offering teachers a basis to support their students as they tackle obstacles and rise to the next level of learning and (4) having an assessment instrument to figure out how far students have progressed.

Joyce and Calhoun (2024) suggested that every learning model has the following six main components: (1) Syntax: the phases of activities of a model. (2) Social system: situation or environment and the norms that prevail in the model. (3) Reaction principle: a pattern of activities that illustrate how teachers ought to view and deal with students. (4) Support system: all facilities, materials and tools required to implement the model. (5) Instructional impact: immediate learning outcomes achieved by directing students to the intended goals. (6) Accompanying impact: other learning outcomes generated by the learning process without being directed by the teachers.

### *2.2. Project-Based Learning Model*

Project-based learning (PBL) is a learner-centered instructional approach grounded in three constructivist principles: learning is context-specific, learners are actively engaged in the learning process, and learners attain their goals through social interaction and the sharing of knowledge and comprehension (Kokotsaki, Menzies, & Wiggins, 2016). Some see PBL as a specific form of inquiry-based learning where the learning context is established through authentic questions and real-world problems (Al-Balushi & Al-Aamri, 2014) resulting in compelling learning experiences (Wurdinger, Haar, Hugg, & Bezon, 2007).

Kokotsaki et al. (2016) revealed six key suggestions for a successful implementation of PBL within general education institutions, they are as follows: (1) learner support, (2) teacher support, (3) effective teamwork, (4) striking a balance between autonomous inquiry method work and didactic instruction, (5) evaluation with a focus on introspection, peer and self-assessment, and (6) student choice and autonomy during the PBL process will help learners build a sense of belonging and having control over their learning.

Temel (2014) in his study explained that critical thinking, creative thinking, problem-solving skills and intelligence are interrelated, concluding that problem-solving skills affect HOTS. PBL contributes to learners in many ways. Various studies have concluded several positive effects of PBL including improving communication skills and enhancing problem-solving skills (Kokotsaki et al., 2016; Mettas & Constantinou, 2007).

In PBL, it is believed that students can develop critical and creative thinking when they have the chance to contribute to solving problems and generating knowledge in real-life situations (Santos et al., 2023). Some frameworks are employed in PBL, including information processing, collaborative learning, constructivist learning, and contextual learning theory (Tarmizi & Bayat, 2012). Using PBL, learning would be designed by involving learners in authentic yet interesting problems, enabling them to compile their knowledge, develop HOTS, empower themselves, stimulate rational and critical thinking, and increase their self-confidence (Barak, 2012)

The PBL model has been developed by several experts such as Lucas (2007); Mulyasa (2014) and Supardan (2015). According to Lucas (2007) PBL has the following six steps: (1) determining basic questions. (2) Creating a project design. (3) Scheduling. (4) Monitoring project progress. (5) Assessing results. (6) Evaluating the experience. Furthermore, Mulyasa (2014) simplifies these steps into four main steps: (1) preparing a project question or assignment. (2) Designing a project plan. (3) Preparing a schedule as a set of concrete steps of a project and (4) monitoring the activities and progress of project. Meanwhile, Supardan (2015) simplifies these steps into three stages: planning, creating, and processing. A comparison of the PBL syntax proposed by these experts is presented in Table 1.

**Table 1.** Comparison of PBL syntax from several experts along with their strengths and weaknesses.

| No. | Lucas (2007) | Mulyasa (2014) | Zhang (2013) | Yudiono, Pramono, and Basyirun (2019) | Prince and Felder (2006) | Jalinus, Nabawi, and Mardin (2017) |
|---|---|---|---|---|---|---|
| 1 | Start with the essential question. | Prepare project questions or project tasks. | Project introduction | Product determination. | Starts with a task that must be completed to produce a final product. | Formulating the expected learning outcome. |
| 2 | Design a project plan. | Design a project plan. | Sub-project implementati on. | Product analysis and identification. | Ends or concludes with a verbal or written report, summarising the techniques employed and presenting the findings. | Understanding the teaching materials. |
| 3 | Create a schedule. | Create a schedule as a set of concrete steps of a project. | Sub-project integration. | Design of the production process. | - | Skills training. |
| 4 | Monitor the student and project progress. | Monitor project activities and progress. | - | Product development. | - | Designing the project theme. |
| 5 | Assess the outcome. | - | - | Product evaluation. | - | Making the project proposal. |
| 6 | Evaluate the experience. | - | - | - | - | Executing the project task. |
| 7 | | - | - | - | - | Presenting the project implementation. |
| + an d – | Suitable for use in engineerig, sciences, and languages fields. | Suitable for use in engineering field. | The syntax is too general. | The project oriented on product-centered. | The syntax is too general. | The syntax is more operational but suitable in vocational education. |

**Note:** + and - means strengthens and weaknesses of PBL.

### *2.3. Biology Learning Evaluation Course*

As a compulsory course, biology learning evaluation must be taken by PSBTs in their fifth semester. This course aims to enable these prospective teachers to evaluate learning, especially in their future biology class.

The topics covered in the biology learning evaluation course in the Department of Biology at FMIPA, UNP include (1) measurement, assessment, and evaluation. (2) Evaluation instruments for knowledge aspects. (3)

Evaluation instruments for attitudes. (4) Evaluation instruments for skill aspects. (5) HOTS-based assessment as integrated with 21st-century skills. (6) Analysis of test instruments. (7) Minimum completeness criteria. (8) The basics of alternative and authentic assessment (Lecturer Team of Biology Learning Evaluation, 2023). The eight topics are studied over one semester using various learning strategies. In this study, the PBL with RAHMA syntax was applied to the second, fifth, and sixth topics in six meetings.

### *2.4. Critical and Creative Thinking Skills*

#### *2.4.1. Critical Thinking Skills*

Critical thinking skills mean to think on certain grounds and in a reflective manner focusing on making decisions on what to trust or do (Ennis, 2018; Southworth, 2022). These skills are process skills aimed at reflecting judgment, manifested in offering reasoned and fair evaluation of evidence, conceptualizations, methods, contexts, and standards to determine what to believe or what actions to take (Facione, 2023). Critical thinking skills are individuals' ability to process, analyze and evaluate information to create and resolve new ideas and problems (Kopzhassarova, Akbayeva, Eskazinova, Belgibayeva, & Tazhikeyeva, 2016).

Thinking skills that are trained through explicit exercises will lead to good results (Song, Roohr, & Kirova, 2024). One of the learning models that has been proven effective in developing students' critical thinking skills is PBL model with teams or groups (Kopzhassarova et al., 2016). Therefore, in this study, the learning was carried out in groups.

#### *2.4.2. Creative Thinking Skills*

Creative thinking skills are what individuals use their minds for generating new ideas, new possibilities, and discoveries based on originality in producing their thoughts which can be given in the form of real or abstract ideas (Daud et al., 2012). Creative thinking skills may be stimulated using challenging problems. Exercises that develop creative thinking skills allow learners to employ their creativity to develop concepts, pose questions and hypotheses, test different approaches, and assess both their own and their peers' ideas, results, and methods (Kampylis & Berki, 2014).

