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Stimulating Metacognitive and Problem Solving-Skills Students' on Chemical Equilibrium through Modified Problem-Based Learning (M-PBL) Strategy

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Abstract: This quasi-experimental aim is to examine the effect of implementing the M-PBL strategy on the metacognitive and problem-solving skills of Chemistry Education students. The number of research samples was 35 and 33 students for the experimental and control classes were selected randomly. The experiment class uses the M-PBL strategy. In contrast, the control class usages a verification strategy for Chemical Equilibrium, Advance Basic Chemistry courses in the even semester of the 2020/2021 academic year. Two instruments used are, 1) 12 items of Objective test on Chemical Equilibrium (CE) to measure students' problem-solving skills. 2) 12 Essay Test items to measure metacognitive knowledge. Assessment of metacognitive Knowledge adapts Rompayom's rubric. Implementing the M-PBL Strategy affected students' declarative, procedural, and conditional knowledge. The MPBL strategy had a better effect than conventional strategies on students' problem-solving skills.

Keywords: Chemical Equilibrium; Metacognitive knowledge; M-PBL Strategy; Problem solving

Introduction

The skills to think metacognitive is one of the students' skills, including students in the 21st century (Greenstein, 2012). Metacognitive refers to students' skills consciously in monitoring thinking processes during learning. Metacognition is one of the thinking skills of individuals in managing thought processes and products and ways to monitor and regulate their cognitive processes actively. Metacognition includes awareness and knowledge of self-cognition. Metacognition awareness is an attitude of recognizing awareness at the level of thinking (Schraw, 1998). Metacognition as knowledge is the skills of cognition to regulate thought processes. In Marzano's taxonomy, the metacognitive skills is included in the metacognitive system. It is assumed to be higher than the cognitive system. Marzano developed and rearranged the level of thinking skills in three (3) systems: Self-System, Metacognitive System, and Cognitive Systems. The three systems work in tandem. When faced with the choice of solving a problem, at the same time, the Self-System decides whether to accept the challenge or choose another activity; The Metacognitive System sets goals and monitors how well the problem-solving activities are progressing. The metacognitive system is the "controller" of the thought process and regulates all other systems. This system sets goals and decides which information is needed and which cognitive processes best suit a particular purpose. This process can then monitor higher-order thinking processes such as critical and creative thinking (including metacognitive) to solve problems (Zubaidah et al., 2017).

Several previous studies have shown the low skills of metacognitive thinking and problem-solving. Ijirana et sal. (2018) reported that as many as 87% of chemistry education college students at UNTAD had low metacognitive thinking skills. Gayon (2007) said that

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most high school students and university students had low chemistry problem-solving skills. The declarative and procedural Knowledge of Chemistry students at the State University of Malang is in the medium category, while the conditional knowledge is low (Parlan et al., 2019; Rahman, 2019). Furthermore, Parlan et al. (2018) found that this metacognitive knowledge is the best predictor of student learning outcomes, especially problem-solving. Students with good problem-solving skills can stimulate critical and creative thinking skills.

Chemical Equilibrium (CE) is one of the Advanced Basic Chemistry course materials with a weight of 3 credits. The concepts in this subject are essential to understand because they are the basis for understanding related materials, such as Acid-Base Equilibrium, Hydrolysis, and Solubility (Voska et al., 2000). According to a survey conducted on chemistry teachers in the United States This difficulty causes misconceptions in almost all CE concepts (Jusniar et al., 2020, 2021, 2022); Several studies that reveal misconceptions about chemical equilibrium are (Barke et al., 2009; Ilyas et al., 2018; Karpudewan et al., 2015; Kaya, 2008). This phenomenon is thought to be related to the characteristics of the CE material, which is generally a well-defined concept and also involves algorithmic operations that require a high level of understanding. The characteristics of this subject are that it contains defined concepts, and requires graphical and algorithmic understanding. Thus, it is essential to implement learning strategies that can stimulate good metacognitive and problem-solving skills to understand the concept of CE (Jusniar et al., 2022). Thus, the research questions are: 1) Does the application of the M-PBL strategy affect students' metacognitive knowledge of the Chemistry Education Study Program, Faculty of Mathematics and Natural Science UNM? 2) Does the application of the M-PBL strategy affect the problem-solving skills of students of the Chemistry Education Study Program, Faculty of Mathematics, and Natural Science UNM? 3) Is there a relationship between students' metacognitive knowledge and problem-solving skills in the chemical equilibrium material?

