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Improving Students' Scientific Reasoning and Problem-Solving Skills by The 5E Learning Model

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Abstract

Biology learning in MA (Madrasah Aliyah) Khas Kempek was still dominated by teacher with low students' involvement. This study would analyze the effectiveness of the 5E (Engagement, Exploration, Explanation, Elaboration, Evaluation) learning model in improving scientific knowledge and problems solving. It also explained the relationship between students' scientific reasoning with their problem-solving abilities. This was a pre-experimental research with one group pre-test post-test. Sixty students of MA Khas Kempek from XI MIA 3 and XI MIA 4 involved in this study. The learning outcome of the students was collected by the test of reasoning and problem-solving. The results showed that the rises of students' scientific reasoning ability were 69.77% for XI MIA 3 and 66.27% for XI MIA 4, in the medium category. The problem-solving skills were 63.40% for XI MIA 3, 61.67% for XI MIA 4, and classified in the moderate category. The simple regression test found a linear correlation between students' scientific reasoning and problem-solving ability. This study affirms that reasoning ability is needed in problem-solving. It is found that application of 5E learning model was effective to improve scientific reasoning and problem-solving ability of students.

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INTRODUCTION

Biology Learning in SMA (Senior High School)/ MA (Islamic Senior High School) is expected to develop high-order thinking skills such as developing reasoning ability and problem-solving. The curriculum of 2013 emphasizes that every learning should improve students' creativity. According to DeHaan (2009), students' creativity can be achieved through a conducive learning by helping students engage in reasoning, practice high cognitive skills, and solve scientific problems.

Based on the preliminary study at MA Khas Kempek, Cirebon, the Biology lesson was less suited to the learning needs of the year of 2013 curriculum. Previous observation found that teaching and learning activities were still dominated by teachers as resulting low student's involvement. Direct teaching brings the tendency of teachers to give too much material without a deep understanding, with the expectation that students can understand by themselves. The results of interviews with some biology teachers showed that the teacher presented more questions to improve the cognitive knowledge, while scientific reasoning and problem-solving skills had never been trained to the students.

Scientific reasoning and problem-solving are skills that are expected to be taught in science classes to prepare students for global challenges. The reasoning is needed to understand complex theories and concepts, avoid scientific misunderstandings, and be necessary for complex decision-making and problem-solving (Bao *et al*, 2009). While the problem-solving ability is one of the essential life skills that must be taught and trained so that students are accustomed to facing problems both in an academic environment and in a complex daily life (Effendi, 2012). Problem-solving skills involve critical thinking skills, observing, interpreting data, formulating hypotheses and finding solutions for some problems (Chang & Taipei, 2002).

According to Lawson (1994), scientific reasoning involves empirical inductive reasoning and hypothetical-deductive reasoning, which is synonymous with concrete and formal reasoning in Piaget's intellectual development theory. Inductive empirical reasoning includes inclusion class, conservation, and serial ordering. While deductive hypotheses reasoning includes proportional reasoning, identify and control of variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning. In this study, the reasoning components to be examined include inductive empirical reasoning, correlational reasoning (decide the strong interrelationships between two variables, identifying and verifying relationships among variables), and probabilistic reasoning (deciding the probability of right or wrong of a conclusion) (Lawson, 2004). Schraw *et al.* (2006) mentioned that the strategies used in solving problems include identifying and recording the problem, representing the problem, selecting a solution, and evaluating the solution.

One of the models which provide meaningful Biology learning in SMA / MA and appropriate with Biology learning characteristics as well as support the meaning of the 2013 curriculum is the 5E model. It includes Engagement, Exploration, Explanation, Elaboration, and Evaluation. Application of the 5E model as the Minister of Education Regulation No. 22 of 2016, which explains that science learning should be implemented by applying discovery-based learning, i.e. learning that can foster the ability to ask questions, solve problems, develop reasoning ability, and strengthen thinking ability. Scientific learning should be directed to students to form understanding through knowledge building so that the learning process becomes meaningful to them (Fitriani *et al.*, 2013).

