JPII 5 (1) (2016) 69-74

Jurnal Pendidikan IPA Indonesia

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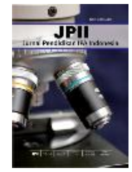

SCIENTIFIC REASONING ABILITY OF PROSPECTIVE STUDENT TEACHER IN THE EXCELLENCE PROGRAM OF MATHEMATICS AND SCIENCE TEACHER EDUCATION IN UNIVERSITY OF MATARAM

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DOI: 10.15294/jpii.v5i1.5792

Accepted: 18 January 2016. Approved: 27 March 2016. Published: April 2016

ABSTRACT

The purpose of this study is to investigate the scientific reasoning ability of the prospective student teacher, and to analyze the difference in scientific reasoning ability between students in the study programs. The sample set consisted of 179 students joining the Excellence Program of Mathematics and Science Teacher Education in the Faculty of Teacher Education (FTE) in the University of Mataram. The Classroom Test of Scientific Reasoning (CTSR) was translated into Indonesian language and used to measure the student scientific reasoning ability. The results of this study revealed that 95.5% students had low reasoning ability and were categorized as concrete and transitional reasoner. Only few students (4.5%) reached the category of formal operational reasoner. In addition, significant differences of the students reasoning ability emerged among the third and the fifth semester students, as well as students in the four study programs.

Keywords: concrete, CTSR, formal operational scientific reasoning, transition

INTRODUCTION

One of teaching goals in Sience, Technology, Engineering, and Mathematics (STEM) education is fostering student s' content knowledge and developing general scientific abilities (Bao et al. 2009), and one of the abilities is scientific reasoning. It is a part of cognitive skills required to evaluate scientific information and resolve complex problems (Bao, *et al*. 2009; Lee & She, 2010; Piraksa, et al. 2014). It involves the abilities which have long-term impact accompaniment on student's academic achievement.

The ability to reason scientifically is a reflection of a person's thinking skills about the processes of inquiry which include designing experiments, analyzing scientific evidences, inferencing, evaluating the results of investigation, and understanding the concepts and the complex theories of science (Zimmerman, 2005; Piraksa *et al.* 2011). It is manifested as a strategy of making conclusion based on scientific evidences (Lee & She, 2010), and closely related to cognitive processes in relation to the way of making decisions and the results of academic learning (Kuhn & Dean, 2004; Bao et al. 2009).

Scientific reasoning consists of some aspects that are interconnected as proportions of arguments about probability, relation between two or more variables, and social process to seek the truth based on the theory and scientific evidence (Lawson, 2000; Kuhn, 2004). Several research studies indicate that scientific reasoning ability is necessary for students as to be able to compete in the global era. Therefore, students' performance on scientific reasoning is important to be developed in science teaching and learning process (Chen & Klahr, 1999; Bao et al. 2009) from elementary through college level of education.

Scientific reasoning skills can be developed

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through training and transferred in the supporting academic environment (Bao et al., 2009; Piraksa et al., 2011). Training in scientific reasoning has a long term impact on student academic achievements. Therefore, the STEM education community considers that transferable general abilities are at least as important for students to learn as is the content knowledge (Bao et al. 2009). Undergraduate students and science teachers in secondary schools should have the valuable attributes of scientific reasoning (Tajuddin et al., 2012). However, the majority of undergraduates are lack of advanced reasoning patterns, which are necessary for significant achievement in college science courses (Deamfle, 2006). Science teachers and prospective student teachers in college should have the strategies to train and transfer scientific reasoning skills to students (Johnson & Lawson, 1998). Mathematics and science teachers should develop scientific reasoning ability of middle school students as a component of the 21st century skills (Annetta et al., 2010; Piraksa et al., 2014). To support the that process, prospective student teachers in college especially in the faculty of teacher education (FTE) in the University of Mataram must be facilitated to develop their reasoning ability. The purposes of the research are to: (1) identify the scientific reasoning ability of prospective student teacher who were in the Excellence Program of Mathematics and Science Teacher Education (EPMSTE) in the FTE, University of Mataram, and (2) to analyze the differences of scientific reasoning ability of third and fifth students semester as well as in the four Study Programs in the academic year 2012/2013.

METHOD

The research was conducted during September to November 2013/2014 in the Department of Mathematics and Science Education of FTE in University of Mataram. The subjects of the research consisted of 179 prospective student teachers in the third and fifth semester. The instrument used to collect the data of this study is the test of scientific reasoning which is translated from the Classroom Test of Scientific Reasoning (CTSR) developed by Anton E. Lawson (2000). The test consists of 24 items or 12 pairs of items with four alternative answers. Odd-numbered test items contain the statement about the cause of an event/natural phenomenon and the even-numbered test items are the alternative reasons' arguments which support the answer chosen. The CTSR has been used worldwide and proven to be able to measure student's concrete and formal operational thinking abilities in secondary level and higher education (Lawson, 2000; Bao, et al. 2009, Piraksa, et al. 2014). This test serves to measure student's ability to reason and to think proportionally, probabilistically, correlationally and hypothetico-deductively. The reliability of the test items is 0.78. Data were analyzed with the One-way Analysis of Variance (ANOVA) by SPSS computer program.

