PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

O EFEITO DA ESTRATÉGIA DE APRENDIZAGEM SMART-PBL E DA APRENDIZAGEM ACADÊMICA AUTORREGULADA SOBRE AS HABILIDADES METACOGNITIVAS E DE RESOLUÇÃO DE PROBLEMAS NA APRENDIZAGEM EM QUÍMICA

THE EFFECT OF SMART-PBL LEARNING STRATEGY AND ACADEMIC-SELF REGULATED LEARNING ON METACOGNITIVE & PROBLEM-SOLVING SKILLS IN LEARNING CHEMISTRY

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RESUMO

O aprendizado da química no século XXI deve enfatizar não apenas os resultados da aprendizagem cognitiva, mas também as habilidades metacognitivas e de resolução de problemas. O metacognitivo precisa ser aprimorado para que os alunos possam praticar a organização, o monitoramento e a avaliação do processo de raciocínio na solução de problemas químicos. É necessário desenvolver a solução de problemas para treinar o aluno a tomar decisões e explicações científicas apropriadas ao encontrar problemas químicos. Com base no resultado da observação, as habilidades metacognitivas e de resolução de problemas de professores de ciências em treinamento em Malang, na Indonésia, foram baixas. As habilidades metacognitivas e de resolução de problemas são afetadas pelo aprendizado acadêmico auto-regulado (ASRL) dos alunos O objetivo deste estudo foi conhecer o efeito da Estratégia Atende à Aprendizagem Baseada em Problemas de Tecnologia de Realidade Aumentada (SMART-PBL) e da aprendizagem acadêmica autorregulamentada (ASRL) na melhoria das habilidades metacognitivas e de resolução de problemas na aprendizagem da química. A SMART-PBL foi modificada pela estratégia de aprendizagem baseada em problemas (PBL) que auxiliou a tecnologia de realidade aumentada como mídia visual. Os sujeitos da pesquisa foram 64 professores de ciências em treinamento divididos em classe controle e experimental, respectivamente de 32 alunos. O método de pesquisa foi o delineamento quasi experimental, com fatorial de projeto de grupo de controle não equivalente 2x2. A classe experimental usou SMART-PBL, enquanto a classe controle PBL. O SMART-PBL teve uma influência significativa nas habilidades metacognitivas e de resolução de problemas em comparação com a estratégia PBL. Além disso, a abordagem SMART-PBL não interagiu com o ASRL para melhorar as habilidades metacognitivas e de resolução de problemas. A implementação do SMART-PBL aprimora não apenas as habilidades metacognitivas e de resolução de problemas, mas também desenvolve habilidades criativas e de pensamento crítico, comunicação e raciocínio científico que aparecem nos alunos durante o aprendizado de química.

Palavras-chave: *habilidade metacognitiva, habilidade para resolver problemas, aprendizado baseado em problemas, realidade aumentada, ensino de química.*

ABSTRACT

Learning chemistry in the 21st century should emphasize higher-order thinking skills such as metacognitive and problem-solving skills besides cognitive learning outcomes. Metacognitive needs to be improved so students can practice organizing, monitoring, and evaluating their thinking process in solving chemical problems. Problem-solving needs to develop to train students in making the appropriate decision and scientific explanation when encountering chemical issues. Based on observation results, the metacognitive and problem-solving skills of a pre-service science teacher in Malang, Indonesia, were low. Metacognitive and problem-solving skills are affected by academic-self regulated learning (ASRL) by students. This study aimed to know the effect of the Strategy Meets Augmented Reality Technology-using Problem Based Learning (SMART-PBL) and Academic-self regulated learning (ASRL) on improving metacognitive and problem-solving skills in learning chemistry. The SMART-PBL was modified by Problem Based Learning (PBL) strategy, which assisted by Augmented Reality technology as visual media. The research subject was 64 pre-service science teachers divided into control and experimental class, respectively, of 32 students. The research design was Quasi-

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Experimental, with Nonequivalent Control Group Design using factorial 2x2. The trial class performed SMART-PBL, which showed a more significant influence on metacognitive and problem-solving skills than the PBL class. The SMART-PBL not interacted with ASRL to improve metacognitive and problem-solving skills. By implementing SMART-PBL improves not only metacognitive and problem-solving skills but also evokes creative and critical thinking, communication, and scientific reasoning skills that appear in students during learning chemistry.

Keywords: *metacognitive skill, problem-solving skill, problem-based learning, augmented reality, learning chemistry.*

1. INTRODUCTION:

Chemistry is a science dimension that tried to explain the occurrence of natural phenomena in the universe scientifically. One of the goals of learning chemistry is building concepts and then using them to solve various natural events in chemistry (Parlan *et al.*, 2018). The idea of chemistry was abstract (Üce and Ceyhan, 2019) and taught in hierarchical manners (Zheng *et al.*, 2017; Armengol and Plaza, 2005). It said to be abstract because it studied real objects which invisible by human vision, for example, the concept of the atom as a constituent of a chemical element. Concepts are arranged in a hierarchy from the basic into the most complex ones consisting of microscopic, symbolic, and macroscopic domains (Jong and Taber, 2007).

Since chemistry concepts were abstract and hierarchy, it considers to be hard to comprehend as a class by students, then the learning process of chemistry has been carried out by teachers with extreme care to prevent misconceptions as were widely reported (Yiin, 2010; Özmen, 2004). So learning activities tend to use a teacher-centered approach. This approach indeed helps students in accelerating in understanding concepts but is not honing their thinking abilities. Whereas higher-order thinking skills such as critical thinking and problem-solving are essential for students in the 21st century (Griffin, Patrick Mcgraw, 2012).