According to Sternberg (2012) creative thinking skills are affected by various factors such as cognitive ability, accumulated knowledge, cognitive style, personality traits, motivation levels, and learning environment. Furthermore, Wang (2012) reviewed that creative thinking skills in individuals are influenced by cognitive, motivational, personality, and social aspects.

Creative thinking skills will develop when learners get the opportunity to think divergently. Students should be encouraged to break free from established patterns, explore novel approaches and have the chance to express innovative ideas and solutions (Zubaidah & Aloysius, 2016).

### *2.5. Research Discrepancy*

It is imperative for PSBTs to train their critical and creative thinking skills in this global era. Theoretically speaking, PBL has the basis to boast itself as the most effective learning model to enhance students' critical and creative thinking skills. The phases of PBL that several experts propose have been used in engineering, sciences, and language domains. However, they need to be adjusted for use in pedagogical courses that focus on designing, implementing, and evaluating learning based on findings in the field. This study attempts to fill this gap by developing a PBL that aligns with the goals of educational programs. These adjustments to the stages of PBL are intended to make them more suitable for teaching pedagogical courses to pre-service teacher students, namely PBL with RAHMA syntax.

## 3. METHODOLOGY

### *3.1. Research Design*

The design employed in this study was the research and development one as used in the Plomps' development model (Akker, Van Den, Kelly, Nieveen, & Plomp, 2013). This design comprised three main stages: (1) Preliminary research. (2) Prototyping. (3) Assessment. The research procedure is detailed in Figure 1. This study is a qualitative one since it tries to measure the feasibility and practicality of PBL with RAHMA syntax.

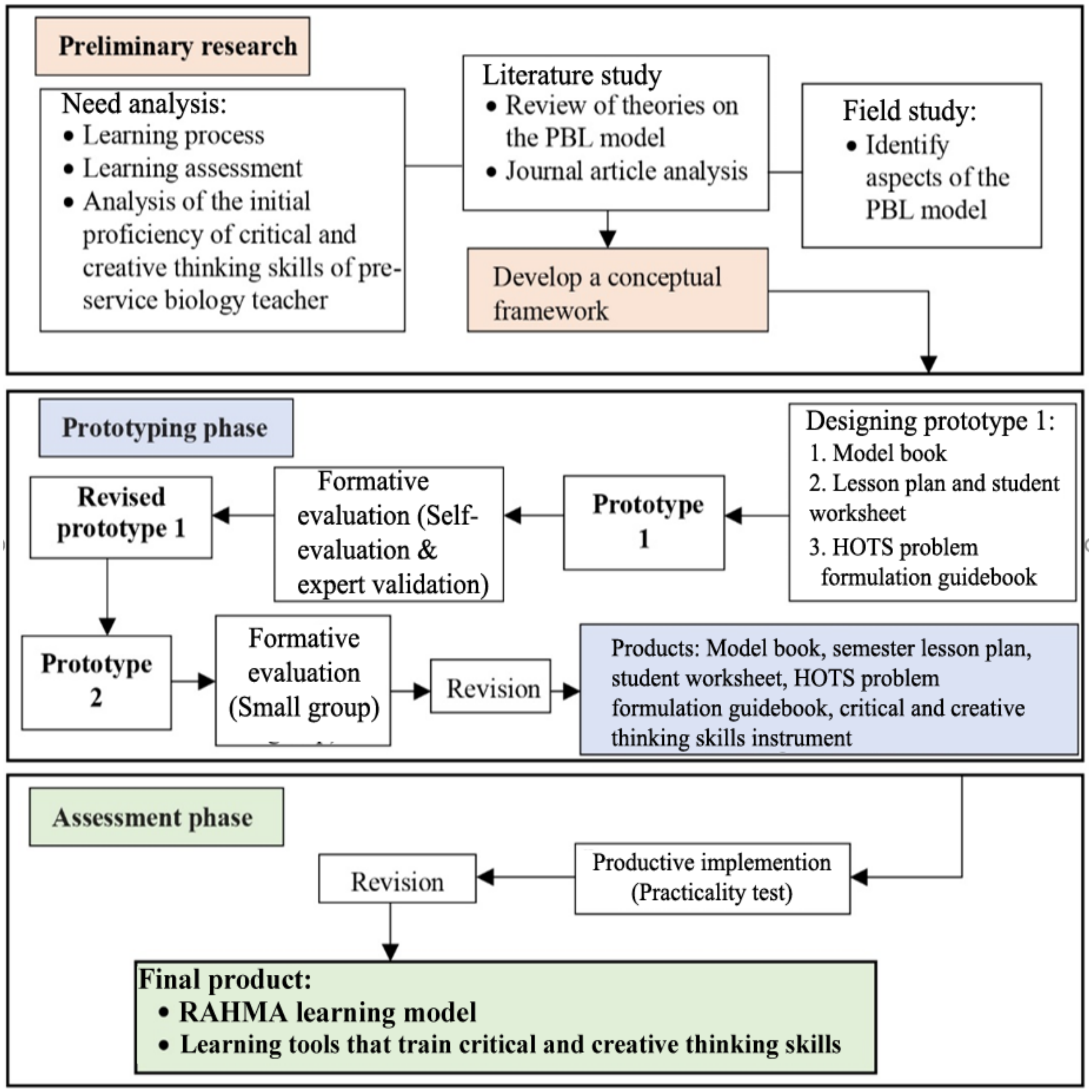


**Figure 1.** Research procedure.

### *3.2. Sample*

Validators and observers served as the samples in this study. Six experts from a university with excellent accreditation in West Sumatera, Indonesia, namely Universitas Negeri Padang were involved to evaluate and validate the product. The experts had at least 10 years of teaching experience and assumed at least a position of associate professor as shown in Table 2.

**Table 2.** List of validators and areas of expertise.

| No | Area of expertise | Validator code |
|---|---|---|
| 1. | Learning evaluation | E-1: Professor<br>E-2: Associate professor |
| 2. | Learning strategy | E-3: Associate professor<br>E-4: Associate professor |
| 3. | Educational technology | E-5: Professor<br>E-6: Associate professor |

During the assessment phase, four observers who held the titles of Bachelor and Master of Education observed how the learning model was implemented in two universities (Universitas Negeri Padang and Universitas PGRI Sumatera Barat), both of which were located in West Sumatera Province, Indonesia. Additionally, responses were requested from 28 PSBTs regarding the practicality of PBL with RAHMA syntax.

### *3.3. Instrument*

Product validation sheets and model implementation sheets which were detailed into four instruments were used. Firstly, the product in this study to be validated was the PBL with RAHMA syntax book for its nine indicators are as follows: construction, rationale, theory, syntax, reaction principle, social system, supporting system, instructional and complementary impacts and learning scenario (Darmansyah, 2023; Joyce & Calhoun, 2024). The second thing to be validated was the instruments to measure critical and creative thinking skills. The validation was carried out using validation sheets under the four indicators: content, construction, language, and ethics. Thirdly, the implementation of the PBL with RAHMA syntax was measured using an observation sheet that covered ten aspects: introduction, recognize the problem phase, analyze the problem phase, handle a project phase, monitor the progress phase, assess the result phase, supporting system utilization, students' involvement in learning, the model impact, and closing activity. Finally, how practical the PBL with RAHMA syntax was as assessed by PSBTs under such indicators as convenience, benefits, usability, and lecturers' roles in learning (Creswell, 2012). All of the instruments had been logically validated by three evaluation experts, as attached in the Appendix.