RESULT AND DISCUSSION

The average score of students' scientific reasoning ability ranged from 22.45 to 38.25. The lowest average scores (Mean 22.45) obtained by the students of the third semester of Biology Education Study Program and the highest average scores (Mean: 38.25) obtained by the fifth semester students of Mathematics Education. In detail, the average scores of student scientific reasoning ability are presented in Table 1 and the student distributions based on their level of reasoning ability are shown in Table 2.

Referring to the average score of students reasoning ability as shown in Table 2, it can be stated that most of the students of the EPMSTE University of Mataram is still in the category of concrete operational and transitional thinking (95.70%), and only 4.30% students reached the formal operational thinking. This condition indicates the weakness of the prospective student teachers reasoning ability. According to Lawson (2004), based on their reasoning ability, learners can be classified as concrete operational reasoner (score 0-30), transitional reasoner (score 30- 70), and reflective or formal operational reasoner (score 80 - 120).

Moore & Rubbo (2011) stated that the students classified as mostly concrete operational reasoner are characterized by their appropriate use of logic. However, they struggle with solving problems outside of a concrete context, demonstrating significant difficulty with abstract concepts and hypothetical tasks. Formal operational reasoner begins to think abstractly, reason logically, and draw conclusions from available information. Unlike the concrete operational reasoners, the formal operational reasoners are able to apply appropriate logic to hypothetical situations in most contexts. In this way, formal operational reasoner can begin to think like a scientist, and specifically develops srong hypothetico-deductive reasoning. Transitional reasoner falls between the other two classifications where they find success with hypothetical tasks in some contexts. Formal operational thinking skill develops gradually bet-

Table 1. Distribution of Mean Scores of Students Scientific Reasoning

	Study program/semester							
	Biology		Chemistry		Physics		Mathematics	
	3rd	5th	3rd	5th	3rd	5th	3rd	5th
N	22	22	25	21	19	22	27	20
Mean	22.45	26.54	27	23.54	30	28.95	32.44	38.25
Min	8.00	8,00	8.00	8.00	8.00	8.00	16.00	8.00
Max	4.,00	58..	58.00	50.00	50.00	58.00	66.00	66.00
StDev	11.42	14.67	14.54	14.83	10.13	15.17	13.05	13.72

Table 2. Student Distributions According to Their Levels of Reasoning Abilities

Study Programs	N	Percentage of Students in each Level of Reasoning Ability			Total Percentage
		COR	TR	FOR	
Biology	44	12.3	12,3	0.5	25.1
Chemistry	47	9.4	15	1.3	25.7
Physic	41	4.2	17	1,4	22.6
Mathematics	47	3.2	22,3	1,1	26.6
		29.10	66.60	4.30	100

Note: COR: concrete operational reasoner, TR: transitional reasoner, FOR: formal operational reasonerv

ween 11-18 years of age and results in a refinement or perfection of operations developed at the concrete stage (Valanides, 1997). The third and fifth semester of college students should have developed the skill, in fact this study shows the contradictive reality. This fact should become a valuable condition to evaluate and improve the model of teaching and learning process, especially in the Department of Mathematics and Science Education of FTE in University of Mataram.

The students' scientific reasoning scores differ significantly between semesters and the study programs ($p < 0.05$) as shown in Table 3. Data regarding the difference in the average scores as well as the level of significance of differences between study program and semester are presented in Table 4.

The data in Table 4 show the differences in the level of reasoning ability between groups and between semesters. The reasoning ability of the 3rd semester students in the Biology Education Program differs significantly from that of the students in the Physics Education Program and Mathematics as well as the 5th semester. The 5th semester studens of Biology only differs significantly from the students in the Mathematics Education Program, and the students of the 5th semester in the same study program also significantly differ from the students in the third semester Chemistry Education Program and in both semester of student in the Physics Education Program. The difference in scores of reasoning ability between other groups of students was not significant ($p > 0.05$).

