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Influence of Problem Solving Based on Multiple Representations Model on Teaching and Learning of Chemistry on Student's Academic Self-efficacy and Student's Cognitive Achievement

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Abstract The aim of the research was to investigate the difference of the mean value of student's academic self-efficacy and student's cognitive achievement between the application of problem-solving based on multiple representations model and problem-solving model regarding topic related chemical equilibrium. The method of research was quasi-experimental. The design of research was posttest only design with equivalent control group. Fifty students of State Senior High School in Yogyakarta, Indonesia were recruited for participation (sample) in the study which were divided into two groups. The experimental group consisted of 26 students (11 male and 15 female) and a control group consisted of 24 students (15 male and 9 female). The experimental group applied the problem-solving based on multiple representations model, while the control group applied the problem-solving model. The data were analyzed by using MANOVA-test statistics. Hypothesis test showed that there were differences of the mean value of student's academic self-efficacy and student's cognitive achievement between the experimental group and the control group on topic related chemical equilibrium. This result presented that the mean value of student's academic self-efficacy and student's cognitive achievement taught by the problem solving based on multiple representations model was better than by the problem solving model.

Keywords: *problem-solving, multiple representations, self-efficacy, cognitive achievement*

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1. Introduction

Chemistry is one of the subjects of science that is considered difficult by students especially on abstract concepts. The chemistry subjects considered difficult by students include orbital and atomic hybridization [1], chemical bonds [2], and chemical equilibrium [3,4]. Basically in studying chemistry must be based on multiple representations that reveal phenomena at the macroscopic, submicroscopic and symbolic levels of Jhonstone [5]. This is in accordance with Akaygun's assertion that the chemistry learning process should involve an understanding of phenomena at the macroscopic, symbolic, and particulate levels [6]. Macroscopic representation represents a real observation of a chemical phenomenon that can be perceived by the senses such as changes in color, temperature, pH and the formation of sediments that can be observed when chemical reactions occur. The submicroscopic representation describes the processes that occur at the level of atomic or molecular particles to phenomena occurring in macroscopic representations, whereas symbolic representation involves the use of symbols, reaction equations, chemical formulas, drawings and diagrams. But the learning process in schools generally rarely reveal submicroscopic aspect so that many students who do not understand intact chemistry.

Implementation of the learning process in schools is also influenced by the use of learning models. Teachers should really think of a learning model that can help students to understand the concepts of the science being studied. One of the learning models that can be used is the problem-solving learning model. Anderson [7] says problem-solving is an important life skill involving a range of processes including analyzing, interpreting, reasoning, predicting, evaluating, and reflecting. Problem-solving can be a prerequisite for improving learning motivation and providing challenges for authentic learning possible. According to Robertson [8], problem-solving is something that involves a path to a goal. Meanwhile, Posamentier & Krulik [9] said problem-solving is a way of thinking. This is intended that students can't exploit learning to overcome problems with no regard to techniques in the process. Problem-solving can be a prerequisite for improving learning motivation and providing challenges for authentic learning possible. But in reality, many students are only able to master mathematical problem solving but do not understand the concepts of chemistry well [10]. Therefore, multiple problem-based problem-solving learning in chemistry can help students to be good problem solvers and can also master the concepts of chemistry well.

Another factor that also affects the success of students in learning is psychological factors of students. One of the psychological factors that influence is self-efficacy. Bandura states that self-efficacy is a person's ability to organize and implement the program of action necessary to manage various possible situations [11]. Self-efficacy is a strong predictor of achievement in science [12] According to Schunk [13], self-efficacy is a person's beliefs about the ability to complete a task and can influence one's choice of activities, effort, persistence, and achievement. Meanwhile, Zimmerman [14] stated self-efficacy is something that plays an important role in motivating someone to be diligent and achievers in the academic field. Self-efficacy becomes one of the factors that influence success in a learning because it can be a motivation for students to learn and solve problems given. The results of research conducted by Tenaw states that the self-efficacy and student achievement is positive and significant, so in self-efficacy science, learning becomes one of the important factors for students [15]. This is because self-efficacy affects not only performance, but also cognitive, motivation, and feelings.

