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DEVELOPMENT OF A MODIFICATION PROBLEM-BASED LEARNING (M-PBL) STRATEGY TO STIMULATE CHEMISTRY EDUCATION STUDENTS' METACOGNITIVE ABILITY

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Abstract – This study aims to describe the development of the M-PBL strategy with the ADDIE pattern (Analyze, Design, Develop, Implementation, and Evaluate) and test its validity and practicality. The research involved two basic chemistry lecturers and 35 chemistry education students from Universitas Negeri Makassar (UNM) for the 2020/2021 academic year. The instruments were validation sheets and teaching instruments (lesson plan, worksheet, and ability assessment; 2) lecturer and student perception questionnaires and observation sheets on the implementation of the M-PBL strategy to test the product's practicality. Testing the validity of the development product (M-PBL strategy Design and its tools) found that all products were in the very high category. The practicality of the M-PBL strategy based on the perceptions of two lecturers was 100%, giving a positive response, while the student's perception was 94.6%, giving a positive response. The implementation of the stages of the M-PBL strategy is carried out with a high category of student activities. Thus, the product is declared feasible and acceptable based on its validity and practicality.

Keywords: Development; M-PBL strategy; Metacognitive; Chemical Equilibrium.

INTRODUCTION

Several previous studies showed the low ability of metacognitive thinking and problem-solving. Ijirana (2018) reported that 87% of chemistry education students at UNTAD demonstrated low metacognitive thinking skills. Gayon (2003) reported that most high school and university students had low chemistry problem-solving abilities. The ability to think metacognitively is one of the skills students must possess in the 21st century (Greenstein, 2012). Metacognitive refers to students' skills consciously in monitoring thinking processes during learning and is the ability of individuals to think in managing their cognitive processes (Schraw, 1998). Metacognition awareness is the attitude of recognizing awareness at the level of thinking. Metacognition as knowledge is the ability of cognition to regulate thought processes. In Marzano's taxonomy, the metacognitive ability is assumed to be higher than the cognitive system.

It is necessary to improve the quality of chemistry learning to develop students' thinking skills. From the perspective of chemistry learning, Treagust & Reinders (2009) suggest improving

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ISSN 2528-6536(print)/ISSN 2579-5945 (online)@2022 J-PEK

the quality of learning by redesigning learning activities by embedding innovative learning models so that conceptual changes occur.

This M-PBL strategy is an adaptation of the Problem-based learning (PBL) model by Hamelo-Silver (2004) and the generative learning strategy (Wittorck, 2009). M-PBL is one of the recommended strategies to produce a generation with 4C abilities (collaboration, communication, critical, and creative thinking). The learning theory that underlies the M-PBL is a constructivist theory that emphasizes the importance of student involvement in constructing the concept in groups. This process involves contextual problems that are familiar in students' real lives. A similar strategy (EMBE-R) can also improve students' conceptual understanding of chemical equilibrium (Jusniar et al., 2021).

The theoretical rationale for the development and adaptation process of M-PBL are exploration, problem-oriented, grouping, guiding investigation, presenting & discussions finding, and strengthening & validating the concepts. The exploration stage intends to explore and assimilate initial concepts according to Piaget's theory (Joyce & Weil, 2009) by utilizing the initial regulators and Ausubel's theory of meaningful learning (Gagne, 2005). Problem-oriented covers package problems in videos or pictures to guide students in formulating problems. Grouping: the analysis of the problem was carried out in groups with the help of M-PBL-based student workbooks. Guiding investigation; the problem-solving process is carried out by collecting experimental data, analyzing, and then discussing it in small groups. The next guise is presenting and discussing the findings of each group in class discussions. Strengthening and validating the concepts with practice questions. Provide scaffolding and validate the results obtained by students and conclude the constructed concepts. The four stages (problem-oriented, grouping, guiding investigation) are adapted from the PBL stages by operationalizing and simplifying the stages. In contrast, the presenting & discussion, finding, strengthening, & validating of the concepts stages are adapted from generative learning strategies emphasizing information storage (information storage) with validation activities for understanding the concept.