The model's validity and practicality were measured using a Likert scale with four modified scales with the following descriptions:

1 = Strongly disagree if the validator or observer thinks that only 0-24% of the statement is fulfilled.

2 = Disagree if the validator or observer thinks that 25-49% of the statement is fulfilled.

3 = Agree if the validator or observer thinks that 50-74% of the statement is fulfilled.

4 = Strongly agree if the validator or observer thinks that 75-100% of the statement is fulfilled.

### *3.4. Data Analysis*

The validity and practicality data were analyzed using Cohen's Kappa coefficient. The following formula was used to calculate Cohen's Kappa coefficient:

$$k = \frac{Po - Pe}{1 - Pe}$$

Where

k = Cohen's Kappa coefficient. po = Realized proportion calculated by summing the scores given by the validator/observer divided by the maximum number of scores.

pe = Unrealized proportion, calculated by summing the maximum score minus the total scores given by the validator or observer divided by the maximum score.

Decision categories based on Cohen's Kappa coefficient value are shown in Table 3.

**Table 3.** Decision categories based on Cohen's Kappa coefficient.

| Interval | Validity or practicality category | Decision |
|---|---|---|
| 0.81 – 1.00 | Very high | Usable |
| 0.61 – 0.80 | High | |
| 0.41 – 0.60 | Medium | Usable with revision |
| 0.21 – 0.40 | Low | |
| 0.01 – 0.20 | Very low | Not usable |
| ≤ 0.00 | Invalid or not practical | |

**Source:** Boslaugh and Watters (2008).

Furthermore, the inter-observer percentages of agreements (reliability) of Sürücü and Maslakci (2020) were used to determine the level of consistency of reliability between validators in validating the developed instruments and products, as well as between observers in making observations. Models and other products of this study were considered reliable if the reliability coefficient was ≥ 70 (Hancock, Stapleton, & Mueller, 2019; Herbert, Fischer, & Klieme, 2022). The reliability coefficient was calculated using the following formula:

$$R = \left(1 - \frac{A - B}{A + B}\right) x\ 100\%$$

Description:

R = Percentage of agreements (reliability) coefficient.

A = Highest score from validator or observer.

B = Lowest score from validator or observer.

## 4. RESULTS

### *4.1. Components of PBL with RAHMA Syntax*

This study developed a PBL with RAHMA syntax that met the valid and practical criteria, described in the form of a model book. The PBL with RAHMA syntax was an innovation of PBL. The acronym RAHMA stood for recognize the problem, analyze the problem, handle a project, monitor the progress, and assess the result. The RAHMA syntax was based on the principle that a biology learning evaluation course required exercises for creating questions accompanied by revisions and feedback for improvements.

#### *4.1.1. Component 1: Rational Theory*

Theoretically, the PBL with RAHMA syntax was constructed upon various learning theories, including cognitive constructivism (Piaget, 1972) social constructivism (Vygotsky, 1980) meaningful learning theory (Ausubel, 1968) and discovery theory (Bruner, 1966). The relationships between the syntax, learning activities and supporting theories of the model are shown in Table 4.

**Table 4.** Theoretical support of the development of PBL with RAHMA syntax.

| Syntax | Learning activities | Theoretical support |
|---|---|---|
| Recognize the problem. | • Lecturers instruct students to observe and find problems in the school.<br>• Students observe the schools' midterm and final examination questions.<br>• Students identify the quality of the midterm and final examination questions using question identification cards. | • Learning is based on the interconnectedness of the student's environment, personal beliefs, and student behaviour (Moreno & Park, 2010).<br>• Constructivism emphasizes that knowledge must be based on experience to understand all forms of information (Vogel-Walcutt, Gebrim, Bowers, Carper, & Nicholson, 2011).<br>• The activity of gathering and analyzing information to find problems contributes positively to empowering students' critical |

| Syntax | Learning activities | Theoretical support |
|---|---|---|
| | • Students formulate the problems found. | thinking skills (Bassham, Irwin, Nardone, & Wallace, 2011). |
| Analyse the problem. | • Students analyse the problem.<br>• Students formulate solutions to the problem. | • Vygotsky's zone of proximal development (ZPD) concept proposes that students can examine phenomena and formulate problems at a cognitive level higher than their current level of cognition (Moreno & Park, 2010).<br>• The primary goal of education is to develop students' critical thinking skills and their ability to solve problems effectively (Gagne, 1965; Temel, 2014). |
| Handle a project. | • Scenario: Lecturer and students design the scenario of the project to be carried out.<br>• Scheduling: Lecturers and students create a project implementation schedule.<br>• Review: Students are asked to review the instrument that has been developed.<br>• Revise: Students are asked to revise their products in groups based on their friends' suggestions.<br>• Trial: Students are asked to test the instrument that has been developed for first-year students who are taking a general biology course. | • The ZPD concept reveals that the difference between students' independent work and their activities with the support of others and interactions within their ZPD enhances cognitive growth (Schunk, 2012).<br>• Meaningful learning theory is characterized by the existence of advanced organizers, which when well-designed will make it easier for students to understand and grasp knowledge (Mohammadi, Moenikia, & Zahed-Babelan, 2010).<br>• Student involvement in reflecting, assessing, and evaluating provides opportunities to develop critical thinking skills (Moreno & Park, 2010).<br>• Learning in small groups is a social condition that supports the learning process, particularly within the context of the development of cognition (Slavin, 2012).<br>• Learning through discovery can train problem-solving thinking skills and is in line with constructivism theory (Slavin, 2020). |
| Monitor the progress. | • Students submit a project progress report.<br>• Lecturers monitor the progress of project implementation and completion and provide feedback. | • Knowledge is gained when there is specific and immediate feedback (Arends, 2012). |
| Assess the result. | • Students are asked to assess the quality of the test items.<br>• Students formulate conclusions based on the project phases that have been carried out regarding the quality of questions. | • Feedback helps students improve their work quality, perceived competence and intrinsic motivation (Moreno & Park, 2010).<br>• Decision-making is a form of cognitive operation that a person uses to respond to a stimulus (Susilo, 2014). |

#### *4.1.2. Component 2: Syntax (Instructional Process)*

The syntax of the PBL with RAHMA syntax is described through its stages as shown in Figure 2.