Method

Research Types and Design

This research is quasi-experimental research using a post-test control group design. Table 1 shows a quasi-experimental design.

Table 1. Quasi-Experimental Research Design (Creswell et al., 2012)

Subject	Treatment	Post-test
Experiment Class	T	O
Control Class	-	O

Information

O = Problem-solving skills and metacognitive knowledge

T = Treatment with the implementation of the M-PBL strategy

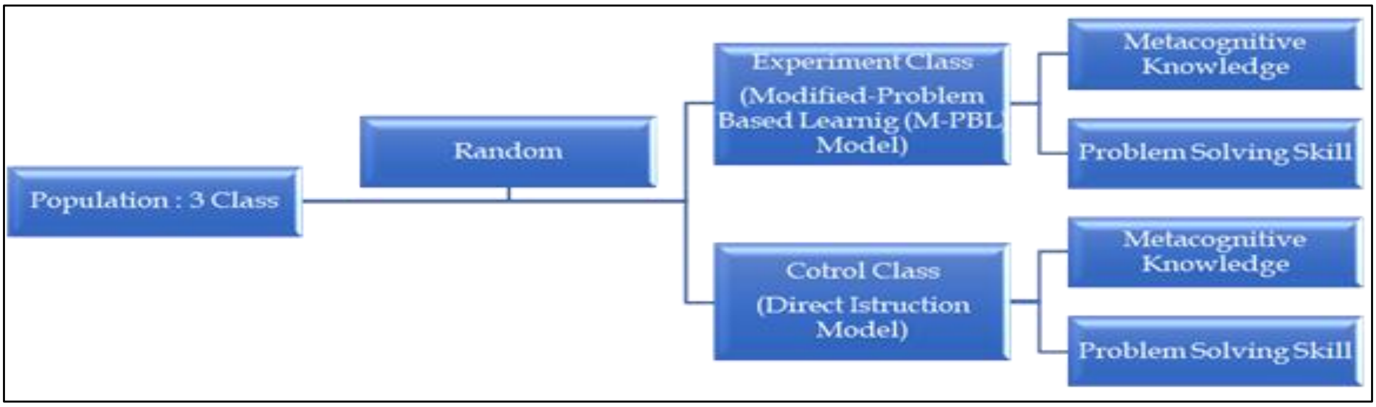


Figure 1. Research stages chart

Research Population and Sample

The population in this study were all students of the Chemistry Education program who programmed Advanced Basic Chemistry in the 2020/2021 academic year. 104 students take this course, which is distributed into 3 classes. Two samples were taken randomly, selected classes A and B. Using the lottery technique, Class A was chosen as the control class and class B as the experimental class. The control class is 33 students, and the experimental class is 35 students.

Research Instrument

The instruments in this research are: (a) The problem-solving skills test on the concept of a chemical equilibrium shift consists of 12 objective items. This test is an instrument to measure the problem-solving skills of students. (b) Essay test 36 items to measure metacognitive knowledge (12 items each for declarative, procedural, and conditional knowledge). Assessment of metacognitive Knowledge adapts Rompayom's rubric, as shown in Table 2.

Table 2. Metacognitive Knowledge Assessment Rubric

Types of Metacognitive Knowledge	Description	Scale
Declarative Knowledge	Able to determine factual knowledge in the form of the basic information needed to be processed related to the questions given.	2
	Able to write down ideas but not be specific. Concepts are related to chemistry but not related to questions.	1
	Unable to describe things related to the given task. There is nothing to say regarding question	0
Procedural Knowledge	Able to explain how and apply the right strategy to be used to answer the questions given. Students explicitly determine the implications between the information provided and the questions.	2
	Able to understand the purpose of the assignment, but students make ideas that are not specific and are not related to the information provided or the questions asked.	1
	Unable to describe the strategy that should be used to answer the question and explain how to solve the question.	0
Conditional Knowledge	Able to give reasons when and why to choose information (declarative) and use strategies (procedural) to solve the given problem. Overview of process related to factual matters in providing information and answers.	2
	Able to state the strategies that can be chosen to solve the problem but cannot explain why these strategies are used.	1
	Unable to name and explain when and why to use these strategies to solve problems.	0

Data Analysis

After the inferential prerequisite test, the data obtained were analyzed using Analysis of Covariates (ANCOVA). Those are normality and homogeneity tests. This analysis was carried out with the help of SPSS for windows 21. The normality test results can be seen in Table 3, Table 4 shows the homogeneity test result.