5E is one of the inquiry-based learning models developed by Bybee, the executive director of the Biological Science Curriculum Study (BSCS). It covers five phases of learning i.e. engagement, exploration, explanation, elaboration, and evaluation. 5E model is one of the solutions introduced in the context of biology learning that can help students build the concepts and conceptual systems as well as develop more effective reasoning patterns, as it allows students to test ideas, and to participate in the knowledge construction process (Lawson, 2001).

Shofiyah *et al.* (2013), stated that the 5E learning model could effectively improve students' scientific reasoning skills and provided a positive response to learning. Balci *et al*. (2006); Warapond *et al.* (2010); Acisli *et al.* (2011); and Qarareh (2012) explained that students in experimental groups using the 5E model performed significant improvements in conceptual understanding, science process skills, and critical thinking skills.

This study provides an overview of the application of the 5E model in improving scientific reasoning and problem-solving abilities of students. Correctly, this study answers the following questions: 1) How is the effectiveness of the 5E learning model in biology learning to improve scientific reasoning and problem-solving skills? 2)

How is the relationship between scientific reasoning abilities and problem-solving abilities after the learning process?

This research can increase the skills of teachers in applying the 5E model which is an alternative innovative learning model. While it also gives a positive influence for students, and can improve reasoning ability and problem-solving.

METHODS

This study was a pre-experimental research with one group pre-test post-test design. The population in this study was all students of class XI MIA (Mathematics and Natural Sciences) as many as 208 students consisting of 5 classes in semester 2 at MA KHAS Kempek (school name) in Cirebon Regency in 2016/2017. The research sample was defined by cluster random sampling. It involved 60 students of class XI MIA 3 and XI MIA 4.

Prior to the implementation of learning using the 5E model, a pre-test was performed to determine the level of students' reasoning ability and prior problem-solving. Then, during the learning process, the implementation degree of the 5E learning model was also observed. At the end of the study, a post-test was given to explore the level of students' reasoning ability and problem-solving.

This research would confirm the hypotheses as follow 1) biology Learning using 5E model was effective to improve scientific reasoning and problem-solving; 2) there was a positive correlation between reasoning ability with problem-solving ability. N-gain test, simple regression and correlation test were performed to support the explanation.

RESULTS AND DISCUSSION

Implementation of learning activity was observed by observation sheets. The measured aspect included all aspects listed in the lesson plan (RPP). The lesson plan itself was prepared based on the syntax of the 5E model. Implementation of learning with the 5E model obtained results as shown in Table 1.

Learning implementation scores on the application aspects of the 5E model in class XI MIA 3 were in high category. It is meant that students were actively involved in the learning process by doing activities as teacher's instruction. Teachers provided guiding questions for students so that they could directly interact. Student involvement in learning cannot be separated from the role of the 5E model that reflects inquiry learning to help students engage in a new concept as well as trigger students' curiosity and interest (Hanuscin & Lee, 2008).

Table 1. Implementation of 5E Learning Model in class of XI MIA 3

Aspects Observed	Average Score (%)	Description
Apperception and motivation	86.11	Good
Mastery of subject matter	91.67	Very good
Application of 5E model	95	Very good
Utilization of learning resources	44.44	Poor
Student involvement in learning	88.89	Good
Correct and correct use of language in learning	91.67	Very good
Closing of lesson	37.50	Very poor
Mean score	76.46	Adequat

The low aspect of the implementation was the use of learning resources, which was in less category. Learning resources owned by students were only a workbook from any publishers and another which was prepared by researchers. In the learning process, learning resources are very helpful for students to achieve learning objectives, facilitate the learning process. Therefore, schools should provide relevant learning resources needed by students to support the success of the learning process. In general, all activities in the lesson plan could be implemented in class XI MIA 3, which is in enough category with a score of 76.46% (Table 1).

Based on Table 2, the implementation of 5E learning model in class XI MIA 4 reached maximum score on aspects of apperception and motivation, and mastery of learning materials. While the minimum score was found on the use of learning resources. In general, the results of observation indicated that all activities in the lesson plan could be implemented in class XI MIA 4 with a score of 67.53% in enough category.