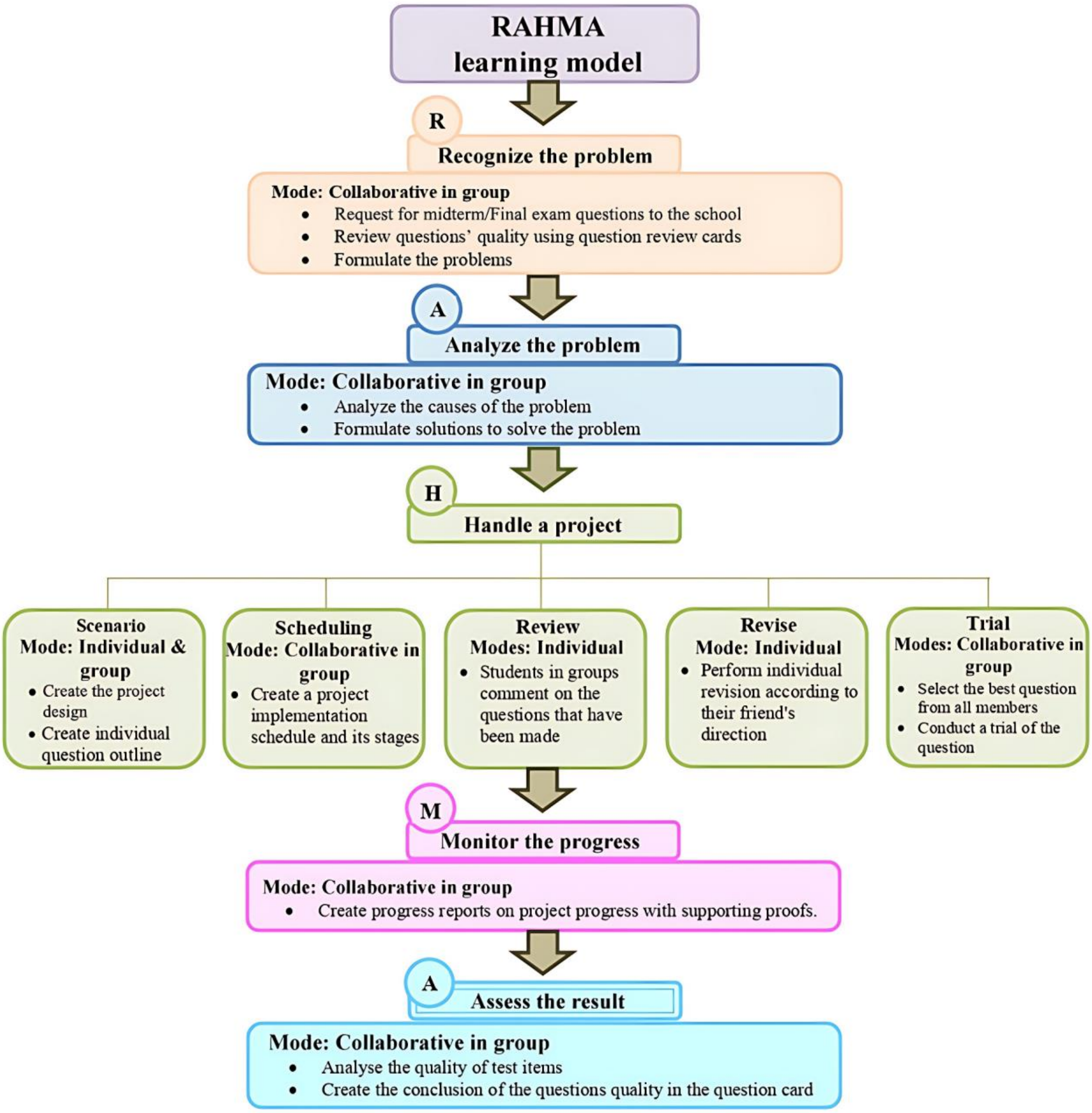

**Figure 2.** Syntax of the PBL with RAHMA syntax.

### *4.1.3. Component 3: Reaction Principles*

The reaction principle outlines the activities that illustrate the lecturer's behavior in responding to students. It provides rules in the process that apply to each learning model. Lecturers act as facilitators and guides for the students providing direction and explanations when students encounter difficulties. The application of the reaction principle in the PBL with RAHMA syntax is shown in Table 5.

**Table 5.** Reaction principle of PBL with RAHMA syntax.

| Syntax | Lecturers role | Students role |
|---|---|---|
| Recognize the problem. | • Provide instructions for students to observe and find problems in the field or schools. | • Conduct observation.<br>• Identify the quality of midterm and final examination questions using question identification cards.<br>• Formulate problems. |
| Analyse the problem. | • Provide stimulus and motivation for students to be able to formulate problems and problem-solving | • Analyse the problem.<br>• Formulate problem solving solutions. |

| Syntax | Lecturers role | Students role |
|---|---|---|
| | solutions. | |
| Handle a project. | • Together with students, design a scenario and create a schedule for the implementation of the project to be carried out. | • Formulate problem solving solutions.<br>• Develop a project implementation schedule.<br>• Review the instrument that has been developed.<br>• Revise the product in the group according to the feedback from their peers.<br>• Testing the instrument that has been developed on first year students who are taking a general biology course. |
| Monitor the progress. | • Monitor the progress of project implementation and completion. | • Report the progress of the project through monitoring instruments. |
| Assess the result. | • Guiding and supervising students in assessing data on the results of the quality of trial items, concluding quality questions and publishing selected questions. | • Students assess the quality results of the trial items.<br>• Conclude based on the stages of the project that have been carried out, quality questions and publish questions. |

#### *4.1.4. Component 4: Social Systems (Learning Activities)*

In this study, the social system or learning environment encompassed the situation and norms that were applied in the PBL with RAHMA syntax. Philosophically, the PBL with RAHMA syntax had the following two objectives: enabling PSBTs to construct their own understanding through HOTS question-making exercises on how to create good questions and training PSBTs to always stay connected to various learning resources, including peers and references available on the Learning Management System (LMS) and other internet sites.

A social system is how the relationships between lecturers and students take shape during the teaching and learning process. This part exhibits the functions, pursuits, and interactions that occur between lecturers and their classrooms. In this study, PSBTs with assistance from the lecturers selected the theme and the procedures they would have to take to complete the project in the PBL with RAHMA syntax. Together, lecturers and PSBTs actively engaged in the learning process.

#### *4.1.5. Component 5: Supporting System*

The supporting system included all facilities, materials and tools needed to assist the optimal implementation of the teaching and learning process. The system outlined the requirements or conditions to apply the PBL with RAHMA syntax, such as classroom settings, instructional systems, learning resources and facilities. The supporting systems needed for an effective and efficient implementation of PBL with RAHMA syntax included laptops, projectors, smartphones, internet network access, whiteboards and stationery.

Additionally, other supporting systems in the development of PBL with RAHMA syntax were as follows:

(1) Semester learning plan: A tool used by lecturers to organize material and organize classes for one semester.

(2) Lecturer's manual for the use of PBL with RAHMA syntax: A guide to help lecturers teach students using the PBL with RAHMA syntax.

(3) HOTS instrument preparation guidebook: A tool to provide students with knowledge on HOTS concepts and guide them in creating good HOTS questions.

(4) Student worksheets: A tool for students to use in building knowledge, comprehending information, and practicing their critical and creative thinking skills.

(5) Instruments: Tools used by lecturers to measure students' critical and creative thinking skills after the PBL with RAHMA syntax was implemented.