The most fundamental concept in chemistry was to learn about elements and chemical compounds (Hendry, Robin, 2006; Partington, 1948). This basic concept needs to be master because it studied the atom structure as a constituent of an element, knows the physical and chemical properties, and understands chemical elements' uses before exploring the further complicated concept. When students have mastered the basic concepts, they will find it easier to learn more complex thoughts (Jusniar *et al.*, 2020) to explain the process of occurring natural phenomena caused by the reaction of chemical elements and compounds scientifically.

To explain the process of occurrence of chemical phenomena in daily life, the student needed higher-order thinking skills (HOTS), such as problem-solving skills (Symington, 1977). Developing problem-solving skills required the ability to manage the thinking process, known as the ability to think metacognitive (Jauhangeer, Shuib, and Azizul Hasan, 2018).

Metacognitive is one of the individual thinking skills in managing the process and product of thinking and how to actively monitor and regulate their cognitive processes (Flavell, 1979). Developing metacognitive skills is crucial because it helps identify the level of consciousness, training and tracking this way of thinking, and training on how to solve the problem heuristically (Aurah *et al.*, 2011).

Information about students 'metacognitive knowledge is needed to identify and improve students' thinking patterns in studying chemical material (Parlan, 2019). It supported by research proving that metacognitive skills can help develop problem-solving skills in learning chemistry (Azizah and Nasrudin, 2019). Success in learning chemistry will produce students with analytical thinking skills and scientific attitudes to solve problems scientifically in various situations (Dasna, 2012).

Problem-solving skills also suggested developing in science students while studying chemistry (Stockwell, Stockwell, and Jiang, 2017) due to the fundamental human cognitive processes. The problem occurs when students have no clue how to solve the cases. Problem-solving was a process, consists of systematic observation and critical thinking to find an appropriate solution(Rahman, 2019).

However, based on observations on the research location found several conditions. Besides, low cognitive learning outcomes, apparently new problems were found, metacognitive and problem-solving skills were similar. The level of metacognitive thinking skills was low (51.70%); some students still mistakenly mention the halogen group's chemical elements as noble gas elements. The majority of students still classify the chemical element of Hydrogen as an alkali metal group. If they had more profound thought about the characteristics of metals, this error would not have occurred. It indicated lower in thinking strategically. This finding supported by a previous study by Ijirana (2018) said that as much as 87% of chemistry educational students had low metacognitive thinking skills.

The level of problem-solving skills was low at (48.07%). Results of interviews with lecturers found that the majority of students still had difficulty explaining scientifically how the reaction of sulfur and other chemical elements can lead to acid rain in industrial and urban areas. This condition was consistent with the findings of Gayon (2003) reported majority high school students have low chemical problem-solving skills. It supported by a similar result by previous studies that science education students have a problem-solving ability that still needs to be improved (Widiasih, 2018).

Based on the results of interviews, students tend to collect assignments lately. It indicates that student's academic self-regulated learning in learning chemistry also found still low. Previous research reported similar findings that only 37% of students used their self-regulated learning ability to predict their performance in general chemistry courses (Miller, 2015).

Based on the explanation above, an effort should be made to develop the ability to think metacognitive and solve problems in pre-service science teachers by improving the quality of the chemistry learning process to provide better learning outcomes.

Previous research published mood for learning chemistry can be built by knowing and linking chemical issues in the history of the invention (Kupatadze, 2018). Improving the quality of learning can be done in several ways, like to empower technology or media in education (Setyosari, 2005). To learn chemistry with complicated and abstract concepts requires media assistance with high abstraction or visualization, such as Augmented Reality technology (AR).

AR was a new technology as well as a field of research sitting at the interface of Virtual Reality (VR), Artificial Intelligence (AI), and Computer Graphics (CG), which the simulated data displayed in a real-world environment. It impacted chemistry for educational purposes and enhanced the illustration of chemical communications (Steven V. Ley, 2016).

The results of a previous study proved that AR could increase interest and motivation to learn chemistry on the learner (Cai, Wang and Chiang, 2014) and help solve chemical problems (Núñez *et al.*, 2008). Besides, the success of AR has widely publicized in improving academic learning outcomes (Efimova, 2012) and chemistry learning outcomes (FS, Irwansyah. Y M, 2018). AR technology cannot be implemented individually in learning. It needed procedural steps in the form of learning strategies (Rosli, 2018). Learners who choose to use a variety of learning strategies tend to earn higher learning outcomes (Simsek, 2010).

(Dewey, 1910) postulated that the thinking process cannot happen suddenly, but can stimulate by presenting a problem, cases, questions, conflict, or confusion about something. Gao *et al.*, (2018) showed his research findings that conceptual understanding and problem-solving skills could improve by implementing learning problem based learning (PBL) strategy. Kamdi (2007) defined PBL as one of the innovative learning models for instructions. PBL famous for using real-world or concrete cases to facilitate learning through a student-centered approach (Salinitri *et al.*, 2015). PBL was modular by Self-Regulated Learning in discovering success. Learners gave responsibility for their learning process and results (Hmelo-Silver, 2004). Academic Self-Regulated Learning (ASRL) affected metacognitive and problem-solving skills. This statement supported by several studies showing the success of self-regulation in solving problems (Ahghar, 2013). The literature states that learners' self-regulation in learning was related to metacognitive skills possessed (Isaacson and Fujita, 2006).