Generative learning focuses more on how to find meaningful relationships. In this strategy, understanding is defined as the result of building relationships between concepts and prior knowledge, learning experiences, and new information (Wittrock, 1992). The link between the initial concept and the concept to be learned is important to build knowledge stored in long-term memory. The exploration stage in the syntax utilizes an advanced organizer aiming to link students' initial knowledge and the concept to be studied with the assistance of concept map facilities. The validation and strengthening phase validate and monitor students' conceptual understanding to reflect on their concept acquisition. The stages of M-PBL, a combination of PBL and GL, are expected to stimulate students' metacognitive abilities as the basis for creative thinking skills.

METHOD

Research Design and Procedure

The development of the M-PBL strategy follows the ADDIE (Analyze, Design, Develop, Implement, Evaluate) pattern (Branch, 2009) and is presented in Figure 1.

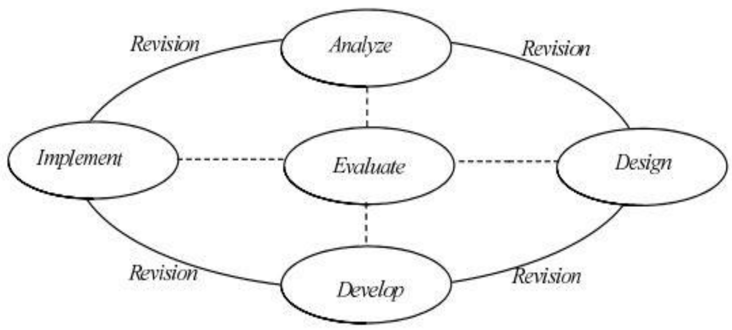

Figure 1. Development Steps with ADDIE Model

The evaluation stage aims to test the feasibility (validity, effectiveness, and practicality) of the M-PBL model product and its tools for stimulating metacognitive knowledge abilities.

Research Instruments

The research instruments were 1) device validation sheets (design of M-PBL strategy, LP, ability test assessment (52 items), and metacognitive knowledge (twelve items each for declarative, procedural, and conditional knowledge), M-PBL implementation observation sheet, and lecturers' perception questionnaire and student. 2) Practicality test instruments, namely observation sheets on implementing the M-PBL stages and questionnaires on perceptions of lecturers and students.

Data Analysis

Analysis of the Validity of the M-PBL strategy and its Tools

This analysis was conducted to assess the M-PBL strategy design and the tools developed at the Develop stage. The M-PBL validity and its tools were analyzed with the following procedure: 1) calculating the score of each item for all validators; 2) calculating the average score of each aspect of each validator; 3) calculating the average score of each aspect for all validators; 4) concluding the validity of M-PBL and its tools. The criteria for the validity of the M-PBL, LP, WS, and assessment are given in Table 1.

The consistency of assessment between validators is determined by calculating the reliability coefficient (R) (Percentage of Agreement). The design of M-PBL strategy and its tools are declared as reliable as the criteria of Borich (2003) if R 75%. The formula of Emmer and Miller formula in Borich (2003) was applied:

$$R = \left[1 - \left[\frac{\Sigma(A-B)}{\Sigma(A+B)}\right]\right] X\ 100\%$$

Information:

R = Reliability Coefficient
A = The maximum rating of the indicator observed by the validator.
B = Minimum assessment of the indicators observed by the validator.

Table 1. Criteria for the validity of the M-PBL strategy and its tools

Average Validity Score of Each Aspect	Criteria
4.05 - 5.00	very high
3.05 – 4.00	high
2.05 – 3.00	average
1.05 -2.00	low
0.00 – 1.00	very low

Strategy Practicality Data Analysis

The practicality data of the M-PBL strategy describes the user's response (teachers and students) to the M-PBL and its tools. The criteria for the practicality of M-PBL is also measured based on user responses. The data collection used a four-scale questionnaire. It demonstrates that more than 80% of users responded positively.