#### *4.1.6. Component 6: Instructional and Complementary Impacts*

The PBL with RAHMA syntax had both instructional and complementary impacts. The former meant the direct result of learning. In this case, it enabled students to foster critical and creative thinking skills through instructional activities as measured using test instruments in the form of questions and non-test instruments in the form of project assessment sheets.

The latter meant the indirect outcome of the reaction principle, social system and supporting system throughout the learning process. The complementary impact of using the PBL with RAHMA syntax was that it allowed PSBTs to be more confident in finishing the projects. Furthermore, the cooperation between students in their groups on project tasks was expected to improve their communication and collaboration skills. Further description on the matters above is provided in the RAHMA learning model book available in both Indonesian and English, accessible at: https://www.shorturl.asia/id/zMgXW.

### *4.2. Expert Validation of the PBL with RAHMA Syntax*

This section described the validity values of the PBL with RAHMA syntax book and its supporting components which included a lecturer's guidebook, a guidebook for making HOTS question instruments, and critical and creative thinking skill assessment instruments. The results of validation data analysis were used to revise the developed learning model. The validation results are elaborated as follows:

#### *4.2.1. Validation Results of PBL with RAHMA Syntax Book*

The PBL with RAHMA syntax designed and packaged in the form of a model book was validated by experts in such fields as learning evaluation, learning strategies, and educational technology. The validity data for the PBL with RAHMA syntax book were collected using the model book validity assessment instrument. The results of recapitulation for the validation of PBL with RAHMA syntax book are shown in Table 6.

**Table 6.** Validity and reliability of PBL with RAHMA syntax book.

| No | Assessed aspects | Validity (%) | Reliability (%) |
|---|---|---|---|
| 1 | Model book construction | 0.65 | 85.71 |
| 2 | Model rational | 0.91 | 85.71 |
| 3 | Supporting theory | 0.82 | 66.67 |
| 4 | Syntax | 0.85 | 85.71 |
| 5 | Reaction principle | 0.83 | 85.71 |
| 6 | Social system | 0.87 | 85.71 |
| 7 | Supporting system | 0.86 | 85.71 |
| 8 | Instructional and complementary impacts | 0.80 | 85.71 |
| 9 | Learning scenario | 0.84 | 85.71 |
| Average | | 0.83 (Very valid) | 83.60 |

Table 6 shows that the average validation score of the PBL with RAHMA syntax book reviewed across nine aspects was 0.82 meaning it was highly valid. The average reliability coefficient was above the threshold of 70% inter-observer agreement value (Hancock et al., 2019) except for the supporting theory which was scored 66.67% for its reliability, indicating that it was not yet reliable. During the validation, this occurred because many suggestions were proposed to enhance the philosophical and theoretical aspects of the model book. These suggestions were considered and incorporated into the product after validation.

#### *4.2.2. Results of Critical and Creative Thinking Skill Instrument Validation*

The critical and creative thinking skill instruments were validated comprehensively on the following four aspects: content feasibility, construction, language, and ethics. The validators assessed the instruments logically using a test consisting of 10 multiple-choice questions and four descriptive questions accompanied by a rubric for the assessment of critical thinking skills as well as a project assessment sheet and a rubric for aspects of creative thinking skills. A summary of the instrument validation results is shown in Table 7.

**Table 7.** Results of validity and reliability analyses for the critical and creative thinking skill instrument.

| No. | Assessed aspects | Validity (%) | Reliability (%) |
|---|---|---|---|
| 1 | Content or material feasibility | 0.92 | 85.71 |
| 2 | Construction | 0.92 | 85.71 |
| 3 | Language | 0.92 | 85.71 |
| 4 | Ethics | 0.96 | 85.71 |
| Average | | 0.93 (Very valid) | 85.71 |

### *4.3. Observation Result of Implementation of PBL with RAHMA Syntax*

The data regarding the implementation of PBL with RAHMA syntax were collected from the learning implementation sheets filled in by the observers. The observation showed that all syntaxes of PBL with RAHMA syntax had been implemented as shown in Table 8.

**Table 8.** Observation results of the implementation of PBL with RAHMA syntax.

| Observation aspects | Value | Criteria | Reliability |
|---|---|---|---|
| Introduction activities | 1.00 | Very high | 100.00 |
| Phase 1: Recognize the problem. | 0.98 | Very high | 85.71 |
| Phase 2: Analyse the problem. | 0.95 | Very high | 85.71 |
| Phase 3: Handle a project. | 1.00 | Very high | 100.00 |
| Phase 4: Monitor the progress. | 1.00 | Very high | 100.00 |
| Phase 5: Assess the result. | 0.98 | Very high | 85.71 |
| Supporting system utilization. | 1.00 | Very high | 100.00 |
| Student involvement in learning. | 1.00 | Very high | 100.00 |
| Instructional and accompanying impact of the learning model. | 0.99 | Very high | 85.71 |
| Closing activities | 1.00 | Very high | 100.00 |
| Average | 0.99 | Very high | 94.29 |

Table 8 shows that the average score for the implementation of PBL with RAHMA syntax was 0.99 indicating that all aspects of learning had been implemented. Each of the observed aspects received an average score of 0.99 from the observers placing it in the extremely high category. It means that the PBL with RAHMA syntax can be effectively implemented.

### *4.4. Results of Practicality Assessment of PBL with RAHMA Syntax*

The PBL with RAHMA syntax was implemented over six meetings with students in the biology learning evaluation course. Following the course series, students were requested to complete a questionnaire on the practicality of the PBL with RAHMA syntax (see Table 9).

**Table 9.** Results of practicality assessment of PBL with RAHMA syntax.

| No. | Assessed aspects | Practicality |
|---|---|---|
| 1 | Convenience in performing the PBL with RAHMA syntax. | 0.85 |
| 2 | Advantages of PBL with RAHMA syntax. | 0.86 |
| 3 | Usability and benefits of guidebooks in the learning process. | 0.82 |
| 4 | Lecturers' role in learning. | 0.88 |
| Average | | 0.85 (Highly practical) |

## 5. DISCUSSION

The PBL with RAHMA syntax was developed based on PBL principles that referred to the constructivism learning theory with an authentic approach aligning with real-world conditions. This learning model was relevant to the 21st-century paradigm that emphasized learning to know, learning to do, learning to be, and learning to live together.

The PBL with RAHMA syntax encouraged students to actively develop their thinking skills, both individually and collaboratively in groups. This is in line with Binkley et al. (2012) who revealed that 21st-century education focuses on activity-based learning to train thinking and social skills. According to Neo-Vygotsky, effective learning lies in activity, context and collaboration (Karpov, 2013).

The PBL with RAHMA syntax was considered a good learning model based on the validation results from experts who had stated that it was highly valid and feasible for implementation. According to Akker et al. (2013) the quality of a learning model is assessed based on various criteria such as validity, practicality, and effectiveness.

The assessment of the PBL with RAHMA syntax referred to five components based on Joyce and Calhoun (2024): learning syntax, social system, reaction principles, supporting system, instructional impact and complementary impact. The PBL with RAHMA syntax obtained an average score in the highly valid category based on the assessment of the learning syntax aspect. Arsih, Zubaidah, Suwono, and Gofur (2021) suggested that learning syntax is considered valid when the purpose is clear. In this study, the purpose of PBL with RAHMA syntax was to enhance PSBTs' critical and creative thinking skills.