This study implemented the *Strategy Meets Augmented Reality Technology-Using Problem Based Learning* abbreviated as SMART PBL, which integrating Generative and Problem Based Learning (PBL) strategy with Augmented Reality (AR) technology that has successfully developed in the previous study. The difference SMART-PBL from PBL has implemented chemical augmented reality technology as learning media and assignments as a method to explore prior knowledge and build new expertise while solving problems. Modifications added by providing reinforcement of motivation, giving positive perception, constructing knowledge, refining experience, and using knowledge to resolve issues adapted from generative learning theory (Wittrock, 1992).

Several studies have published research about PBL successfully enhanced metacognitive (Pratama, 2018), improved problem-solving skills (Kadir *et al.*, 2016). Generative learning increased problem-solving ability (Wittrock, 1994), increased science comprehension, and self-regulation (Lee, Grabowski and Lim, 2009; Reid and Morrison, 2014).

However, there were no studies yet reported the SMART-PBL learning strategy's success in improving metacognitive thinking and problem-solving skills. Therefore, this study aimed to know the effect of the SMART-PBL learning strategy and academic-self-regulated learning on metacognitive and problem-solving skills in learning chemistry.

Hypothesis:

This study has six hypotheses:

H_1. There was a significant difference in the metacognitive skill of learners who taught by using the SMART-PBL strategy compared to the PBL strategy.

H_2. There was a significant difference in the metacognitive skill of learners with high ASLR skills and low ASLR skills.

H_3. There was a significant interaction between learning strategies and ASLR's skills to learners' metacognitive skills.

H_4. There was a significant difference in learner's problem-solving skills, which taught using SMART-PBL compared to the PBL strategy.

H_5. There was a significant difference in learner's problem-solving skills with high ASLR skills and low ASLR skills.

H_6. There was a significant interaction between learning strategies and ASLR's skills to learners' problem-solving skills.

2. MATERIALS AND METHODS:

2.1. Research Design and Samples

This study used a Quasi-experimental design. Following the variables studied, the factorial design used was 2x2 by multivariate analyzes, with Nonequivalent Control Group Design used to play the effect and interaction effect on the dependent variable (Table 1).

The trial class treated using the SMART-PBL strategy with generative assignments, while the control class treated with a PBL strategy without any task. The research subjects involved 64 pre-service science teachers in Malang, Indonesia, on chemical elements and compounds. All participants have agreed to participate as subject research in each class. Trial and control class each comprised 32 students.

The procedure to implement SMART-PBL learning strategy consists of ten phases namely: (1) attentional focusing and motivational process; (2) problem orientation; (3) student orientation; (4) fact identifications; (5) generate hypothesis; (6) identification knowledge deficiencies; (7); knowledge creation process; (8) generation process; (9) apply new knowledge; (10) abstraction (Figure 1).

2.2. Data Collection Tools and Analysis

The statistical test in this study carried out using statistical data processing software in the form of IBM SPSS Statistics 21 using MANOVA parametric analysis. Quantitative data obtained using MAI (*Metacognitive Awareness Inventory*) by Schraw & Denison with a range scale of 1-5. The metacognitive knowledge data obtained using the rubric by Rompayom on a range scale of 0-2. Data on problem-solving skills were collected using the problem-solving rubric by Greenstein on a range scale of 1-4.

3. RESULTS AND DISCUSSIONS:

The Shapiro-Wilk's normality test results showed the acquisition of a significant value of metacognitive skills of 0.06 in the experimental class and 0.12 in the control class. The acquisition of the problem-solving skills in the trial class was 0.587, while in the control class was 0.146. The overall value was more significant than the standard criteria (sig)> 0.05, so it can conclude that the data distributed. Levene's test showed the acquisition of metacognitive skills of 0.111 and problem-solving skills of 0.596. While the Box's M test was 6.784 with a significance value of 0.709, obtaining all the significance values were more significant than the standard criteria (sig)> 0.05, so the data can be said to be homogeneous and come from the same variant, so it is worth to compare.

The hypothesis test performed using; 1) Multivariate analysis to examine the effect of strategy on metacognitive and problem-solving skills simultaneously. This test aimed to assess the significance of the difference in scores between the SMART-PBL group on the metacognitive and problem-solving skills variable due to the primary influence and interaction between the independent variables. Results showed that each learning strategy's main effect obtains a probability value smaller than the standard criteria (sig) 0.000 <0.005. The result of ASLR was 0.705> 0.005, so it concluded that ASLR does not affect metacognitive and problem-solving simultaneously.

After knowing the presence or absence of the influence from each independent variable on the dependent variable, then performed 2) Hypothesis test using a *Test of Between-Subjects Effects* to determine the effect between subjects by testing the comparison between the average scores estimated average and interactive influence analysis in Table 2.

3.1. Hypothesis Testing 1

Data results from table 2 showed a significant difference in metacognitive skills among learners taught using SMART-PBL. PBL strategies due to both of the acquisition of significant value were smaller than the standard criteria (0.000<0.005). The addition of metacognitive awareness scores of students treated using the SMART-PBL strategy increased from 2.58 to 4.18. Whereas in the PBL class, the average value increased from 2.39 to 3.84 (Figure 2). The data analysis results showed that the gain score in the SMART-PBL was 66.04%, with quite a practical interpretation (56-76%). While the PBL class obtained a gain score of 55.37% in the correct interpretation category (40-55%). It concluded that the SMART-PBL strategy was more effective in increasing students' metacognitive awareness than the PBL strategy.

There was a significant difference between before and after implementing the SMART-PBL strategy on the acquisition of an average score of metacognitive knowledge. The increase in the average value of the metacognitive abilities of the trial class from 0.97 to 1.191 while increasing the control class from 0.60 to 1.50 (Figure 3). There was a significant value difference in the aspect of metacognitive knowledge between the SMART-PBL with higher grades than the PBL class. It means the SMART-PBL strategy could increase learners' metacognitive skills more effectively than the PBL strategy.