Table 3. Normality Test of Problem Solving (PS) Skills and Knowledge, Metacognitive Control and Experimental Group Students

Test Variable	Test used	Test Criteria	KS-Test Value	KS-Table Value	Conclusion
PS (CG) Score	Kolmogorof- Smirnof (KS) Test	Distribution is Normal When $KS_{-test} < KS_{-Table}$	0.143	0.223	Distribution is normal
PS (EG) Score			0.197	0.224	Distribution is normal
DK CG Score			0.219	0.223	Distribution is normal
DK EG Score			0.131	0.224	Distribution is normal
PK CG Score			0.217	0.223	Distribution is normal
PK EG Score			0.218	0.224	Distribution is normal
CK CG Score			0.202	0.223	Distribution is normal
CK EG Score			0.219	0.224	Distribution is normal

Description:
CG : Control group
EG : Experiment group
PS : Problem-solving
DK : Declarative Knowledge
PK : Procedural Knowledge
CK : Conditional Knowledge

The calculated KS value of the SPSS output is the most extreme absolute difference. Table 3 shows that the problem-solving scores and students' metacognitive knowledge of the concept of Equilibrium conditions and Le-Chatelir's principle are all normally distributed in both the control and experimental classes. This can be seen from the calculated KS value, which is smaller than the table KS value.

Table 4. Summary of PS Score Homogeneity Test and Metacognitive Knowledge

Test Variable	Test Used	Test Criteria	$F_{\text{-test}}$	$F_{\text{-table}}$	Conclusion
PS CG–EG Score	Levene's Statistic Test	Varians is Homogen when *F-test* < *F-Table*	0.11	3.78	Variance KK-KE homogenous
DK CG-EG Score			3.5		The Variance is homogenous
PK CG-EG Score			2.9		The Variance is homogenous
CK CG-EG Score			2.1		The Variance is homogenous

Result and Discussion

Result

The researcher tested the effectiveness of the M-PBL strategy to improve problem solving skills and students' metacognitive knowledge on the concept of Chemical Equilibrium by using the ANOVA test. Table 5 shows the ANOVA test results from two different groups. Before the ANOVA test, the prerequisite tests for normality and homogeneity must be met as in Tables 3 and 4. The ANOVA calculation was carried out with the help of the SPSS program.

Table 5. Summary of ANOVA Test Effect of M-PBL Strategy on Problem Solving Skills (PS) and Metacognitive Knowledge

Variable-Test	N	Mean	Sum of square	Df	Mean square	F	Sig.
Score PS CG – EG (bet (Within groups)	33	7.42	22.35	1	22.35	11.29	0.001
	35	8.57	130.63	66	1.98		
Skor CG-EG	33	7.76	451.67	1	451.67	36.41	0.000
	35	12.91	818.8	66	12.41		
Skor PK CG-EG	33	7.85	347.47	1	347.47	31.14	0.000
	35	12.37	736.41	66	11.16		
Skor CK CG-EG	33	8.15	226.1	1	226.1	23.32	0.000
	35	11.8	639.84	66	639.84		

Table 5 shows a significant difference between the control and experimental classes on problem-solving abilities and metacognitive knowledge. Price means determining a better class. Students' problem-solving skills on the concept of Chemical Equilibrium in the experiment class by M-PBL have an average of 8.57 out of a maximum score of 12. The experimental class has a higher mean score than the control class (conventional learning), with an average of 7.42.

The experimental class's average declarative, procedural, and conditional knowledge were 12.91, 12.37, and 11.8 higher than the control class, with an average score of 7.76 and 7.85, respectively, and 8.15. The maximum score for the instrument that adopts Rompayem (2007) rubric is 24. Thus the M-PBL Strategy can be effective in improving problem-solving abilities and metacognitive knowledge.