Previous research results show a positive relationship between self-efficacy and learning. Students with high self-efficacy are more energetic and strive to do their work, especially when they face difficulties. Evidence suggests that self-efficacy has a positive effect on academic performance [13,16,17]. Research conducted by Baanu, and Oyelekan, Olorundare states that self-efficacy has no significant effect on student achievement because besides self-efficacy there are other factors that also support student's academic achievement such as representative laboratory, qualified teacher, conducive groups and applied learning models [18]. Therefore, in this study is considered necessary to know the self-efficacy of students after being given treatment in the form of application of problem-solving learning based on multiple representations.

Chemical equilibrium is one of the chemicals deemed difficult by students [3]. One of the factors causing students to have difficulty in studying chemical equilibrium material is the concept of abstract chemical equilibrium [19,20]. Chemical equilibrium materials include concept definition, graphics, and mathematical calculations. Students are required to master other concepts related to equilibrium, among others, the concept of mol, gas, concentration, and stoichiometry. In studying chemical equilibrium students must be able to master concepts at macroscopic, submicroscopic and symbolic levels in order to understand equality equations [5]. But in chemistry equilibrium learning schools are generally still studying the phenomenon at the macroscopic and symbolic levels while the submicroscopic level has not been studied well so that many students are unable to master the concept of chemistry as a whole. Therefore, the application of multiple representation-based learning methods to chemical equilibrium material is needed so that students can understand the chemistry intact.

1.1. Purpose of the Study

The purpose of this research was to identify the differences of the student's academic self-efficacy and the student's cognitive learning achievement between the application of the problem-solving learning based on multiple representations model and the problem-solving learning model regarding topics related chemical equilibrium.

1.2. Research Questions

This research was conducted to answer the question: (1). Are there difference of the mean value of student's academic self-efficacy and student's cognitive achievement between the application of problem-solving based on multiple representations model and problem-solving model?. (2). Which model the two teaching and learning models of chemistry provide a better the mean value of the student's academic self-efficacy and the student's cognitive achievement ?.

2. Materials and Methods

2.1. Research Design

The method of research was quasi-experimental. The design of research was posttest only design with equivalent control group. The research was conducted on State Senior High School of IPA (Natural Sciences) class XI consisting of two groups: experimental group and control group. The experimental group applied the problem-solving based on multiple representations model, while the control group applied the problem-solving model. Problem-solving based on multiple representations models and problem-solving learning models have four syntax that follow the learning model of Polya [21]. The syntax of the two learning models can be seen in Table 1.

Table 1. The syntax of problem-solving based on multiple representations(PS-MR) and problem solving (PS) models

Syntax	PS-MR	PS
Understanding the problem	Students read and understand the issue of chemical equilibrium which contains macrosco-pic, submicroscopic, symbolic & mathe-matical aspects	Students read and understand the issue of chemical equilibrium topic
Devising a plan	Students identify chemical equili-brium issues based on multiple repre-sentations and find ways to solve the problem from source books	Students identify chemical equilibrium issues and find ways to solve the problem from source books
Carrying out the plan	Students answer all chemical equili-brium issues con-tained in the work-sheet that contain macroscopic, sub-microscopic, sym-bolic & mathema-tical aspects.	Students answer all issues concerning chemical equilibrium contained in worksheet
Looking back	Students review the completed answers & match them with the source book.	Students review the completed answers & match them with the source book

2.2. Participants

The total sample used in this study was 50 students who came from two groups. The experimental group consisted of 26 students (11 male and 15 female) and a control group consisted of 24 students (15 male and 9 female). This research was undertaken at one of the senior high schools in Yogyakarta (Indonesia) from October to November 2017.

2.3. Instruments

2.3.1. Instruments for Measuring Student's Academic Self-efficacy

Instruments to measure student's academic self-efficacy are done by spreading questionnaires, interviews, and observations. The instrument was first validated by three expert lecturers and has been revised according to the advice of the three experts. The instrument of later validation results are applied to the student after the implementation of multiple problem-based problems solving and problem-solving learning model.