The PBL with RAHMA syntax comprised the following five stages as represented by the acronym RAHMA: Recognize the problem, analyze the problem, handle a project, monitor the progress, and assess the result. The first phase, i.e., recognize the problem involves identifying problems from the real-world conditions in the field. The process of identifying real problems allowed PSBTs to use their thinking skills through discovery efforts. This aligns with Bruner's (1966) discovery learning theory which states that cognitive development occurs gradually and is determined by how individuals perceive their environment and find their problem and this makes their learning more meaningful (Lufri, Ardi, Muttaqiin, & Fitri, 2020).

In the “recognize the problem” phase, the lecturer directed PSBTs to observe and explore problems connected to the use of learning evaluations within schools. PSBTs were asked to collect questions of daily quizzes, midterm tests, or final examinations from biology teachers at schools and then identify the quality of these questions using question identification cards. Afterward, PSBTs formulated the problems they found in group discussions and uploaded the problem formulation to the LMS for review and feedback from the lecturer.

All activities in this first phase aimed to enable students to think critically about real problems related to how biology learning evaluation was implemented in schools. Hung (2016) stated that problems create a connection between knowledge and real life enabling individuals to develop contextualized situational knowledge that can be used at the right time and place. This aligns with Marnewick (2023) who revealed that providing real problems is important in applying PBL and offers a better learning experience for students.

The second phase was “analyze the problem”. At this stage, PSBTs analysed the problems they had identified in the first phase and worked collaboratively in groups to develop solutions to these problems. The objective of this group was to help PSBTs build habits on how to think and collaborate. Cooperative and collaborative activities promoted PSBTs’ critical thinking skills (Lestari et al., 2021) and led them to actively engage in discussion (Murphy, Rowe, Ramani, & Silverman, 2014). Furthermore, Farcis (2016) revealed that thinking skills need to be continuously trained through the learning process to make it a habit. The solutions to the problem that the group had decided were uploaded on the LMS for the lecturer’s review and feedback.

The third phase was “handle a project” where PSBTs designed and implemented a project to develop HOTS question instruments as a solution to the problems found in the first two stages. This phase included the following five steps: scenario, scheduling, review, revise, and trial. At the scenario step, students, together with the lecturer, designed the project’s scenario. Cooperation at this stage was based on the ZPD concept which showed that the difference between students' individual performance and their performance with support promoted cognitive growth (Schunk, 2012).

The design created in the scenario step was then used to create a time allocation and implementation plan at the scheduling step. Making a schedule helped familiarize students with managing learning progress which aligned with the theory of meaningful learning characterized by advanced organizers. This facilitated learning and understanding by structuring information (Mohammadi et al., 2010). This activity allowed PSBTs to learn meaningfully since they could put their experiences into practice in a project. Similar practice had been proven successful when applied to some professional disciplines (Ennis, 2018; Pai, 2016; Southworth, 2022).

Once the project implementation schedule was finalized, students individually created HOTS question instruments based on the directions in their worksheets. The questions were then reviewed by group members, with students exchanging questions to provide mutual feedback. When questions were reflected on, assessed, and evaluated, an opportunity occurred for students to develop their critical thinking skills (Ennis, 2018; Moreno & Park, 2010).

Based on peer feedback, students then revised the HOTS question instruments they had developed during the revise step. Slavin (2012) revealed that learning in small groups is a social condition that supports the learning process, especially in cognitive development. The best questions selected by the group were then tested on first-year students taking a general biology course. At this rate, students had learnt through discovery. This trained their problem-solving thinking skills and aligned with constructivism theory (Slavin, 2020).

The fourth phase was "monitor the progress". At this phase, students reported their project's progress using the format provided. The lecturer supervised the project's progress and provided feedback on the LMS. Feedback helped students improve the quality of their work, perceptions of competence and intrinsic motivation (Marnewick, 2023; Moreno & Park, 2010). It also measures the effectiveness of group work which indicates active participation from all group members (Kokotsaki et al., 2016).

The final phase was "assessing the result". At this stage, the lecturer guided PSBTs to assess the quality of the test items formulated in the previous phase. PSBTs concluded their groups about the quality of the questions. This activity involved decision-making skills, a cognitive operation used to respond to stimuli (Susilo, 2014). In this phase, PSBTs' self-regulated learning was practiced since it was one of the important aspects that future teachers needed to nurture (Latva-aho et al., 2024).

In each phase, PSBTs uploaded their assignments to the LMS for lecturer feedback. According to Arends (2012) knowledge was acquired when specific and prompt feedback was provided.

Activities in the PBL with RAHMA syntax were dominated by collaborative activities that helped build a sense of teamwork. Collaborative activities were involved during the entire learning process allowing students to be responsible for each other in achieving goals (Ali, 2015) because learning collaboratively would lead students to realize that knowledge and information could be obtained from various sources, not only from their lecturers (Slavin, 2012) promoted positive socio-emotional interactions between them (Linnenbrink-Garcia, Rogat, & Koskey, 2011) and made students more motivated and contributed more significantly to the learning (Bakhtiar, Webster, & Hadwin, 2018; Mänty, Järvenoja, & Törmänen, 2020; Rogat & Adams-Wiggins, 2015; Volet, Summers, & Thurman, 2009).

## 6. CONCLUSION

The PBL with RAHMA syntax was an innovative project-based learning that significantly improved PSBTs' critical and creative thinking skills. Designed specifically for pre-service teachers in general and students attending biology learning evaluation courses in particular, this instructional model included such components as (i) theoretical aspects, (ii) syntax, (iii) reaction principles, (iv) social systems, (v) supporting systems and (vi) instructional and complementary impacts. The syntax of this PBL with RAHMA syntax was implemented in the following phases: (1) Recognize the problem. (2) Analyse the problem. (3) Handle a project. (4) Monitor the progress. (5) Assess the result. PSBTs played a more active role while the lecturer simply facilitated them under the guidance of cooperative and collaborative learning principles throughout the entire teaching and learning process. The instructional impact of PBI with RAHMA syntax was that it made PSBTs' critical and creative thinking skills better. Meanwhile, some of the complementary impacts were PSBTs' improved confidence, communication and collaboration skills. Upon their validation, experts declared that all components of the PBL with RAHMA syntax were highly valid. Additionally, the assessment of the model practicality and implementation showed that it was highly practical. Similarly, the instruments to measure the critical and creative thinking skills had met the highly valid criteria. Therefore, the PBL with RAHMA syntax and its supporting tools were valid and practical for further use.

## 7. LIMITATIONS

While the findings of this study are promising, it has two limitations. The first limitation was the fact that this study was limited to one university in Indonesia. Despite this, considering that the said university was on the list of world-class universities with excellent accreditation, it should be sufficient to show that the learning model in this study is of good quality. The second one is the fact that this PBL with RAHMA syntax was specifically designed for a pedagogical course, namely a learning evaluation course. It is suggested for future researchers to consider the adjustment and implementation of PBL with RAHMA syntax in the other courses.