Discussion

Study of the effectiveness of the M-PBL strategy to improve problem solving skills and metacognitive knowledge of students on the concept of chemical equilibrium

The M-PBL strategy based on the results of the ANOVA test was declared effective in improving student learning outcomes and metacognitive knowledge, as shown in Table 5. The average score describes three aspects of metacognitive knowledge and student problem-solving abilities on the concept of Chemical Equilibrium. Students in the class taught with the M-PBL Strategy had a higher scores than the control class. The stages of learning with the M-PBL strategy, from exploration to strengthening and validating concepts, are enriched with questions that can stimulate students' thinking skills. According to Zimmermann et al. (2021) this stimulation can develop students' thinking skills and facilitate problem-solving (Parlan et al., 2018; Schrock et al., 2015) and Improve Critical thinking (Hasanah et al., 2019). Inquiry-based models and improving critical thinking skills and problem-solving can also enhance creative thinking skills (Zubaidah et al., 2017). Declarative, procedural, and conditional knowledge must be trained in students during the learning process. Declarative knowledge is basic knowledge that asks about "What." Procedural knowledge is related to "How" questions. All the knowledge relates to strategies, methods, or procedures in solving a problem. Conditional knowledge is a continuation of the reasons for using problem-solving methods or strategies on procedural knowledge.

Table 6 shows an example of problem-solving skills to analyse substances that are part of the reactants and products of chemical equilibrium reactions. Given a table illustrating the change in the concentration of a substance with time in the gas phase.

Table 6. Table of Hydrogen and Nitrogen Gas Equilibrium to Form Ammonia

Time	Concentration (Mol/L)		
	N_2	H_2	NH_3
0	3	3	0
2	2.75	2	0.5
4	2.6	1.7	0.8
6	2.5	1.5	1

The table shows an alternating reaction that reaches the equilibrium state of the reaction ….

A. $N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g)$
B. $2NH_3(g) \rightleftarrows N_2(g) + 3H_2(g)$
C. $N_2(l) + 3H_2(g) \rightleftarrows 2NH_3(g)$
D. $2NH_3(l) \rightleftarrows N_2(g) + 3H_2(g)$

This problem-solving question is then followed by a question about students' declarative knowledge, asking what the essence of the question above is? One of the students' answers is declarative knowledge with a metacognitive score of two, as shown in Figure 2.

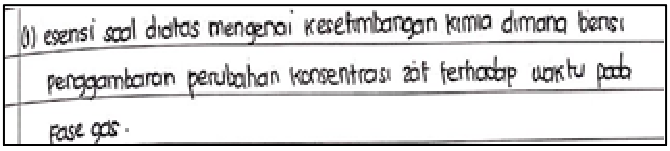

(1) esensi soal diatas mengenai kesetimbangan kimia dimana berisi penggambaran perubahan konsentrasi zat terhadap waktu pada fase gas.

Figure 2. Student answers for declarative knowledge

One of the student answers that descrybe procedural knowledge with a score of 2 can be seen in Figures 3 and 4. The questions given are about how you solve the problem?

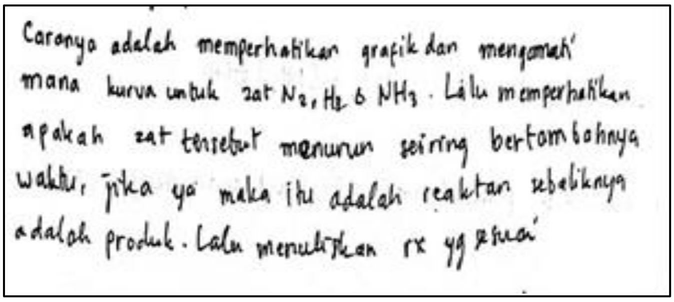
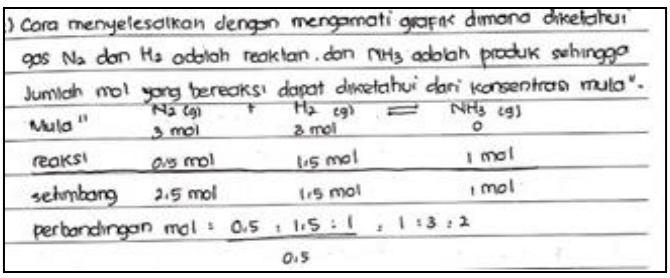

Caranya adalah memperhatikan grafik dan mengamati mana kurva untuk zat N_2, H_2 & NH_3. Lalu memperhatikan apakah zat tersebut menurun seiring bertambahnya waktu, jika ya maka itu adalah reaktan sebaliknya adalah produk. Lalu menuliskan rx yg sesuai

Figure 3. Students' procedural knowledge answers

The student's answer suggests that he solves the problem by looking at the graph and analysing the curves for substances N_2, H_2, and NH_3. Of the three species, one decreases with increasing reaction time (a reactant), and one increases (the product).


) Cara menyelesaikan dengan mengamati grafik dimana diketahui gas N_2 dan H_2 adalah reaktan. dan NH_3 adalah produk sehingga jumlah mol yang bereaksi dapat diketahui dari konsentrasi mula".