Instrument of student's academic self-efficacy is developed from the synthesis of various definitions a expressed by Schunk [13], Zimmerman [14] and Bandura [11]. Instrument grille to measure student's academic self-efficacy as in Table 2. Student self-efficacy questionnaires in the form of Likert scale which is qualitative data then converted into quantitative data through scoring with the following provisions:

- Score 1 is awarded for the Strongly Disagree (STS) category
- Score 2 is awarded for category Disagree (TS)
- Score 3 is awarded for the category of doubt
- Score 4 is awarded for category Agree (S)
- A score of 5 is awarded for the Strongly Agree (SS) category

The scores obtained are then converted into values by equations (1):

$$Value = \frac{Scores\ obtained}{Maximum\ Scores} x100\% \quad (1)$$

2.3.2. Instruments for Measuring Student's Cognitive Achievement

Instruments to measure student's cognitive achievement used posttest result data on chemical equilibrium in the form of multiple choice questions containing macroscopic, submicroscopic, symbolic and math aspects as well as containing Bloom's cognitive level from C1 to C4. Instruments to measure student's cognitive achievement were first validated by two experts, then revised according to expert advice. After the revision, the instrument consisting of 29 such questions was piloted to 50 students at the same school, but outside the study sample. The items were revised based on suggestions submitted by the experts. Chemical content, indicator of competency, type of representation and cognitive level of the instrument are shown in Table 3.

2.4. Data Collection Procedures

The student's cognitive achievement data is collected after the end of the learning process by giving posttest at the last meeting (fifth meeting). Meanwhile, self-efficacy data of the students in the form of observation was done during the learning activity, while the questionnaire and the interview were done after the learning activity took place.

2.5. Data Analysis

Data analysis technique used is multivariate analysis with MANOVA technique with significance level 0,05. This analysis is undertaken on the basis of the efficacy and cognitive achievement of the students after the application of problem-solving model based on multiple representation and problem-solving models. MANOVA test can be done if it has fulfilled the normality and homogeneity of the data. data normality can be tested using Shapiro-Wilk test and homegeneity using Box's M test.

Table 2. Grid to measure student's academic self-efficacy

Conceptual Definition		
Schunk [13]	Zimmerman [14]	Bandura [11]
A person's beliefs about the ability to complete a task and can affect a person's choice of activities, endeavors, persistence, and achievements.	Something that plays an important role in motivating someone to be diligent and achievers in the academic field	Confidence in one's ability to successfully organize and execute actions to achieve desired results and is one of the most powerful and reliable problem-solving predictors of success
Indicator: • Task completion • Choice of activities • Business • Persistence • Achievement	Indicator: • Motivation • Persistence • Academic achievement	Indicator: • Organize actions • Implement action • Solution to problem
Operational definition: Self-efficacy is a person's beliefs about his ability to manage actions by motivating himself to continue to work diligently in accomplishing a task and solving problems, to achieve satisfactory academic achievement.		
Indicator: - Self Motivation - Persistence - Task completion - Problem-solving - Academic achievement	Sub-Indicator: - Sure able to be motivated to learn - Sure can study diligently - Sure able to prepare task and Sure able to perform the task - Sure able to solve the problem - Sure capable of good achievement	

