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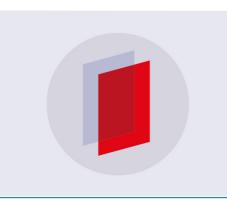To cite this article: S Haryani *et al* 2018 *J. Phys.: Conf. Ser.* **983** 012174

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Improvement of metacognitive skills and students' reasoning ability through problem-based learning

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Abstract. The aim of this research is to know the influence of PBL application to the improvement of metacognitive skill and students' reasoning ability on Constanta solubility product (Ksp). The research used mix method with concurrent triangulation strategy and pretest-posttest control group design. Metacognitive skills are known from the results of written tests and questionnaires with N-Gain analysis, t-test, whereas reasoning ability is known from observations and interviews with descriptive analysis. The results showed that the N-Gain effect of PBL on metacognitive skills is 0,59 with medium category and N-Gain value of PBL influence on reasoning ability is 0.71 with the high category. The steps in the PBL affect the metacognitive skills and can train learners to develop their reasoning skills in the solving problems.

1. Introduction
Understanding of a material does not merely look at science's understanding and knowledge alone but also involves the process of reasoning and the ability to apply in real life [1-2]. The ability of students to understand the concept of chemistry relates to the abstract characteristics of chemistry for various concepts [3]. Related to the characteristics of chemistry and understanding of a concept, then the design of learning processes that can motivate students to participate actively and provide to construct its knowledge needs to be done seriously. Based on government regulation, the competency standard of graduates is a qualification of graduate ability that includes the attitude, knowledge, and skills of students. These three domains can be achieved following the abilities and intelligence possessed by each. One aspect of the human intellect (human intelligence) is the reasoning aspect. Scientific reasoning is a mental activity / thinking skill involved in the process of discovery, judgment, conclusion, and argumentation Otherwise, metacognition is a mental activity in the cognitive structure that a person consciously organizes, control, and examine the process of thinking. Thus both the thinking skills will affect the success of students learn[4].

This metacognition development and scientific reasoning is important, because the process of cognition students can guide them in to developing the learning atmosphere becomes more meaningful, develop thinking skills, involved in the process of analyzing / problems solving, making generalizations, as well as well as in selecting strategies to improve cognitive performance in future[5-6] . Further Duschl and Gitomer revealed that the improvement of education involves the development of thinking, reasoning, and problem-solving skills to prepare students to participate in making and evaluating knowledge claims, explanation, model, and design a scientific experiment. Various opinions that support the statement that the *Problem Based Learning* (PBL) provides a learning environment that is appropriate to increase metacognitive learners and scientific reasoning [7-8].

Based on the previous description, it is necessary and important to research to find out whether there is an increase in metacognitive skills and reasoning ability through PBL in the solubility and solubility product (Ksp) concept. Ksp material is chosen because this material is one of the material that is considered difficult by teachers and prospective teachers regarding how to teach and the level of difficulty of the material [9].

2. Methods
This research used mix method experimental by concurrent triangulation. Pretest- posttest control group design and the difference between the initial test and final test is assumed to be the effect of the treatment. The research was conducted in XI science grade of the Year 2016/2017 one of the high school / MA schools in the city of Semarang. Samples were taken using purposive random sampling technique. The experimental group is subject to problem-based learning, while the control group uses lecture and discussion methods as usual.

Metacognition skills measured through tests and questionnaires in narrative form Metacognitive Activities Inventory (MCA-I), while the reasoning ability measured by test results, observations, and interviews. All instruments have been validated with validity test and reliability test. The validity of the instrument consisting of the form test, the teacher's observation sheet, the student's attitude questionnaire sheet, attitude and skill observation sheet, student response questionnaire, and instructional tools were established based on the assessment and consideration of the validator team. Test instrument reliability can be done by using KR-21 formula, while the observation sheet refers to Mardapi calculation. Metacognition skills data were analyzed using N-Gain, t-test, biserial correlation, a coefficient of determination, while reasoning ability was analyzed descriptively. Product moment analysis is also conducted to find the magnitude of the relationship between metacognition skills and reasoning ability. Descriptive analysis was also conducted to find the linkage between PBL use with metacognition skills and reasoning ability at once.

3. Results and discussion
The data of metacognitive skills of the control class and experiment class were seen from the average of the form description score and the result of the questionnaire which both contained metacognition indicator. Through the results of the written test, each component of metacognitive skills that consists of the ability of planning, monitoring ability, and the ability of the evaluation of learners can be known. Furthermore, for the data of students' reasoning ability based on the results of written tests, observation results, and interviews with learners. Written tests are used based on a description of metacognitive skills on item d (conclude your answers). Answers to point d above should contain claims accompanied by data, backing, and warrant as strengths in reasoning ability. Table 1 shows the mean N-Gain metacognitive skills and students' reasoning ability for the control class and the experimental class.