	N_2 (g) +	H_2 (g) ⇌	NH_3 (g)
Mula"	3 mol	3 mol	0
reaksi	0,5 mol	1,5 mol	1 mol
setimbang	2,5 mol	1,5 mol	1 mol

perbandingan mol : 0,5 : 1,5 : 1 / 0,5 ; 1 : 3 : 2

Figure 4. Students' procedural knowledge answers

Students' answers related to conditional knowledge asking why they used a strategy or method on procedural knowledge points to solve the problem are presented in Figure 4. The responses in Figure 4 only scored one because the explanation was incomplete.

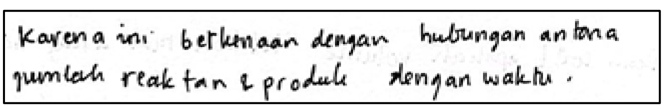

Karena ini berkenaan dengan hubungan antara jumlah reaktan & produk dengan waktu.

Figure 5. Students' conditional knowledge answers

The effectiveness of the M-PBL strategy in improving students' problem-solving skills shows that the application of this strategy provides a better conceptual understanding of chemical equilibrium material than conventional strategies. This success is certainly supported by integrating the stages of learning activities, namely, students in groups observing, analyzing animated videos, and working on their student worksheets. The role of the lecturer is as a facilitator and mediator and provides minimal assistance in the learning process. Moreover, the side effects caused by the implementation of this strategy can improve students' skills to collaborate, communicate, think critically, and be creative. This learning helps students learn in a fun way and helps them gain depth in concepts (Zubaidah et al., 2017). Another advantage is that it provides opportunities for students to find ideas in making their concepts based on pre-existing concepts (Pedaste et al., 2015). As a supporter of the relationship between metacognitive knowledge and problem-solving abilities in the experimental class, it is shown by the correlation as shown in Table 7. These results indicate that the three metacognitive knowledge is strongly and significantly correlated with students' problem-solving skills in understanding the concept of Chemical Equilibrium.

Table 7. Correlation Test of Problem-Solving Skills with Metacognitive Knowledge

Bivariate Correlation	R table	r table	Sig.	Information (category)
Score DK – PS EG	0.594	0.334	0.000	Significant (strong)
Score PK – PS EG	0.478	0.334	0.004	Significant (strong)
Score CK – PS EG	0.435	0.334	0.009	Significant (strong)

Conclusion

There is an effect of implementing the M-PBL strategy on problem-solving abilities and students' metacognitive knowledge of the concept of Chemical Equilibrium. A significant correlation between metacognitive knowledge and problem-solving skills in the experimental class provides information that strengthens the study results. This research is still limited to one topic, namely Chemical Equilibrium. The M-PBL model trial was only carried out in one class to see its effect on problem-solving abilities and metacognitive knowledge. Further research on other topics in chemistry is needed as a basis for comparing results to enrich the scientific treasures of chemistry education.

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References

Barke, H.-D., Hazari, A., & Yitbarek, S. (2009). Chemical Equilibrium. In *Misconceptions in Chemistry* (pp. 145–172). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-70989-3_7

Creswell, J. D., Irwin, M. R., Burklund, L. J., Lieberman, M. D., Arevalo, J. M. G., Ma, J., Breen, E. C., & Cole, S. W. (2012). Mindfulness-Based Stress Reduction training reduces loneliness and pro-inflammatory gene expression in older adults: A small randomized controlled trial. *Brain, Behavior, and Immunity*, *26*(7), 1095–1101. https://doi.org/10.1016/j.bbi.2012.07.006

Gayon, E. E. P. (2007). The Problem-Solving Ability of High School Chemistry Students and its Implications in Redefining Chemistry Education. *International Conference on Science and Mathematics Education, Penang, Malaysia.*, *1*(1), 1–6. shorturl.at/huV45

Hasanah, A. F., Raharjo, & Rachmadiarti, F. (2019). Practicality and effectiveness of SETS based learning materials to trained students' higher-order thinking skills. *Journal of Physics: Conference Series*, *1417*(1), 012079. https://doi.org/10.1088/1742-6596/1417/1/012079

Ijirana, I., & Supriadi, S. (2018). Metacognitive Skill Profiles of Chemistry Education Students in Solving Problem at Low Ability Level. *Jurnal Pendidikan IPA Indonesia*, *7*(2), 239–245. https://doi.org/10.15294/jpii.v7i2.14266