Several phases on the SMART-PBL strategy contributed to enhancing metacognitive skills for students, that's; **Phase 1,** (Attentional Focusing & Motivational Processes). Before learning begins, students gave generative assignments to draw a mapping concept or to summarize related to the next meeting material. Tasks were optional according to students' learning preferences to help students collect initial information on these materials (*declarative knowledge*).

This phase was successfully improving student metacognitive skills. The study (Astriani *et al.*, 2020) reported concept mapping applied in the syntax of learning models could improve the metacognitive skills of science students. **Phase 2** (Problem Orientation). Students presented several cases caused by chemical elements in the alkali metal group and others.

At this stage, students practiced thinking about solving problems by identifying what kinds of chemical elements are involved in every case. Students also started practicing metacognitive thinking way by asked themselves how to resolve the issues (*procedural knowledge*). Problems to be solved were products from developing textual concepts became contextual concepts. It could provide a better chemistry learning experience and a positive effect on content comprehension (Silva, Daniele dos Santos; Yamaguchi, 2018).

Some assistance (scaffolding) included in every case. The latest research supports that increasing chemistry learning motivation could use experiments based on concrete evidence (Lima, Alexsandra Rodrigues; Silva, Flávia Cristiane Vieira da; Simoes Neto and Euzebio, 2019). Scaffolding also improves metacognitive skills and interest in learning chemistry for learners with a profound understanding of science (Tosun and Senocak, 2013). Cases presented in Table 3.

3.2. Hypothesis Testing 2

Data analysis results showed no significant difference in metacognitive skill among learners who had a high level of ASLR and low level of ASLR skills; this was due to the acquisition of considerable value higher than the standard criteria (0.690>0.005). Results of previous studies showed that there was an effect of one's Self Regulated Learning ability on metacognitive skills. However, in this study, ASRL skills did not significantly influence metacognitive skills. Data in Figure 4 showed learners with a low level of ASRL reached metacognitive value almost equals with high-level ASRL student groups in PBL class. Interestingly, a similar result found by (Nietfeld, 2015) the group with the low academic ability could obtain a higher value of the metacognitive ability (conditional knowledge aspect) than the group with high ones. The high level of ASLR learners described as disciplined and always active individuals. They have a good strategy in remembering subject matter; a brief target goal should achieve, a structured plan in attaining these goals, and proper evaluation in measuring the progress of learning. They also have a high effort in seeking help for the needs of the learning process either through literature, friends, teachers, and even parents actively, make arrangements or a suitable provision of the learning environment to obtain comfort and focus during learning. They have high priority in completing school assignments and finishing as soon as possible. While the characteristics of groups of students with low ASRL levels are less active in doing these things, it concluded that a high level of ASRL students tended to have higher physical activity in regulating their learning process than the lower level of ASLR students.

The research results from the *Journal of Health Psychology* (Mcelroy, Dickinson and Dickinson, 2015) psychologically explained these findings; they reported that individuals who tend to reduce physical activity appeared to have higher thinking activity. Instead, they were more likely to use this time to think efficiently. They practiced becoming strategic thinkers who can find smart shortcuts to solve problems, save time, and generate innovative ideas. This condition happened to the groups of students with low ASRL capability. They lack physical activity in regulating the learning process, but reportedly high-value metacognitive skill.

Meanwhile, groups of students with high activity (high ASRL) said they were easily bored when they had to sit still and observe their abstract thoughts. Instead, they prefer to stimulate their minds by doing physical activities, such as doing assignments, organizing the study room to be comfortable, making a list of study plans, and other physical activities. The low level of ASRL only indicates the low physical activity in the self-regulation of learning and not as a measure of the low activity (ability) of thinking. It concluded that the low-level ASRL student group had higher thinking skills and was equivalent to the high-level ASRL group. As a result, there was no significant difference between the level of ASRL and metacognitive skills.

3.3 Hypothesis Testing 3

The results showed no interaction between SMART-PBL strategy and ASLR skills towards metacognitive skills; this is due to the acquisition of significant value was higher than the standard criteria (0,463>0,005). These results indicated that the SMART-PBL strategy not influenced by the ASRL skills of students in improving metacognitive skills. The findings of this study reported that in certain circumstances, SRL also found no effect on the school's academic abilities and learning outcomes (Johny and Magno, 2012). SMART-PBL not affected by ASRL to enhance metacognitive skills; this strategy emphasized training how to know what concepts to learn, how to rearranged thinking ways to solve a problem, and why to choose and use this knowledge and procedures through a series of learning steps that have developed.

3.4 Hypothesis Testing 4

The analysis showed a significant difference between student ability to solve problems treated using SMART-PBL and PBL strategy due to the significant value was smaller than the standard criteria (0,000 <0,005). The acquisition of problem-solving skills in the trial class 85.10, with a standard deviation of 1.38 (Figure 5). From the results of the analysis, the ability of the experimental class taught by using the SMART-PBL strategy obtained higher average value than the control class taught by using the PBL strategy.