Table 2. Practical Criteria for the M-PBL strategy and its tools

Average practicality score	Category
$3.0 < P \leq 4.0$	High
$2.0 < P \leq 3.0$	average
$1.0 < P \leq 2.0$	Low

Description: P = Practicality (Source: Adaptation Hobri, 2009)

The practicality of the M-PBL strategy is determined based on the implementation of the learning strategy and students' activities, as given in Table 3.

Table 3. Criteria for the Implementation of the M-PBL Stage and Student Activities

Average implementation score	Category	Average Activities	Category
$2.0 < I \leq 3.0$	High	$3.0 < A \leq 4.0$	High
$1.0 < I \leq 2.0$	Average	$2.0 < A \leq 3.0$	Average
$0.0 < P \leq 1.0$	Low	$3.0 < A \leq 4.0$	Low

Description:
I = Implementation
A : Activities

RESULTS AND DISCUSSION

M-PBL Learning Strategy Development Results

The development stages of the M-PBL strategy are the adaptation and modification of the PBL learning model and Generative Learning (GL) stages. The steps are shown in Figure 2.

Figure 2. Description of the M-PBL strategy stages

Validity Test Results

The validity results covered the validity of the contents of the M-PBL strategy book and its tools and test and non-test instruments. The results of content validity are presented in Table 4. The validities of the M-PBL book, LP, and WS are in the average score of 4.2, 4.27, 4.27, respectively, with the very high category. The reliability coefficient (R) of the M-PBL, RPS, and MFI strategy books are 94.1, 91.0, and 93.1%, respectively. Thus, the M-PBL strategy book and tools are declared feasible and acceptable.

Table 4. The validity of M-PBL Design Strategy

Tools	Average Scores			Average	R (%)	Criteria
	1	2	3			
M-PBL Book	4.30	4.20	4.10	4.20	94.1	Very high
LP	4.20	4.20	4.40	4.27	93.0	Very high
WS	4.30	4.30	4.20	4.27	93.1	Very high

The M-PBL strategy refers to the standard of learning model development proposed by Joyce et al. (2011), with the following stages: supporting learning theory, social systems and reaction principles, instructional impact, and accompaniment impact. Education practitioners can easily use this strategy because it contains a guide to implementing the M-PBL strategy equipped with examples of its application for teaching the Le-Chatelir Principle. The Lesson Plan (LP) component is in accordance with the rules for preparing the Outcome-Based Education (OBE).

Validation of Test and Non-Test Instruments

The results of the content validity test for the Test and Non-Test Instruments are presented in Table 5. The results of the expert's assessment (three lecturers) on the conception test and metacognitive knowledge were declared feasible and acceptable with an average percentage of 98.6% (very high category). The percentage of assessment consistency between validators is 97.8.0%. The three validators stated that the Metacognitive Awareness Inventory (MAI), Student Activity Observation Sheet (SAOS), Learning Implementation Observation Sheet (LIOS), Lecturer Perception Questionnaire (LPQ), and Student Perception Questionnaire (SPQ) Instruments were feasible and acceptable as presented in Table 5. Chemistry learning experts assessed that the SAOS instrument containing student activities in M-PBL strategy learning had decent and acceptable. The activities observed in SAOS were adapted from indicators of performance outcomes by Borich (2003: 357), covering aspects of cooperation, involvement, attention, and student discipline.