Table 3. Grid question to measure student's cognitive learning achievement

Chemistry content	Indicator of competency	Question No.	Type of representation	Cognitive Level (Bloom)
Reversible and irreversible reaction	Write down the equation for reversible and irreversible reaction	1	Symbolic	C1
		2	Symbolic and microscopic	C4
	Differentiating reversible and irreversible reaction	3	Microscopic	C1
		4	Macroscopic	C4
Dynamic equilibrium	Describes dynamic equilibrium	5	Macroscopic	C2
	Write down the reactions that occur in dynamic equilibrium and explain the mechanisms that occur at the submicroscopic level	6	Symbolic and microscopic	C3
		7	Symbolic	C2
Homogeneous and heterogeneous equilibrium	Distinguish homogeneous and heterogeneous equilibrium	8	Symbolic	C2
		9	Symbolic and mathematics	C3
Factors that affect the shift in equilibrium	Predict the direction of equilibrium shift by using Le Chatelier principle	10	Symbolic and macroscopic	C2
		11	Symbolic and macroscopic	C2
		12	Microscopic and mathematics	C3
		13	Symbolic	C2
		14	Microscopic, symbolic and mathematics	C4
	Analyze the effect of change of concentration, pressure, volume and temperature on equilibrium shift through experiment	15	Macroscopic and symbolic	C4
		16	Macroscopic and symbolic	C2
		17	Macroscopic	C3
		18	Macroscopic, symbolic and mathematics	C4
Equilibrium constant	Determine the equilibrium constant of a reaction and describe the mechanism occurring at its submicroscopic level	19	Symbolic and mathematics	C2
		20	Microscopic and symbolic	C3
		21	Symbolic and mathematics	C3
		22	Microscopic, symbolic and mathematics	C3
	Calculates the K*c* value based on the concentration of the substance in equilibrium and the K*p* value based on the partial pressure of reactant gas and the reaction product in equilibrium	23	Symbolic and mathematics	C3
		24	Microscopic and Symbolic	C4
		25	Microscopic and mathematics	C3
		26	Symbolic and mathematics	C3
	Determine the relationship between K*c*, K*p*, and degree of dissociation	27	Symbolic and mathematics	C3
		28	Symbolic and mathematics	C2
	Interpreting experimental data on reagent concentrations and reaction products in equilibrium to determine dissociation and equilibrium levels	29	Symbolic and mathematics	C3

3. Results

3.1. Result Questionnaire Student Self-efficacy

After being given treatment in the form of application of problem-solving learning model and problem-solving based on multiple representations, students are given a questionnaire to find out their efficacy. Question Self-efficacy consists of 30 items. Each item has a score range of 1 to 5, so the total self-efficacy score ranges from 1 to 150. The highest score obtained by the students in the experimental group is 135 while the lowest score is 84. While in the control group the highest score is 122 and the score the lowest obtained is 75. The self-efficacy measurement data of the experimental group and control group can be seen in Table 4.

Table 4. Description of Self Efficacy data in experiment group and Control group

Description	**Exp. Group**	**Control Group**
Highest Score Possible	150	150
The lowest possible score	30	30
The highest score achieved by students	149	122
The lowest score achieved by students	84	75

The scores obtained by the students are then converted into values using the equation (1). Based on the equation, the mean value of the student's academic self-efficacy of the experimental group is 77 and the mean self-efficacy value of the control group is 67. This shows that the students in the experimental group have higher self-efficacy than the students in the control group.

3.2. Statistical Assumption

3.2.1. Normality Test

Normality test in this study using Shapiro-Wilk test. The results of the test can be seen in Table 4. Based on the data above can be seen that the significance of self-efficacy and cognitive achievement of students from the experimental group and control group is greater than 0.05 so it can be concluded that the data is normally distributed.

Table 5. Shapiro-Wilk test results

Group	***Shapiro-Wilk***	
	Self-efficacy	Cognitive achievement
	Significance	*Significance*
Exsperiment	0.423	0.126
Control	0.072	0.060

3.2.2. Homogeneity Test

Homogeneity test in this research is done by using Box's M test. The result of the test can be seen in Table 6.

Table 6. Box's M test results

Box's M	5.137
F	1.635
df1	3
df2	5.305
Sig	0.179

Based on the above table shows that the value of Box's M test is 5.137 and F value of 1,635 with a significance level of 0.179 greater than 0.05 so that the null hypothesis that states the matrix of variance is the same accepted. Thus this data is homogeneous and meets the assumptions for parametric

3.2.3. MANOVA Test

Based on the assumption test results that have been met, it will be continued with MANOVA test. MANOVA test is used to know the existence of differences of self-efficacy and cognitive achievement of students between the application of problem-solving learning model with the application of problem-based problem-solving model based on multiple representations. The MANOVA test used in this study is Hotelling's Trace because this study involves two dependent variables and qualifies normal and homogeneous distributed data. MANOVA test results can be seen in Table 7.