Several phases in SMART-PBL designed to enhance problem-solving skills in learning, such as **Phase 3** (Students Orientation). A division of the groups has aimed to make students able to solve cases collaboratively. Many advantages if learning sets in teamwork (collaborative) will support sharing knowledge and developing communication skills. Next was **Phase 4** (Facts Identification). Students practiced to identify solutions by looking for facts can be in their prior knowledge or clues that contribute to solving cases. The information obtained at this stage was general and original (authentic) then continued in the next phase. **Phase 5** was (Generate Hypotheses). Students practiced finding the solution of the cases by predicting some of the elements involved in the given problems. In the group, students with the correct hypothesis continued to prove their hypotheses scientifically. Similar things applied to groups with false assumptions. They studied more deeply to find why their predictions cannot be accepted scientifically. At this stage, all students training their conditional knowledge to evaluate the solutions by using their critical thinking and scientific reasoning skills.

Phase 6 (Identification Knowledge Deficiencies), at this stage, students got a new learning experience. The limited knowledge in formulating hypotheses completed at this stage. Through the process of searching for information that still needed to build appropriate explanations for solving the problem correctly. Students used mobile Augmented Reality technology in the form of a scanner application to present the desired elements of information. The information displayed is 3D visuals represented the physical form of chemical elements (solid phase, gas phase, liquid phase), atomic number, a symbol of the elements, and the general properties of the elements accompanied by audio when the information is displayed. Data obtained through the interview method as much as 80% of the students like this media, 20% still prefer to use the periodic table element as data collection instruments. These results were similar to research findings, which reported that Augmented Reality could provide an authentic new learning experience (Suartama, Kadek Setyosari, and Ulfa, 2019).

Figures 6 - 9 showed the activities of students when involved with the mobile Augmented Reality. AR technology used in this study took the form of mobile Augmented Reality application using an application on a smartphone equipped with cards containing chemical element information. The mobile Augmented Reality chosen in this study supported by literature, which stated that the form of mobile learning media had a significant impact on learning success due to its ability to take over the role of computers in the speed of accessing information as a learning source (Ulfa, 2013).

Phase 7, (The Knowledge Creation Processes). This stage was crucial because students carried out the process of constructing knowledge. (Wittrock, 1992) stated that the knowledge construction process occurs when students manage to connect old information (fundamental knowledge, clues, and hypotheses) that they have with new information obtained. The success of the knowledge construction was if students can explain how to solve the problems and found the chemical elements involved in the case. They analyzed the suitability of new with old information in the form of instructions found. At this stage, students defend solutions by using their creative and critical thinking skills.

Phase 8 (The Generation Process). This phase also called the refinement or maturation of knowledge. Students directed to make a categorization or classification of elements been found based on group, nature, and usefulness. **Phase 9** was (Apply New Knowledge). This stage tested the new knowledge that students have about elements and compounds by giving further questions about daily life problems compared to the character of chemical elements found. This phase tested whether students can use their knowledge in solving problems.

Phase 10 (Abstractions). Students and lecturers conducted to join evaluations related to chemical elements, and compounds learned on that day. In this last stage, students practiced maintaining their solutions by making deductive or inductive conclusions related to the case resolved. This conclusion makes ensured students had solved the problem correctly, and students have understood the concept thoroughly and anticipated the occurrence of misconceptions.

3.5 Hypothesis Testing 5

The analysis showed no significant differences in the problem-solving skill of students who had a high and low level of ASLR due to the acquisition of considerable value that is greater than the standard criteria (0,476>0,005) (Figure 10). The addition of the ability to solve problems among high and low ASRL student groups had a small difference, so it concluded that there were differences, but otherwise not significant. Several findings reported similar things (Barış, 2018). Research of Nurhayati and Retnowati (2018) found that students with low SRL abilities could solve problems better than the high one. In other words, the high and low level of SRL was not significantly different in solving problems.

SMART-PBL strategy was not depending on how the high-low quality of self-regulation (ASRL) of students will enhance problem-solving skill, and this strategy had phases which designed to improve problem-solving ability. One of them was at the stage of the *Attentional Focusing & Motivational Process*. Pre-meeting assignments must complete before the class meeting; this task optionally gave in the form of making a general description related to the next subject matter could be to draw a concept map or make a summary. The optionally tasks done so that students were more motivated to work on tasks. Summarizing techniques make a significant contribution to students in understanding information, transferring it to long-term memory, and improving memory and knowledge by ensuring practical mental skills (Özdemir, 2018). Wammes, Meade, and Fernandes (2015) found that students who given the task to draw the word (mapping concept) can remember twice as high as those who wrote it. When it completed, unconsciously, students with high and low ASRL levels already have the same composition of prior knowledge as a knowledge saving in the process of constructing knowledge to help them solve problems during learning. Thus, this explained why students who have high and low ASRL abilities found to have a similar ability to solve problems in this study.

3.6 Hypothesis Testing 6

The results showed no interaction between SMART-PBL strategy and ASLR ability to problem-solving skills due to the acquisition of significant value was higher than the standard criteria (0.743>0.05). ASRL level less considered implementing the SMART-PBL strategy in the future because it was not proven to provide significantly different learning outcomes in solving problems. Following research (F Sulistyowati, B Budiyono, 2017), SRL was not effective in improving problem-solving skills. There was no interaction between SRL on students' mathematical communication and problem-solving abilities. SMART-PBL not influenced by the quality of self-regulation (ASRL) to improve problem-solving skills, but emphasized the process of motivating and focusing the attention of students before starting learning, introducing the content in the form of contextual cases, analyzing cases to collect clues, looking for facts through various learning sources, observing chemical elements in 3D, and learning to formulate hypotheses.