Table 2. Implementation of Learning Model 5E in class XI MIA 4

Aspects Observed	Average Score (%)	Description
Apperception and motivation	80.55	Good
Mastery of subject matter	80,55	Good
Application of 5E model	78.33	Good
Utilization of learning resources	44.44	Poor
Student involvement in learning	72.22	Good
Correct and correct use of language in learning	79.17	Good
Closing of lesson	37.50	Very poor
Average	67.53	Adequat

The implementation of the 5E model learning in both XI MIA 3 and XI MIA 4 classes are included in the adequately implemented category, but there are some contradictory aspects such as aspects of mastery of learning materials, application of 5E model, student engagement in learning, and correct and appropriate language usage in significantly different learning in both test classes. This happened because of lack of research in preparing observation sheets and observer limitations in observing the learning process.

Table 3. Pre-test and post-test result of reasoning ability

Score	XI MIA 3		XI MIA 4	
	pre-test	post-test	pre-test	post-test
< 21	6	0	9	0
21 - 40	22	0	21	0
41 - 60	2	0	0	0
61 - 80	0	18	0	23
81 - 100	0	12	0	7

Data analysis of the reasoning ability variable was done to find out the change after learning. Grades were drawn from students' pre-test and post-test who were studying the human reproductive system concept. The calculations of pre-test and post-test are presented in Table 3.

Table 3 concludes that learning using 5E model was effective to improve students' reasoning ability. The rise of reasoning ability was obtained from the gain-test as presented in Table 4. It shows the results of the calculation of the gain based on the average value of pre-test and post-test. The gain values obtained were 69.77% for XI MIA 3 and 66.27% for XI MIA 4. Based on the interpretation of the gain value according to Hake (2002), the improvement of reasoning ability is included in the medium category.

Table 4. Gain Test of Students' Scientific Reasoning Skill

Classes	Average pre-test	Average Post-test	Gain value (%)	Criterion
XI MIA 3	29.06	78.5	69.77	Medium
XI MIA 4	24.1	74.4	66.27	Medium

In Table 5, there is a rise of reasoning component based on post-test value difference with pre-test value. The highest rise is on the inductive empirical reasoning and the lowest is the probabilistic reasoning. It indicates that students' achievement in scientific reasoning has undergone a shifting pattern from empirical inductive reasoning to hypothetical-deductive reasoning. This can be seen in the percentage of inductive empirical reasoning values that is not significantly different from the value of correlational reasoning and probabilistic reasoning even with low-value categories.

Table 5. The rise of Reasoning Ability Components

Aspects measured (%)	XI MIA 3	XI MIA 4
Inductive empirical reasoning	68.67	63.34
Correlational reasoning	56.34	58.66
Probabilistic reasoning	22.67	29.34

Table 5 presents an increase of reasoning component based on the difference of post-test and pre-test score. The highest rise is on the inductive empirical reasoning and the lowest is the probabilistic reasoning. Based on the N-gain test, it can be indicated that students were not only able to understand simple concepts, sorting data, explaining simple analogy (inductive empirical reasoning), but also had been able to consider various hypothetical alternatives by correlating data in search of cause and being able to decide the

likely most true from a conclusion.

The reasoning ability is crucial to be taught to students to understand basic concepts and complex concepts on the complex material along with reasoning skills indispensable in making decisions and solving problems (Lawson, 2004). Based on research by Nurhayati *et al*. (2016), scientific reasoning has a vital role in learning science that links more than one concept. Changes in student reasoning patterns are influenced by the knowledge and experience of students in the learning environment. Gerber *et al*. (2001) suggested that a conducive learning environment and well-planned teaching procedures would give significant positive effects on improving students' scientific reasoning abilities.

Based on the results of Lawson's (2001) the application of 5E in learning could improve the ability of scientific reasoning, help students construct their knowledge, connect the concept that has been understood with the new idea so that learning becomes more meaningful. Shofiyah *et al.* (2013) stated that the 5E learning model could effectively improve students' scientific reasoning skills and provide a positive response to learning. A similar study conducted by Wilson *et al.* (2009) which explained that the 5E model could increase scientific knowledge, scientific reasoning, and scientific construction of students compared to ordinary learning.