Table 1. N-Gain mean of metacognitive skills and students' reasoning ability for control class and experiment class

	N-Gain				
	Metacognition Skills		Ability reasoning		
Class	Written text	a questionnaire	Written Text	Observation Result	't' test
Control	0.21	0.004	0.25	0.005	Significantly different
Experiment	0.59	0.31	0.71	0.6	Significantly different

The result of the improvement of metacognition skill and reasoning ability in Table 1 shows that the improvement of metacognition in the experimental class has not shown optimal ability but still at moderate level ($0,3 < g < 0,7$), while for the control class included in low category ($g < 0.3$), both showing significant differences. This indicates that the implementation of problem-based learning for Ksp material can develop metacognition skills as well as students' reasoning ability. The result of metacognition skills test is supported by questionnaire result, while reasoning ability supported by

observation result. To find out whether the effect of learning treatment showed improvement in each component of metacognition is shown in Table 2.

Table 2. N-gain means of component and indicator of metacognition skill of control and experiment class

Component	Average N-gain class		Metacognition Indicators	Average N-gain class	
	Control	Experiment		Control	Experiment
Planning	0.21	0.48	Set goals	0.28	0.49
			Access information	0.26	0.48
			Allocate time	0.20	0.47
Monitoring	0.11	0.32	Self-test	0.19	0.41
			Understanding task performance	0.20	0.40
			Assess troubleshooting results	0.19	0.45
Evaluating	0.12	0.36	Reevaluate goals and make conclusions	0.20	0.46

Increased metacognition on each component was obtained by the highest planning aspect followed by evaluation and monitoring (Table 2). The mean N-g for the four indicators in the experimental group of 0.59 also showed a higher increase than the control group 0.21. The effect of early-stage treatment of PBL is to orient learners on the problem can be used to train the metacognitive skills of learners on the planning component with indicators to determine the purpose of the problem. Also, in the next stage of exploring the problem of asking students to collaborate in groups to solve the problems presented by looking for material from various sources to answer the problem and make preparations for an investigation to solve the problem. The first two steps in the PBL strongly support planning aspects of metacognition skills, and this is consistent with the results of [10]. At both of these stages, the metacognition skills indicator determines the purpose of the problem is also developed [11-12].

Implementation of the next PBL is to conduct group investigations. At this stage, learners are directed to determine a problem-solving plan that includes determining the tools and materials used for the practicum. Metacognitive skills that can be trained and developed at this stage are metacognitive skills of planning components with time management indicators and monitoring components with self-testing indicators. Also, the indicators of performance understanding of tasks, which can be seen from the ability of learners in analyzing, linking, and applying the knowledge they have in problem-solving can also be developed in the aspects of the monitoring component. Metacognitive skills that can be developed in this third stage following the results of research [13].

The stage after the group investigation is to present the results, evaluation, and self-reflection that lead the learners to adjust the results of problem-solving obtained with the problems presented. In groups, the learners are asked to present the results of problem-solving and other groups evaluate the results of the problem solving of group presentations, and do reflection after each group presented the results. Through group discussions alternately as a group of presenters, learners are trained to develop metacognitive skills of evaluation skill components with indicators assessing the results of problem-solving obtained and reevaluating the purpose of the problem and making conclusions [14-16]. The linking description between the learning steps in PBL and the development of metacognition skills is following research conducted by [17-19].

The steps in the PBL in addition to proven to improve metacognition skills can also develop their reasoning skills in solving problems [20-21] as shown in Table 1. Student-oriented stages of problem identification or problem identification stages give learners an opportunity to understand the problems presented [22]. According to [23], at the identification stage of this problem learners are given the opportunity to analyze what data or information can be used to support the claim when arguing in solving the problem. The next stage of PBL is exploring the problem, at this stage, learners are facilitated to build data analysis and investigation to arrange an argument [24].

Furthermore, after practicing to explore the problem to make an argument, the stage of investigation group can be used as a data and backing to strengthen the claim that will be used in arguing to solve the problem. The investigation can be a temporary argument in solving the problems based on the opinions of various members of the group [24]. The merging stage of the information obtained is a qualifier in the reasoning indicator that is a statement expressing a claim that is supported by the data. This stage helps learners to be able to build their claims, data, justification, support, and reasoning in their arguments [4].

Based on the information obtained from the interview it can be seen that the students sometimes have difficulty in solving the problem, especially related to the material that involves several concepts in solving it such as determining the pH of the salt is difficult to soluble, determining the solubility of a salt added similar ion, and estimate the solution that can be forming a precipitate. Here are examples of interviews related to this stage.

What concepts are used to solve the problem? Explain!
The necessary concepts include the Ksp concept of $CaCO_3$, Ionization of $CaCl_2$

The last stage in PBL is presenting results, evaluation, and reflection. Presentation activity is a claim or statement as the result of an argument in which there is a warrant. A warrant is reasoning that contains data or supporting information that can be used to relate data with claims so that the arguments presented by a group in solving problems can be accepted and criticized by other groups [24].

4. Conclusion

Application of problem-based learning on Ksp materials better improves metacognition skills and students' reasoning abilities than usual learning, and both show significant differences. There is a correlation between metacognitive skills and reasoning abilities in which learners who have high and medium metacognitive skills also have strong reasoning ability and are strong enough.

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