Problem Solving Skill and Cognitive Ability of Prospective Teacher in Analytical Chemistry Learning with Open-ended Experiment

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Abstract: The aims of this study were to increase problem solving skills and to enhance cognitive abilities of prospective chemistry teacher. The subjects of this study were prospective chemistry teacher in one of university in Central Sulawesi using quasi experimental method with one group pre-test and post-test design. Data were collected through problem solving skill test, cognitive ability test, and questionnaires. The results showed that implementation learning using open-ended experiment with group investigation could increase problem solving skill and cognitive ability significantly. The prospective teacher also responded positively to the learning with open-ended experiment in performing chemical quantitative analysis subjects.

1 INTRODUCTION

Fundamentals of Analytical Chemistry (FAC) learning included in the study of analytical chemistry. An analytical chemistry requires cognitive ability and problem solving skills to determine composition and structure of matter. Therefore, FAC learning should be done in the form of lectures in the classroom and experimental activities.

However, FAC learning had been conducted in one of university in Central Sulawesi with emphasis on cognitive aspects. This FAC does not develop higher order thinking skills, procedural, passive learning, and lab work done separately. Based on students interview result, they understand the theory, but when faced the exam they had problems to find the correct answer. It is considered as one cause of poor performance of chemistry teacher's in organizing learning at school, so many students do not like chemistry. According to Wenning (2011), teachers' lack of knowledge about how to teach science related with the experiences of teachers while studying in college. This imply that it is important to provide the laboratory skill to the prospective teacher.

According to the Novice Teacher Competency Standard, one of the basic competencies for prospective teachers of chemistry subjects are able to plan and to carry out laboratory work in chemistry learning. However, laboratory activity had been conducted for prospective teachers using cook-book laboratory so that students are less creative, tend to carry out existing procedures, less in developing scientific attitude, and unable to solve the problems that arise during the activities in the laboratory. Prospective teachers who lack of knowledge and skills on laboratory activities could interference the chemistry learning at schools. Chemistry teacher rarely involve students in laboratory activities. The results of field studies and discussions with high school teachers in a forum group discussion in one town in Central Sulawesi show that a school with complete laboratory facilities didn't used optimally. This is due to the lack of laboratory staff, difficulties in designing a laboratory procedures and the limitations of tools and chemicals. In addition, the students having difficulty in understanding the abstract concepts and analysing the problem properly.

Related with the learning problems in science, FAC learning should be done with experimental activities that provide an opportunity for students to design and carry out the experiment until completion. The effect of open-ended experiment has been investigated by Aydoğdu et al. (2013) and Kofli & Rahman (2012). The results showed the

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implementation of open-ended experiment can improve the science process and students' communication skills. The ability of mechanical engineering students to plan and conduct experiments, to analyze and interpret experimental results, and to work in a group is increasing through the implementation of open-ended experiments (Haron, 2013)

Priemer (2004), Cooper & Kerns (2006), Kelly & Finlayson (2008), and Blonder *et al.* (2008) have made changes in laboratory activities through open-ended problem. These results showed that students could be freely to do some experiments and make decisions, provide more space for the skill developments, understanding the concepts, experimental processes, and problem solving skills. However, Planinsic (2007) concluded in his study that open-ended laboratory requires endeavour and students self-reliance to solve problems in wave experiments.

Problem solving skill would be better if done in small group discussion. Wood (2006) and Mahalingam *et al.* (2008) stated that problem solving skill of students increased rapidly through the group discussion. Peer of interaction and instruction are an effective tool for learning and a good motivator.

Based on the problems and the results of studies that have suggested above, the FAC learning should be modified using open-ended experiment through group investigation and be integrated with the learning with lab work to develop problem solving skills and cognitive abilities of students. In this study, we are develop problem solving skills and cognitive abilities of students using open-ended experiment through group investigation and integrating with the learning with lab work.

2 METHODS

This quasi-experiment study was conducted to eighteen of chemistry students (prospective teachers) in one of the university in Central Sulawesi. Design in this research is One Group Pre-test and Posttest. Pre-test and post-test conducted using the problem solving skills and cognitive abilities test with reliability coefficient of 0.81 and 0.84 respectively. Students' response to the implementation of open-ended experiment in a learning are measured by questionnaire. Pre-test and post-test data were calculated by N-Gain. Furthermore, data of the problem solving skills and cognitive abilities were analyzed with inferential statistic t-test, if data were normally distributed and homogeneous. Data from questionnaire were calculated sum of score and percentage.