## 8. IMPLICATIONS AND RECOMMENDATIONS

It has been confirmed by this study that the PBL with RAHMA syntax has the potential to enhance PSBTs critical and creative thinking skills. Therefore, the researcher recommends future studies investigating the PBL with RAHMA syntax to consider the specific requirements of learning materials to be integrated with this model. The PBL with RAHMA syntax was specifically developed for materials that involve team work to produce a product in pedagogy especially in the development of learning instruments. In addition, the PBL's effectiveness with RAHMA syntax must be evaluated through further tests and implementations in various courses and disciplines. Finally, it is imperative for researchers who wish to employ the PBL with RAHMA syntax to consider both its strengths and weaknesses to achieve better results.

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## APPENDIX

1. Validation sheet of PBL with RAHMA syntax book.

| **No.** | **Assessed aspects** | **Score** | | | |
|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** |
| **A.** Model book construction | | | | | |
| 1 | The layout has been attractive | | | | |
| 2 | The structure is logically systematic | | | | |
| 3 | The grammatically is precise | | | | |
| 4 | The language is communicative | | | | |
| Model rational | | | | | |
| 1. | The introduction is clear | | | | |
| 2. | The aim of developing learning model is clear | | | | |
| Supporting theory | | | | | |
| 1. | The supporting theory about learning model and theories is relevant to PBL with RAHMA syntax | | | | |
| 2. | The theoretical coverage of critical thinking strategies and skills is relevant to PBL with RAHMA syntax | | | | |
| 3. | The theoretical coverage of creative thinking strategies and skills is relevant to PBL with RAHMA syntax | | | | |
| Syntax | | | | | |
| a. | Learning model description | | | | |
| 1. | Each phase of PBL with RAHMA syntax has logical sequences learning activities | | | | |
| 2. | Each phase of PBL with RAHMA syntax has clear learning objectives | | | | |
| 3. | Each phase of PBL with RAHMA syntax has clear organizational activities | | | | |
| 4. | Each phase of PBL with RAHMA syntax has clear lecturer's activities | | | | |
| 5. | Each phase of PBL with RAHMA syntax has clear students' activities | | | | |
| 6. | Each phase of PBL with RAHMA syntax supports the learning outcomes | | | | |
| b. | Syntax implementation | | | | |

| No. | Assessed aspects | Score | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| 7. | Each phase of PBL with RAHMA syntax easy to implement | | | | |
| 8. | Each phase of PBL with RAHMA syntax can implement by lecturers | | | | |
| 9. | Each phase of PBL with RAHMA syntax can implement by students | | | | |
| 10 | The implementation level of each phase of PBL with RAHMA syntax is good | | | | |
| Reaction principle | | | | | |
| a. | Lecturer activities | | | | |
| 1. | Lecturer's activities has clearly stated | | | | |
| 2. | Lecturer's role as a facilitator is clearly visible | | | | |
| 3. | Lecturer's role as a motivator is clearly visible | | | | |
| 4. | Lecturer's role as a supervisor is clearly visible | | | | |
| b. | Reaction principle implementation | | | | |
| 5. | The reaction principle implementation level of PBL with RAHMA syntax is good | | | | |
| 6. | The reaction principles support the implementation of PBL with RAHMA syntax | | | | |
| 7. | The correlation between the reaction principle and other PBL with RAHMA syntax components is well described | | | | |
| Social systems | | | | | |
| 1. | The social systems pattern of lecturer-students in the PBL with RAHMA syntax is clearly visible | | | | |
| 2. | Students' individual activities is clearly visible | | | | |
| 3. | Students' learning activities in each phase is clearly visible | | | | |
| 4. | The social systems implementation of the PBL with RAHMA syntax is well described | | | | |
| 5. | The social systems support the implementation of learning model | | | | |
| 6. | The correlation between the social systems and other PBL with RAHMA syntax components is well described | | | | |
| Supporting systems | | | | | |
| 1. | Activities in the HOTS instruments guidebook is easy to comprehend | | | | |
| 2. | The HOTS instruments guidebook supports learning activities using the PBL with RAHMA syntax | | | | |
| 3. | Activities in the students' worksheet is easy to comprehend | | | | |
| 4. | The students' worksheet supports learning activities using the PBL with RAHMA syntax | | | | |
| 5. | The role of supporting systems is highly visible | | | | |
| 6. | The implementation level of supporting systems is good | | | | |
| 7. | The supporting systems support the implementation of PBL with RAHMA syntax | | | | |
| 8. | The correlation between the supporting systems and other PBL with RAHMA syntax components is well described | | | | |
| Instructional and complementary impacts | | | | | |
| 1. | The instructional and complementary impacts are well described | | | | |
| 2. | The instructional impacts are relevant with the learning outcomes | | | | |
| 3. | The instructional impacts are well described | | | | |
| 4. | The complementary impacts are relevant with the learning outcomes | | | | |
| 5. | The complementary impacts are well described | | | | |
| 6. | The complementary impacts are rational | | | | |
| 7. | The instructional and complementary impacts support the implementation of PBL with RAHMA syntax | | | | |
| 8. | The correlation between the instructional and complementary impacts, and other PBL with RAHMA syntax components is well described | | | | |
| Learning scenario | | | | | |
| 1. | The learning model implementation instructions are easy to comprehend | | | | |
| 2. | The PBL with RAHMA syntax learning model is easy to implement | | | | |
| 3. | The social systems are clearly visible | | | | |
| 4. | The reaction principle is well described | | | | |
| 5. | The instructional and complementary impacts are clearly visible | | | | |
| 6. | The PBL with RAHMA syntax implementation is good | | | | |

2. Validation sheet of instruments for critical and creative thinking skills.

| No. | Assessed aspects | Score | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| A. Content/Material feasibility | | | | | |
| 1. | The questions are relevant with the grid | | | | |
| 2. | The questions are relevant with the critical thinking aspects | | | | |
| 3. | The questions are relevant with the creative thinking aspects | | | | |
| 4. | The questions' stimuli are interested; it encourages students to read it | | | | |
| 5. | The questions' stimuli are contextual | | | | |
| 6. | The questions' stimuli are update | | | | |
| 7. | There are limits to the questions and answers expected | | | | |
| B. Construction | | | | | |
| 1. | The questions' instructions are clearly and easy to understand | | | | |
| 2. | The questions have been clearly formulated | | | | |
| 3. | The questions' statement includes the essential aspects | | | | |
| 4. | The questions' construction does not provide any clues to the answer key | | | | |
| 5. | The questions do not include double negative statements | | | | |
| 6. | The tables, figures, and graphs present clearly and functionally | | | | |
| 7. | The questions do not depend on the answers of the previous questions | | | | |
| C. Language | | | | | |
| 1. | The questions use the proper grammar | | | | |
| 2. | The questions are easy to comprehend | | | | |
| 3. | The questions do not use local or regional languages | | | | |
| 4. | The questions use communicative language | | | | |
| D. Ethics | | | | | |
| 1. | The questions do not include sensitive aspects, such as: Ethnicity, religion, race, pornography, politics, propaganda, and violence | | | | |