The main results from this study found that; (1) There was a significant difference in metacognitive skills in groups of students who taught using the SMART-PBL and PBL strategies during learning. (2) There was no significant difference in metacognitive skills in students with high ASRL levels and low ASRL levels. Student groups with low ASRL levels provide a higher value of metacognitive skills. (3) There was no significant interaction between learning strategies with ASRL's ability to metacognitive skills. (4) There was a significant difference in problem-solving skills in groups of students who taught using the SMART-PBL and PBL strategies during learning. (5) There was no significant difference in problem-solving skills in groups of students with high ASRL levels and low ASRL levels. (6) There was no significant interaction between learning strategies with ASRL's ability to problem-solving skill.

4. CONCLUSIONS:

SMART-PBL learning strategy has successfully improving metacognitive and problem-solving skills in learning chemistry. Besides developing those skills, SMART-PBL also evokes other higher-order thinking skills such as creative thinking and critical thinking skills. Furthermore, communication skills, scientific reasoning skills, teamwork also appeared in students during solving chemical problems. Problem-solving skills mainly needed critical and creative thinking ability, while scientific reasoning and communication skills required for metacognitive skills.

Metacognitive thinking skills are not affected by academic-self-regulated learning but influenced by the ability; to solve real-world chemical problems; to collect prior knowledge; to identify facts; to build and prove the hypothesis. Similarly, problem-solving skills are also not affected by ASRL skills but by various efforts such as doing collaborative-teamwork, collecting more facts and clues, making hypotheses, finding new information needed, and constructing knowledge, applying new knowledge into real-world life, and concluding a solution.

Chemical augmented Reality (AR) technology can evoke student motivation for learning chemistry; students engaged in meaningful learning with a new learning experience.

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Table 1. *Factorial Design 2x2*

Academic-Self Regulated Learning (ASRL) Skill	**Strategy of SMART-PBL (Experimental Class) X^1**	**Strategy of PBL (Control Class) X^2**
High Y^1	X^1Y^1	X^2Y^1
Low Y^2	X^1Y^2	X^2Y^2

Table 2. *Hypothesis Test Results*

Tests of Between-Subjects Effects							
Source	**Dependent Variable**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	Metacognitive Skill	6942.857[a]	3	2314.286	219.452	.000	.916
	Problem Solving Skill	1245.343[b]	3	415.114	259.029	.000	.928
Intercept	Metacognitive Skill	409308.833	1	409308.833	38812.704	.000	.998
	Problem Solving Skill	449846.295	1	449846.295	280701.563	.000	1.000
Strategy	Metacognitive Skill	6241.527	1	6241.527	591.853	**.000**	.908
	Problem Solving Skill	1103.039	1	1103.039	688.290	**.000**	.920
ASRL	Metacognitive Skill	1.699	1	1.699	.161	**.690**	.003
	Problem Solving Skill	.825	1	.825	.515	**.476**	.009
Strategy * ASRL	Metacognitive Skill	5.748	1	5.748	.545	**.463**	.009
	Problem Solving Skill	.174	1	.174	.108	**.743**	.002
Error	Metacognitive Skill	632.745	60	10.546			
	Problem Solving Skill	96.155	60	1.603			
Total	Metacognitive Skill	471762.324	64				
	Problem Solving Skill	512791.748	64				
Corrected Total	Metacognitive Skill	7575.602	63				
	Problem Solving Skill	1341.498	63				

***a**. R Squared = .916 (Adjusted R Squared = .912)*
***b**. R Squared = .928 (Adjusted R Squared = .925)*
***R-Square –** This is the proportion of variability in the dependent variable (useful) that can be explained by the model. It is the ratio of the model sum of squares to the total sum of squares.*
***Source** – This is the source of the variability in the specified dependent variable.*
***Dependent Variable** - This is the variable observed for the effect of treatment on MANOVA.*
***Type III SS** – This is a type of sum-of-squares calculation. SS gives the sum of squares that would be obtained for each variable if it were entered last into the model. That is, the effect of each variable is evaluated after all other factors have been accounted for.*
***df** – This is the number of degrees of freedom in the model.*
***Mean Square** – This is the sum of squares divided by the degrees of freedom.*
***F** – This is the approximate F statistic for the given effect and test statistic.*
Sig. – This is the p-value associated with the F statistic and the hypothesis and error degrees of freedom of a given effect and test statistic.*The null hypothesis that a given predictor has no effect on either of the outcomes is evaluated with regard to this p-value. For a given alpha level, if the p-value is less than alpha, the null hypothesis is rejected and accepted H_1. If not, then we fail to reject the null hypothesis.*
Partial Eta Squared -*The ratio of variance associated with an effect, plus that effect and its associated error variances.*
Asterisk (*) shows signs of interaction between strategy and ASRL. In this study there was no interaction occur due to significant value was higher than 0.005 as standard value (sig.0.463>0.005); (sig.0.743>0.005). as it can be seen in result & discussions of Hypothesis Testing 3 and Hypothesis Testing 6.