Ilyas, A., & Saeed, M. (2018). Exploring Teachers' Understanding about Misconceptions of Secondary Grade Chemistry Students. *International Journal for Cross-Disciplinary Subjects in Education*, *9*(1), 3323–3328. https://doi.org/10.20533/ijcdse.2042.6364.2018.0444

Jusniar, J., Effendy, E., Budiasih, E., & Sutrisno, S. (2020). Misconceptions in Rate of Reaction and their Impact on Misconceptions in Chemical Equilibrium. *European Journal of Educational Research*, *9*(4), 1405–1423. https://doi.org/10.12973/eu-jer.9.4.1405

Jusniar, J., Effendy, E., Budiasih, E., & Sutrisno, S. (2021). Eliminating Misconceptions on Reaction Rate to Enhance Conceptual Understanding of Chemical Equilibrium Using EMBE-R Strategy. *International Journal of Instruction*, *14*(1), 85–104. https://doi.org/10.29333/iji.2021.1416a

Jusniar, J., Yunus, M., Hardin, H., & Syamsidah, S. (2022). Development of a Modification Problem-Based Learning (M-PBL) Strategy to Stimulate Chemistry Education Students' Metacognitive Ability. *J-PEK (Jurnal Pembelajaran Kimia)*, *7*(1), 22–32. https://doi.org/10.17977/um026v7i12022p022

Karpudewan, M., Treagust, D. F., Mocerino, M., Won, M., & Chandrasegaran, A. L. (2015). Investigating high school students' understanding of chemical equilibrium concepts. *International Journal of Environmental and Science Education*, *10*(6), 845–863. https://doi.org/10.12973/ijese.2015.280a

Kaya, O. N. (2008). A Student-centred Approach: Assessing the Changes in Prospective Science Teachers' Conceptual Understanding by Concept Mapping in a General Chemistry Laboratory. *Research in Science Education*, *38*(1), 91–110. https://doi.org/10.1007/s11165-007-9048-7

Parlan, P., Astutik, N. A. I., & Su'aidy, M. (2019). Analisis Pengetahuan Metakognitif dan Kesadaran Metakognitif Peserta Didik Serta Hubungannya dengan Prestasi Belajarnya pada Materi Larutan Penyangga. *J-PEK (Jurnal Pembelajaran Kimia)*, *4*(1), 1–13. https://doi.org/10.17977/um026v4i12019p001

Parlan, P., Ibnu, S., Rahayu, S., & Suharti, S. (2018). Effects of the metacognitive learning strategy on the quality of prospective chemistry teacher's scientific explanations. *International Journal of Instruction*, *11*(4), 673–688. https://doi.org/10.12973/iji.2018.11442a

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., Manoli, C. C., Zacharia, Z. C., & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review*, *14*, 47–61. https://doi.org/10.1016/j.edurev.2015.02.003

Rahman, M. M. (2019). 21st Century Skill "Problem Solving": Defining the Concept. *Asian Journal of Interdisciplinary Research*, *2*(1), 64–74. https://doi.org/10.34256/ajir1917

Schrock, J., & Benko, S. (2015). *Using Fundamental Concepts and Essential Questions to Promote Critical Thinking*. Faculty Focus. https://www.lander.edu/about/_files/documents/whiteboards/whiteboard-15mar.pdf

Voska, K. W., & Heikkinen, H. W. (2000). Identification and Analysis of Student Conceptions Used to Solve Chemical Equilibrium Problems. *Journal of Research in Science Teaching*, *37*(2), 160–176. https://doi.org/10.1002/(SICI)1098-2736(200002)37:2<160::AID-TEA5>3.0.CO;2-M

Zimmermann, F., Melle, I., & Huwer, J. (2021). Developing Prospective Chemistry Teachers'

TPACK–A Comparison between Students of Two Different Universities and Expertise Levels Regarding Their TPACK Self-Efficacy, Attitude, and Lesson Planning Competence. *Journal of Chemical Education*, *98*(6), 1863–1874. https://doi.org/10.1021/acs.jchemed.0c01296

Zubaidah, S., Fuad, N. M., Mahanal, S., & Suarsini, E. (2017). Improving creative thinking skills of students through Differentiated Science Inquiry integrated with mind map. *Journal of Turkish Science Education*, *14*(4), 77–91. https://doi.org/10.12973/tused.10214a