3. Observation sheet of implementation of PBL with RAHMA syntax.

| No. | Observation aspects | Score | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| A. | Introduction activities | | | | |
| 1. | Lecturer greets the students | | | | |
| 2. | Lecturer asks students to pray | | | | |
| 3. | Lecturer prepares students physically and psychologically to participate in learning | | | | |
| 4. | Lecturer check the students' attendance | | | | |
| 5. | Lecturer explain the learning objectives | | | | |
| 6. | Lecturer explain the correlation of learning material with the previous study | | | | |
| 7. | Lecturer emphasizes the benefits of the learning | | | | |
| B. | Phase 1: Recognize the problem | | | | |
| 1. | One group presents the learning material outline about 'create higher-order thinking skills (HOTS) instruments' | | | | |
| 2. | Students discuss some aspects that they do not understand in class discussions | | | | |
| 3. | Students are asked to read the 'HOTS instrument guidebook' | | | | |
| 4. | Students are asked to accomplish the assignment in the worksheet | | | | |
| 6. | Students are listened the instruction to observe and recognize the problems in the school about biology learning evaluation | | | | |
| 7. | Students in their group observe in one senior high school; and identify the biology questions quality using questions' quality card | | | | |
| 8. | Students submit the identified questions quality to their learning management system (LMS) | | | | |
| C. | Phase 2: Analyse the problem | | | | |
| 1. | Students are guided to formulate the problems and its solutions based on the findings in the field | | | | |
| 2. | Students analyse the problems in their group | | | | |

| No. | Observation aspects | Score | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| 3. | Students formulate the problems and its solutions in their group | | | | |
| 4. | Students submit the problems formulation and the solutions to the LMS | | | | |
| D. | Phase 3: Handle a project | | | | |
| Scenario: | | | | | |
| 1. | Students in their group design the project scenario | | | | |
| 2. | Each group are given one difference topic by the lecturer | | | | |
| Scheduling: | | | | | |
| 3. | Lecturers and students create a project implementation schedule | | | | |
| 4. | Each member of the group is asked to create 15 HOTS questions with detail: C4=10 (7 multiple choices, and 3 essays), C5=3 (2 multiple choices, and 1 essay), dan C6=2 (1 multiple choice, and 1 essay) | | | | |
| 5. | Students submit the HOTS questions to the LMS | | | | |
| Review: | | | | | |
| 6. | Students are asked to review their friends' questions that have been created | | | | |
| Revise: | | | | | |
| 7. | Students revise their questions based on their friends' review | | | | |
| 8. | Students are reminded to documenting their activity through photos and videos; then submit it to the LMS | | | | |
| 9. | Students submit the revision questions to the LMS | | | | |
| Trial: | | | | | |
| 10. | One group presents the learning material outline about 'instrument test analysis' | | | | |
| 11. | Students discuss some aspects that they do not understand in class discussions | | | | |
| 12. | Students practice to analyse the items giving by the lecturer | | | | |
| 13. | Students choose 25 best questions in their group with details: C4=20 (17 multiple choices and 3 essays), C5=3 (2 multiple choices and 1 essay), dan C6=2 (1 multiple choice and 1 essay). Furthermore, the students in their group trials that questions to the first-year students. | | | | |
| 14. | Students analyse the trials' result using Anates software | | | | |
| 15. | Students submit the analysis result to the LMS | | | | |
| E. | Phase 4: Monitor the progress | | | | |
| 1. | Students report the project progress using monitoring instrument and submit it to the LMS | | | | |
| 2. | Lecturer monitor the progress and give the comments through the LMS | | | | |
| F. | Phase 5: Assess the result | | | | |
| Assessing: | | | | | |
| 1. | Students are asked to follow up the questions' quality analysis | | | | |
| 2. | Lecturer guide and supervise students in assessing their questions' quality analysis | | | | |
| 3. | Students are asked to give comments and recommendations to each question that have been tried using 'multiple choices and essays' card analysis' | | | | |
| Conclusion: | | | | | |
| 4. | Students are asked to conclude their project result in their group | | | | |
| 5. | Lecturer assess the questions that have been created | | | | |
| 6. | Lecturer inform the good quality questions of the groups through the LMS | | | | |
| 7. | Lecturer give rewards to the best group in accomplishing their project | | | | |
| G. | The using of support systems | | | | |
| 1. | Using the guidebook as the learning sources | | | | |

| No. | Observation aspects | Score | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| 2. | Using the students' worksheet as the learning sources | | | | |
| 3. | Involving students in the use of guidebook during learning | | | | |
| 4. | Involving students in the use of worksheet during learning | | | | |
| H. | Involving students in learning | | | | |
| 1. | Cultivate active student participation through reactions from lecturers, students and learning resources. | | | | |
| 2. | Cultivate student enthusiasm in learning by giving rewards | | | | |
| I. | Instructional and complementary impacts | | | | |
| 1. | Train students' critical thinking skills | | | | |
| 2. | Train students' creative thinking skills | | | | |
| 3. | Train students' communicative skills | | | | |
| 4. | Train students' collaborative skills | | | | |
| 5. | Cultivate students' social attitudes (Cooperation, respecting other people's opinions, helping each other among group members, etc.) during learning | | | | |
| J. | Closing activities | | | | |
| 1. | Students are given the opportunity to ask questions about learning material that they do not understand yet | | | | |
| 2. | Students are facilitated to conclude the learning material | | | | |
| 3. | Lecturer gives the feedback on the learning process and achievement | | | | |
| 4. | Lecturer provides direction for the next meeting learning | | | | |

4. Practicality sheet of PBL with RAHMA syntax.

| No. | Practicality aspects | Score | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| A. | Convenience in performing the PBL with RAHMA syntax | | | | |
| 1. | I can follow each stage of learning carried out by the lecturer well | | | | |
| 2. | When the lecturer provided introductory material for stimulation, I was able to understand the explanation well | | | | |
| 3. | After reading the introductory material, I am able to formulate the learning objectives | | | | |
| 4. | The lecture using PBL with RAHMA syntax make it easier to organize the time well | | | | |
| B. | Advantages of PBL with RAHMA syntax | | | | |
| 1. | The lecture helped me to study independently | | | | |
| 2. | The lecture helped me to practice learning collaboratively in groups | | | | |
| 3. | The lecture helped me to have more confidence | | | | |
| 4. | The lecture train me to manage time well | | | | |
| 5. | The lecture motivates me to learn more | | | | |
| C. | Usability and benefits of guidebook in learning process | | | | |
| 1.. | The guidebook helped me learn the course material | | | | |
| 2. | The guidebook helped me accomplish the assignments | | | | |
| 3. | The guidebook motivated me to create the high-quality instruments | | | | |
| 4. | The questions' examples and stimuli from the contextual problems motivated me to evaluate biology learning | | | | |
| D. | Lecturers' role in learning | | | | |
| 1. | Lecturer facilitates the lecture with the guidebook as the main learning source | | | | |
| 2. | Lecturer provides time to guide students as they comprehend the learning materials | | | | |