3 RESULTS AND DISCUSSION

3.1 Problem Solving Skill

Problem solving skill is individual ability to solve the problem that faced and determine the unknown variable the quantity in the problem statement. The test results of students problem solving skills is shown in Table 1.

Table 1: Result of Problem Solving Skill.

	Problem solving skill		*N-gain <g>*
	Pre-test	*Post-test*	
Highest	55	79	0.53
Lowest	15	31	0.09
Mean	25.22	45.89	0.28
Standard deviation	9.69	10.60	
Test of normality (Sig.)	0.20	0.20	
Test of homogenity (Sig.)	0.79		
One sample t-test (Sig.)	0.00*		

* Significant at Sig. < 0.05

Data in Table 1 shows N-gain of problem solving skills are 0.28 (low category). The low of gain problem solving skills are due to the number of students who make mistakes in writing a chemical reaction. Writing of the correct reaction very required for quantitative analysis, because the quantity of substances present in the sample can be determined based on the mole ratio of the chemical reaction. According to some students, the obstacles encountered in completing the test are: (1) the given problem is quite complex and involves more than one chemical reaction, (2) difficult to write down the results of the reactions, so it can not write a chemical equation correctly and completely, (3) solving problems requires more time, (4) lack of training in solving problems, (5) less mastered the concept very well, and (5) lack of preparation for the test.

Test of significance (see Table 1) refers that data is normally distributed and homogenous. The results of the t-test (1-tailed) concluded problem solving

skill of posttest was better than pretest significantly because students were actively involved in the learning or lab work and built meaningful learning. Students are directly involved when solving the problem both in theory and practice, so that problem solving skills of students tend to increase. This means that learnings through open-ended experiments with group investigation caused of students to take place and motivated more to do exercises and more confident in solving the problem of quantitative analysis. Thus the development of problem solving requires exercise and not a congenital factor.

Problem solving strategies as well as indicators of problem solving skill in finishing problems of quantitative analysis are identification of the problem (I), representation of the problem (R), writing of chemical reactions (W), planning solution (P), implementation of a solution or calculation (IS), making conclusions (C), and evaluation (E). Result of the problem solving skill of students based indicator of problem solving skill is presented in Figure 1.

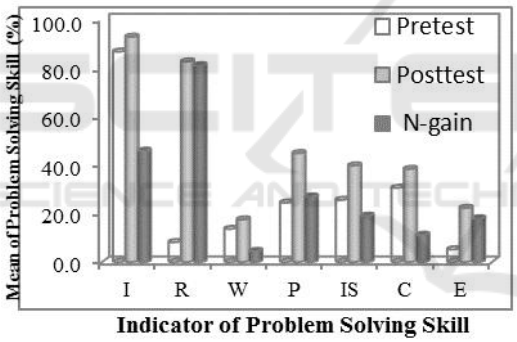

Figure 1: Percentage of Problem Solving Skills in Each Indicator.

The highest enhancement of problem solving skills is in the indicator of representation and the lowest enhancement is in writing of chemical reaction. The high of enhancements in representation can actually help the students in solving a given problem. But, in other sides the students have difficulty in writing of chemical reaction. It will affect the result of problem solving. Difficulty of students in writing chemical reaction caused most of the students have incorrect writing the compunds of the results of reaction. Evaluation phase is still rare done by students, whereas through evaluation student can reflect on what has been done in solving the problem. Students can immediately correct the problem, so that errors can be minimized.

Table 2 shows the increasement of open-ended experiment ability and problem solving skills of students. This is caused by the open-ended experiment activities, students planned and done themselves on their group investigation after defined existing problem, so that the ability of students should be more increased. A similar perception also explained by Zohler and Pushkin (2007), the most dominant segment of laboratory activities is to develop thinking skill such as critical thinking, creative thinking, decision making, and problem solving skills.

Table 2: Average of Open-ended Experiment ability and Problem Solving Skills.

Evaluation Stage	Open-ended Experiment Skill (%)	Problem Solving Skill (%)
First	64.1	49.3
Second	69.3	57.6
Third	81.6	67.4

3.2 Cognitive Abilities

Based on pre-test and post-test from students' cognitive ability on the quantitative analysis matter, acquired the average of matter's proficiency as described at Table 3. The enhancement of students' cognitive ability on pretest was better than posttest. To find more about the significant from enhancement of students' cognitive ability, the statistic test had been calculated and the result described at Table 3.