Table 7. MANOVA test results

	Effect	Value	F	Hypothesis df	Error df	Sig
Group	Pillai's Trace	0.342	12.231	2.000	47.000	0.000
	Wilks' Lambda	0.658	12.231	2.000	47.000	0.000
	Hotelling's Trace	0.520	12.231	2.000	47.000	0.000
	Roy'sLargest Root	0.520	12.231	2.000	47.000	0.000

Based on MANOVA test results can be seen there are differences in self-efficacy and cognitive achievement of students between the application of problem-based problem-solving model based on multiple representations with problem-solving learning model because the value of significance obtained by 0.000 < α (0.05).

4. Discussion

Based on MANOVA test results, the Hotelling's Trace test obtained a significance value of 0.000 < 0.005 indicating that there are difference of the academic self-efficacy and cognitive achievement of students between classes taught with the problem-solving based on multiple representations model and the problem-solving model on topic related chemical equilibrium. The results of this study indicate that the application of problem-based problem-solving based on multiple representations model gives different effects to the application of problem-solving model. Multiple representation-based problem-solving learning models lead students to understand chemistry as a whole, both from the macroscopic, submicroscopic, symbolic and mathematical aspects, as revealed by Jhonstone [5]. The study of chemistry must involve macroscopic, submicroscopic and symbolic representations so that when students learn will connect the three representations. Meanwhile, the problem-solving learning model without multiple representations does not lead the students to understand the chemistry in their entirety, so that students have less confidence or have low academic self-efficacy towards the cognitive achievement. This is in line with Gist and Mitchell's [22] assertion that academic self-efficacy can lead to different behaviors among individuals of equal capacity because of academic self-efficacy influences choice, objectives, problem-solving, and persistence in business. The higher the person's academic self-efficacy, the more he believes in his ability to succeed in a task.

Both groups of research consisted of students who had the same ability. However, the application of different learning models leads to differences in academic self-efficacy and cognitive achievement between the two groups. Students taught with multiple problem-based problem-solving learning models understand the concept of chemistry in their entirety so that they have high confidence or have high levels of academic self-efficacy and impact on the achievement of better academic achievement. Students taught with problem-solving learning models without multiple representations tend not to understand chemistry as a whole. This is in line with research conducted by Wang & Barrow [23] which suggests that learning methods that do not integrate sub-microscopic and symbolic representations, result in students having difficulty drawing and explaining the Bohr atom model in detail and accuracy. The student's lack of understanding of the concept of chemistry causes the student's self-efficacy to be low and has an impact on the achievement of their academic achievement. This is what causes the differences in self-efficacy and student cognitive achievement between the application of problem-based problem-solving model based on multiple representations with problem-solving learning model.

The results of this study are also supported by the results of observations and interviews conducted during the study took place. The four aspects of self-efficacy assessed, namely learning motivation, perseverance, completion of tasks and problem solving, students in the experimental group on average have good learning motivation. The students follow the learning activities passionately and diligently in working on the problem-solving questions provided, although there are still some students who are not able to solve the problem correctly. Most students in the experimental group are happy to participate in learning activities with multiple problem-based problem-solving learning models because they feel better about chemistry so they can be sure they can get a satisfactory score. While students in the control group are less confident of their ability to work on the problem because they feel less understanding of the given problem, especially questions related to submicroscopic aspects.

5. Conclusion

Based on the results of this study it can be concluded that (1). There are difference of the mean value of student's academic self-efficacy and student's cognitive achievement between the application of problem-solving based on multiple representations model and problem-solving model. (2). The mean value of student's academic self-efficacy and student's cognitive achievement taught by the problem solving based on multiple representations model was better than by the problem solving model.

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