Table 5. Validity of Test and Non-Test Instruments

Instrument	Validator Rating (%)			Average		Category
	1	2	3	V(%)	R (%)	
Metacognitive Knowledge Test	94	95	95	98.6	97.8	Very High
MAI	94	94	94	94	93.1	Very High
SAOS	100	100	100	100	100	Very High
LIOS	100	100	100	100	100	Very High
LPQ	95.0	95.0	96.0	95.3	94	Very High
SPQ	96.0	95.0	96.0	95.4	96.5	Very High

Description: V = Validity; ; R = (reliability: consistency between validators)

Student group activities become the focus of observation, which represents the implementation of learning in the classroom. The SAOS instrument, which consists of 7 observed activities is, follows the indicators and is easy to understand from a linguistic point of view. The LIOS instrument consists of 19 activities, including three activities at the exploration stage, two at the problem-oriented stage, two at the grouping stage, four at the guiding investigating stage, four at the presenting and discussion finding stage, and four at the strengthening and validating the concept stage. The LIOS instrument has a content validity and consistency of 100% (very high category). The chemistry learning experts considered that the lecturer perception questionnaire (LPQ) instrument, containing a statement of the lecturer's perception (response) of the M-PBL strategy and its equipment, was feasible and acceptable. The LPQ consists of 20 items (18 positives and two negative statements) following the M-PBL indicator and uses communicative language. Student Perception Questionnaire (SPQ) consists of 15 items for a questionnaire on student perceptions of the implementation of learning and its tools. The mean validity of LPQ and SPQ was 95.3 and 95.4%, respectively (very high). The consistency of assessment between validators for LPQ and SPQ is 94.0 and 94.5%, respectively.

Practical Testing of the M-PBL Strategy and its Tools

Data on the practicality of M-PBL from the implementation aspect of learning are presented in Table 6. The results of observations on the implementation of M-PBL in the experimental class show that the stages of the strategy are implemented well, with an average score of 2.98 (high practicality category). Data on the practicality of M-PBL from the aspect of student activity in learning with M-PBL are presented in Table 7. These results indicate that students in the group are actively involved in learning, with an average score of 3.63 (very high activity). The practicality of learning from the aspect of student SPQ and lecturer LSQ responses in the experimental class after implementing learning with the M-PBL strategy is presented in Tables 8 and 9. The average score of student responses to the Work Sheet and strategy M-PBL is 3.1, indicating that practicality is in the high category. Positive responses from students towards M-PBL strategies and tools were obtained by 94.6%.

Table 6. Observation Results of the Implementation of M-PBL strategy

Stage/Activity	Average
Exploration Initial concept exploration	2.88
Maximizing advance organizer	3.0
Submission of competency achievement indicators	3.0
Problem-Oriented Orient the student to the problem	3.0
Formulate the problem in the form of a question	3.0
Grouping Directing students to form groups (3-4 people)	3.0
Sharing WS	3.0
Guiding Investigation Watching Videos	3.0
Collecting data	3.0
Processing and analyzing data	3.0
Conduct small group discussions	3.0
Strengthening and Validating the Concept Give questions with expanded concepts	2.88
Lecturer gives scaffolding	3.0
Validating the results of concept construction	3.0
Conclude	3.0
Average	2.98

Table 7. Results of Observing Student Activities in Groups

Activities	Average
Collaborating or discussing in groups	3.57
Provide answers, objections, or ideas to the issues discussed.	3.53
Doing practice questions in the assignment folder	4.0
Asking questions related to the problem being discussed, providing alternative solutions to problems, validating other groups' answers, or providing conclusions.	3.57
Pay attention to teacher explanations or directions, discussions, and student explanations from other groups.	3.57
Completing the MFI within the specified time.	3.57
Shows discipline by not doing other activities in carrying out class discussion activities.	3.57
Average	3.63