Table 3: Result of Cogitive Abilities.

	Cognitive Abilities (%)		N-gain <g>
	Pre-test	Post-test	
Highest	66.7	86.7	0.63
Lowest	23.3	46.7	0.30
Mean	33.5	60.6	0.43
Standard deviation	10.4	10.9	0.12
Test of normality (Sig.)	0.06	0.08	
Test of homogenity (Sig.)	0.24		
One sample t-test (Sig.)	0.00*		

* Significant at Sig. < 0.05

The result of normality and homogeneity test showed the value of $p > 0.05$ then H_0 was accepted. It means that those two of data distributed normally and homogeneously. The result of t-test showed the

value of $p < 0.05$, then H_0 was rejected. It could be concluded that the students' cognitive ability on pretest were significantly better than posttest. Through learning by open-ended experiment by group investigation, student could interact with another to develop and build chemistry concepts that have been learned and then provided many chances for students, to work out attractively in developing their knowledge. This result has analog with Blonder, Mamlok-Naaman, and Hofstein (2008) declared that open-ended activities on the laboratory could help students to understand deeper and meaningful. Students' participation in solving problems and open-ended experiment with group investigation made students' knowledge and cognitive abilities increased.

The mean of cognitive abilities is 60.6 have not get the passing grade is 75. It is caused students do not understand well the concepts related to quantitative analysis. Data in Figure 2 shows the performance of students experiencing any understanding of the content in the quantitative analysis that is: intoduction of quantitative analysis (IQA), gravimetric analysis (QA), acid-base titrations (AT), redox titration (RT), precipitation titrations (PT), and complexometric titrations (CT). The highest mastery concept achievement is in the concept of acid-base titrations (N-gain = 52,1%) and the lowest is in complexometry titration (N-gain = 33,3%). It is caused concepts due to the acid-base titration concepts presented is easy to learn.

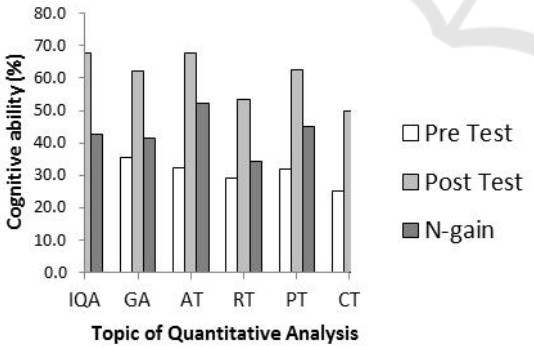

Figure 2: Cognitive ability of Students in Quantitative Analysis.

Problem solving skill requires understanding of the matter. Student success in problem solving is determined by four cognitive variables, namely Specific Knowledge, Concept Relatedness, Idea Association and Problem Translating Skill (Lee *et al.*, 2001) . According Overtoon and Potter (2008), there are a positive correlation between cognitive ability with problem solving skills. Students feel more comfortable and likely to be actively involved in learning. Thus the problem solving skill of students to be improved in the course of Fundamentals of Analytical Chemistry in particular on quantitative analysis of the material.

3.3 Students' Response of The Learning by Open-ended Experiment with Group Investigation

Students' response that received from opened questionnaire mentioned that (1) open-ended experiment was really good and pleased, on account of independence experiment, (2) open-ended experiment could help to understand and perform experiment, (3) students forced to finish the problem inside the experiment and excavating more about next steps, (4) student could plan their own procedures, and received new experiences to build and develop their knowledge.

Depended to students, group investigation was really distinct, they could interchange advises and viewpoints, solving problems together, expanding knowledge, and overcoming to seek things they didn't know yet mutually. This was relevant with the image that students constructed the comprehension and problem solving skills more easily if they shared to each other during the learning process (Slavin, 1995). Group works could intensify students' quality to respond and solve ponderously problems (Reid & Yang, 2002). The benefit of group works is increasing motivation, decreasing unfamiliarity, providing team works, recovering students' active participation, and enhancing students' comprehension and ability (Wright, 1996).

4 CONCLUSIONS

From our research, it can be concludedd that implementation of learning using open-ended experiment with group investigation could enhance students' problem solving skills and cognitive ability significantly. In addition, students responded positively to the learning.

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