Table 3. *Real-world Chemical Problems as Learning Materials*

No	Real-World Chemical Problems To be Solved	Chemical Elements Involved That Must Be Found	Chemical Elements Concepts To Learn More
1	Investigate the chemical elements in the form of compounds in cooking ingredients that can cause high blood pressure if consumed in excessive amounts.	Na in the form of Sodium Chloride (NaCl)	Sodium (Na): atomic structure, physical properties, and chemical properties
2	Investigate the chemical constituents contained in bananas that can save the brain by preventing blood clots if consumed regularly.	Potassium (K)	Potassium (K): atomic structure, physical properties, and chemical properties
3	Investigate the chemical element known as white fire, which will cause a big explosion if given water—formerly used as a war bomb during World War II.	Magnesium (Mg)	Magnesium (Mg): atomic structure, physical properties, and chemical properties
4	Investigate the chemical elements in the form of carbonate compounds contained in oyster shells and can produce beach sand into pearls.	Calcium in the form of Calcium carbonate ($CaCO_3$)	Calcium (Ca): atomic structure, physical properties, and chemical properties
5	Investigate the chemical elements that can nourish human teeth—usually contained in toothpaste at the right levels.	Fluoride (F-)	Fluorine (F_2): atomic structure, physical properties, and chemical properties
6	Investigate the chemical elements in the gaseous form. World War I used as a yellowish-green colored poisonous gas that could attack the enemy's respiratory system.	Chlorine (Cl_2)	Chlorine (Cl_2): atomic structure, physical properties, and chemical properties
7	Investigate the chemical elements in seaweed and other seafood, which, if routinely consumed with the right amount, can prevent hyperthyroid disease.	Iodine (I_2)	Iodine (I_2): atomic structure, physical properties, and chemical properties

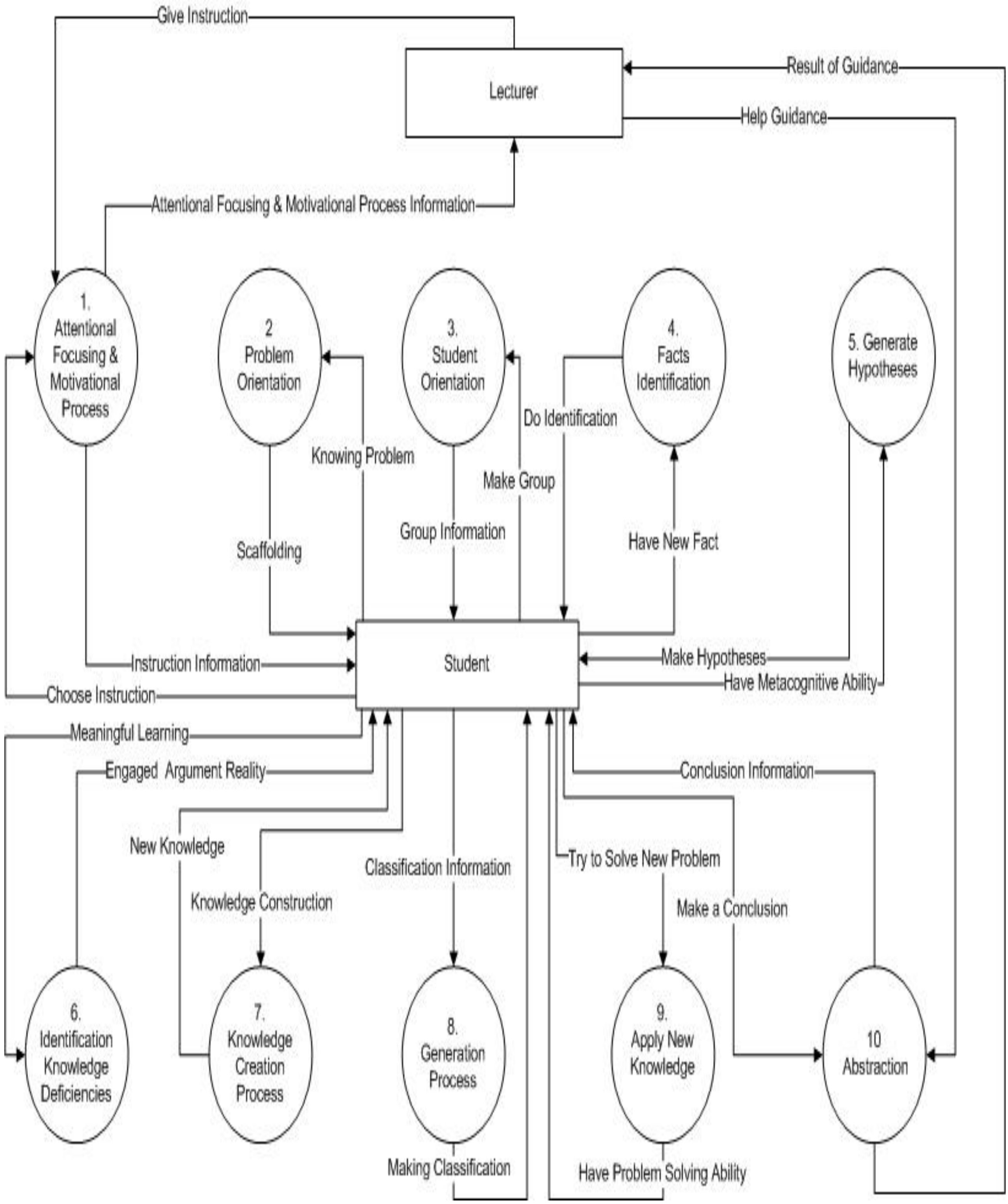

Figure 1. *A procedural framework of lecturer and student activities in the SMART-PBL strategy during the learning process. Source: the author*

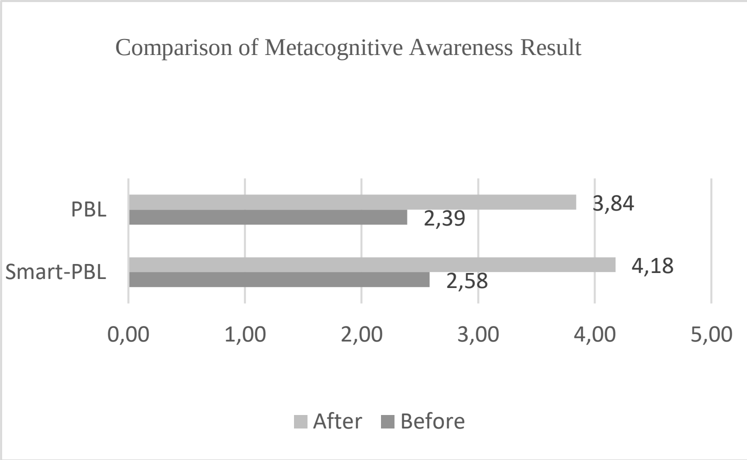

Figure 2. *Comparison of Before-After Metacognitive Awareness Score during 11 Weeks Implementation of Learning Strategies.*