Table 8. Practical Results of the M-PBL strategy from Student Responses

Aspect	**Average**	**% Responses**	
		+	**-**
Student interest in learning with the M-PBL strategy	3.0	97.1	2.9
Ease of understanding the stages of the M-PBL strategy in Chemical Equilibrium learning.	3.1	97.1	2.9
Ease of understanding the concept of chemical equilibrium because the lecturer relates the initial concept to what will be studied.	3.2	97.1	2.9
Interest in learning because of the animated video that is displayed.	3.1	94.3	5.7
Clarity understands the context in animated videos.	3.1	94.3	5.7
Ease of collaborating and discussing within and between groups with M-PBL.	3.1	91.4	8.6
Ease of using worksheet in the learning process.	3.1	91.4	8.6
Ease of understanding the language of the Worksheet	3.0	97.1	2.9
Clarity of indicators of competency achievement in worksheet.	3.1	97.1	2.9
Ease and clarity of experimental data on Worksheet	3.1	100	-
Ease of understanding concepts with practice questions on the Worksheet	3.1	94.3	5.7
Ease of test given at each meeting.	3.1	100	0
The suitability of the test with indicators of achievement of learning competencies.	3.1	85.7	14.3
Clarity of appearance and ease of practice questions on the worksheet.	3.1	91.4	8.6
Interest in the Worksheet view.	3.1	91.4	8.6
Average	3.1	94.6	5.4

The practicality of learning from the aspect of student SPQ and lecturer LPQ responses in the experimental class after implementing learning with the M-PBL strategy is presented in Tables 8 and 9. The average score of student responses to the worksheet is 3.1, indicating that practicality is at the high category. Positive responses from students towards worksheet strategies and tools were obtained by 94.6%. Only 5.4% of students gave a negative response to the items of the perception questionnaire.

Table 9. Practical Results of M-PBL from Advance Chemistry Lecturer Responses

Aspect Practicality	Average (N=3)	Positive Respons (%)
Ease of understanding M-PBL-stage	4	100
Ease of implementing the M-PBL strategy	3.5	100
Ease of understanding the language at the M-PBL stage.	3.5	100
Compatibility and ease of understanding LP.	4	100
Easy to understand M-PBL design book	3.5	100
Ease of applying M-PBL	3.5	100
Time compatibility with Competency Achievement Indicators (CAI) in LP and Worksheet.	4	100
Ease of understanding the language of the LP and Worksheet.	3.5	100
Conformity of CAI on Syllabus, LP and Worksheet.	4	100
Clarity of experimental data and animated videos on worksheet.	3.5	100
The suitability of the questions in the M-PBL Design with the worksheet to make it easier for students to build an understanding of the concept.	4	100
The suitability of the M-PBL strategy Book activity stages with the stages.	3.5	100
The ease of the worksheet facilitates students to build their concepts.	4	100
Ease of understanding experimental and exercise data on the worksheet.	3.5	100
The appearance of the worksheet is attractive and practical to use in learning	3.5	100
Ease of using the M-PBL Design Book on Chemical equilibrium material.	3.7	100
Ease of understanding the language in the M-PBL strategy Book	3.7	100
Conformity of the items on the instrument with the CAI.	4.0	100
Ease of understanding the language on the assessment test instrument.	3.7	100
The suitability of the competency achievement indicators with the cognitive level on the test instrument.	3.7	100
Average	3.6	100

The average score of the lecturer's response to the M-PBL strategy and its tools is 3.6, indicating that practicality is in the high category. Three chemistry lecturers (100%) positively responded to the application of M-PBL and its tools. Thus, M-PBL and its tools from the aspect of implementation and user response imply that it is practical to be applied in chemistry learning to increase awareness and metacognitive knowledge. Akker (1999) stated that practicality can be seen from two aspects, namely 1) how it is actually implemented in the field, 2) the positive response from users, both lecturers and students. Thus, the Modified Problem Based Learning (M-

PBL) learning strategy developed according to the ADDIE model suiting the product criteria for developing an innovative learning strategy is valid and practical. Some suggestions to improve the quality of the product will be further considered to ensure the validity of the product construction produced.

CONCLUSION

This study has produced valid and practical M-PBL strategy books, LP, Worksheet, and metacognitive knowledge assessments on the concept of chemical equilibrium using the ADDIE model. The criteria for the validity of the three experts in developing learning strategies are very high, with very high consistency between validators. Practicality in implementation is in the high category, and user responses from both students and lecturers are also in the very high category. The feasibility of the products reported in this article is only on the aspects of validity and practicality. Further research can be carried out on other chemistry topics to explore students' metacognitive knowledge.

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