Data analysis of problem-solving ability variable was done to know the change of variable after learning treatment. Grades were taken from the students' pre-test and post-test XI MIA 3 and XI MIA 4 who have studied the topic of the human reproductive system. The result of the pre-test for the problem-solving variable is presented in Table 6.

Table 6. Pre-test and post-test Results Problem Solving Abilities

Score	XI MIA 3		XI MIA 4	
	pre-test	post-test	pre-test	post-test
< 21	8	0	6	0
20 - 40	21	0	24	0
41 - 60	1	1	0	3
61 - 80	0	26	0	22
81 - 100	0	3	0	5

Table 6 concludes that there is an increase of students' problem-solving skills after the application of 5E learning models. The problem-solving skills score of students in XI MIA 3 and XI MIA 4 are 96.67% and 90% respectively. That results have met the expectations of this study. Improved troubleshooting capabilities can be calculated by the N-gain formula as presented in Table 7.

Table 7. Test of students' problem-solving skills

Classes	Average Pre-test	Average Post-test	N-gain (%)	Criteria
XI MIA 3	26.03	73.27	63.40	Medium
XI MIA 4	26.3	72.17	61.67	Medium

Table 7 shows the results of the N-gain calculation based on the mean score of pre-test and post-test of students. N-gain value of XI MIA 3 and XI MIA 4 were 63.40% and 61.67% respectively. Based on the interpretation of the value of N-gain, according to Hake (2002), the enhancement of problem-solving capability is calssified in the medium category. The aspects of problem-solving ability measured are presented in Table 8.

Table 8. The Rise of Problem Solving Components

Aspects to be measured	XI MIA 3	XI MIA 4
Identification of problems	52.60	52.59
Representation of the problem	46.67	49.19
Determine the solution	46.67	39.17
Evaluate the solution	43.34	41.57

Table 8 shows the rise of problem-solving components based on the difference score between pre-test and post-test. The highest rise found in problem identification aspect and the lowest was in evaluating the solution.

Increasing value in each stage of problem-solving is an indicator of success in learning. Students were guided in constructing their thoughts so they can find the concepts to solve the existing problems (Sulistyowati *et al*, 2012). Five-E learning model is a learning model that aims to train students in finding the concept independently to develop the ability to think and to solve problems.

High reasoning skills are needed in making decisions and solving problems (Lawson, 2004). Scientific reasoning patterns and problem-solving skills have an important role in science learning that connects more than one concept (Nurhayati *et al*., 2016). Even reasoning ability determines a

person's ability level to solve a problem. Fabby & Koenig (2015) explained that students with high scientific reasoning scores have a better conceptual understanding that is applied in solving complex problems. Whereas if the value of reasoning ability is low, it only depends on the ability to remember facts and simple procedures in solving problems. There was a linear correlation between reasoning ability with problem-solving ability. From the result of the significance test, probability value equal to 0.00 in class XI MIA 3 and 0.04 in class XI MIA 4, so it can be determined that H_0 is rejected. Therefore, it concludes that there is a linear relationship between scientific reasoning and problem-solving skills through the application of the 5E learning model.

From the discussion, the novelty of this research is evidenced by a linear correlation between reasoning ability and problem-solving abilities in students. This finding would be useful for high school teachers / MA in teaching students to always develop students' scientific reasoning abilities. One of the learning models that can be used to generate scientific reasoning and problem-solving skills is the 5E learning model.

CONCLUSION

Based on the results and discussion, it is found that the application of 5E learning model in biology learning on human reproductive system done in enough category. In general, the results showed that all activities in the learning plan could be implemented well with a score of 76.46% in class XI MIA 3 and 67.53% in class XI MIA 4. Improvement of students' scientific reasoning abilities after application of 5E learning model was included in the medium category. This is supported by the gain analysis which shows an increase in reasoning ability of an average of 69.77% in class XI MIA 3 and 65.70% in class XI MIA 4. Th rise of student problem-solving ability after application of 5E learning model is included in the medium category. This is supported by the gain analysis which shows an increase in problem-solving skills by an average of 63.40% in class XI MIA 3 and 61.67% in class XI MIA 4. There is a linear correlation between scientific reasoning ability and problem-solving skills after application of 5E learning model. This means improving reasoning ability is directly proportional to the rise of ability to solve problems.

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