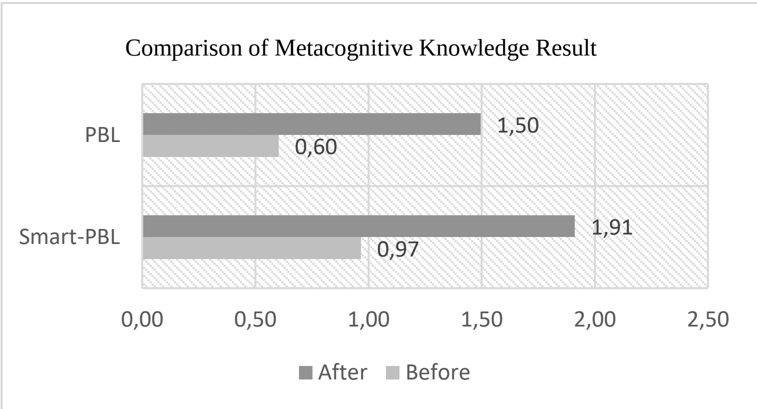

Figure 3. *Comparison of Before-After Metacognitive Knowledge Score during 11 Weeks Implementation of Learning Strategies.*

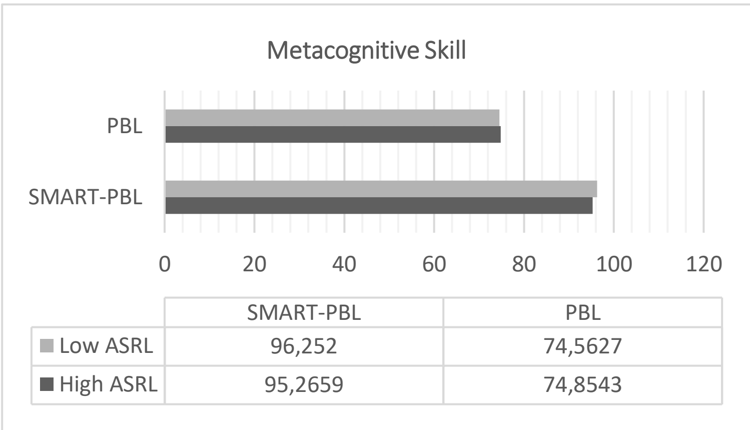

Figure 4. *Comparison of Metacognitive Learning Outcomes between high ASLR and low ASRL students*

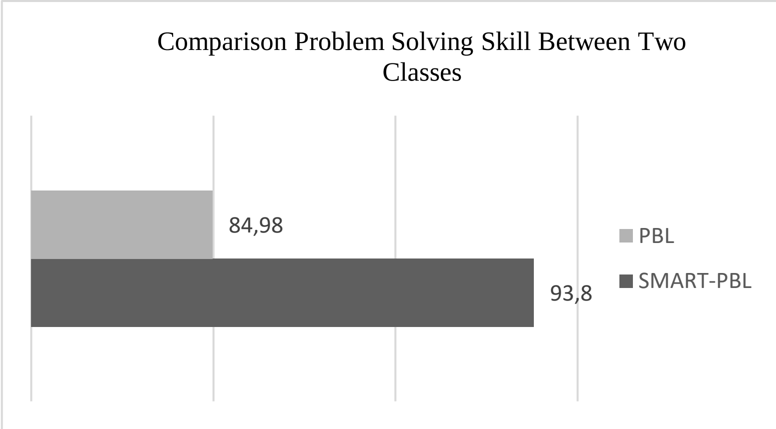

Figure 5. *Comparison Results Problem Solving Ability in class with SMART-PBL and PBL Strategy*

Figure 6. *The scanning process uses a mobile AR application. Source: the author*

Figure 7. *3D visual information displayed in the form of the physical properties of Chlorine. Source: the author*

Figure 8. *Collaborative sharing knowledge to investigate the elements involved. Source: the author*

Figure 9. *Evaluation in the form of a quiz. Source: the author*

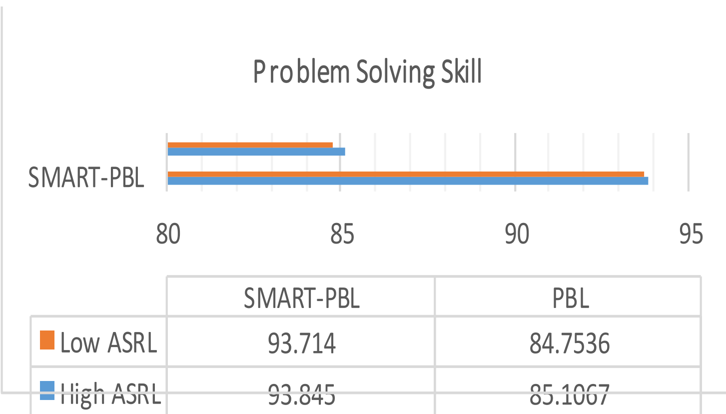

Figure 10. *Comparative Learning Outcomes of Problem-Solving Skills between high ASLR and low ASRL' students*