The results of this study are consistent with the statement of Piraksa, et al., (2014) who found that university students in Thailand mostly think unscientifically. The scientific reasoning ability of the prospective student teachers in University of Mataram really needs attention to be developed through the improvement of the quality of teaching and learning processes. This is in line with the opinions of Piraksa, et al. (2014) which suggested that teaching plans should be designed to support the development of the students scientific reasoning ability. Some relevant models of learning include discovery, inquiry-based, problem-based, and computer-based learning models (Lawson, 2004; Bao et al. 2009; Tajuddin, et al. 2012; Piraksa, et al. 2014). Bao, et al. (2009) quoted the statements of Benford & Lawson, (2001) and Gerber, et al. (2001) that scientific reasoning abilities of students in any level of education can be developed through the implementation of inquiry-based learning. Johnson and Lawson (2004) found that the scientific reasoning and prior knowledge of students taught by inquiry model were higher than those of students taught by exposi-

Table 3. ANOVA Test Results for the Scientific Reasoning Ability Mean Scores of Student Teacher Candidates based on the Sudy Programs

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	3874.042	7	553.435	3.123	0.004
Within Groups	29768.180	168	177.192		
Total	33642.222	175			

Table 4. The Difference of Students' Scientific Reasoning Ability within Study Programs

I (SP-SMT)	J (SP-SMT)	Mean Difference	Std. Error	Sig.
Biology smt 3	Physics smt 3	-8.65072*	4.16894	.040
	Physics smt 5	-8.32806*	3.96965	.037
	Mathematics smt 3	-11.98990*	3.82319	.002
	Mathematics smt 5	-17.79545*	4.11263	.000
Biology smt 5	Mathematics smt 5	-11.70455*	4.11263	.005
Chemistry smt 3	Mathematics smt 5	-10.12500*	4.03021	.013
Chemistry smt 5	Mathematics smt 5	-11.40789*	4.26444	.008
Physics smt 3	Biology smt 3	8.65072*	4.16894	.040
	Mathematics smt 5	-9.14474*	4.26444	.033

tory approach. In this regard, Jufri (2007) found that inquiry-based learning model can improve students' critical thinking skills. Through these models of teaching and learning, students can involve in the process of scientific observation, actively provide explanations, and test their ideas based on scientific evidences accompanied by logical arguments and positive interaction with their colleagues (Lawson, 2004).

Bao, *et al.* (2009) proved that the middle school students in China who learned Physics with training (drill) methods can improve their ability in problem solving, but the same methods does not give significant effect on students scientific reasoning ability. Chin & Osborne (2010) found that there is a positive correlation between the number and the quality of questions, and the quality of written arguments raised by students whose mastery concepts of the subject matter. Therefore, facilitating the development of scientific reasoning ability in science teacher training program is quite urgent to give the opportunity for future teachers to build their own tools that permit them to promote reasoning skills for their students (Archila, 2014).

Even though the reasoning abilities of students tested with CTSR look simple for experts, in fact this is a fundamental component that is quite crucial to support the development of other capabilities that are more vital and more complex (Bao et., 2009). The ability to reason is very important to support other aspects of higher order thinking skills. Lawson (2004) states that the scientific arguments are hypothetico-deductive in structure and consist f some aspects that are interconnected including the proportion of arguments, control of variables, arguments about probability and arguments regarding correlation between variables.

An ultimate goal of higher education is to prepare our future workers with needed knowledge and skills. This includes cultivating students to become proficient reasoner who can utilize proper scientific reasoning to devise causal inferences from observations (Ding et al. 2014). Reasoning ability of students should be the main purpose of the college curriculum that focuses more on the development of learners mathematics and science literacy (Piraksa, et al. 2011). Supposedly, undergraduate or college level students should have been able to reason scientifically and to think reflectively with hipotetico-deductive pattern. However, the results of this study shows that most students in the Department of Mathematics and Science Education of the FTE in University of Mataram are still possessed low reasoning ability. This condition relates to the findings of Jufri & Hikmawati (2012) which show that many science teachers in Lombok have low reasoning ability and also low scientific literacy. These facts are of considerable concern and need to be addressed seriously. If the student teacher reasoning ability is low, then of course and it will closely linked to their pattern of teaching if one day become a teacher.

Based on the findings of this study, it is suggested that the pedagogy of learning science for prospective student teachers should be directed to the learning patterns of (1) how to construct reason based on hypotheses and scientific evidence, (2) how to design a good science experiments, and (3) how to determine the correlation between target variables in order to support the development of student scientific reasoning capabilities. In other words, the faculty has to offer continuous reform to promote education quality. Education reform should be interpreted as an effort to create programs that focus on improving teaching and learning practices, not solely focused on designing a class with a teacher-proof curriculum. Thus, teaching practices actually intend to avoid the problems faced by students in the learning process. Learning practices can be developed through the evaluation and development of teachers' mastery of the subject matter and the way teachers learning to pack and carry the lesson. To that end, it is necessary for teachers' professional development program to provide opportunities to learn how to learn some vital lessons (*learning how to learn*), and learn how to teach (*learning about teaching*). Thus, it is essential to get the attention of the faculty staffs especially lecturers in order to facilitate the development of student ability to reason and skills in science literacy (Schen, 2008). In order to develop the capability of prospective student teachers, the teaching and learning processes in the faculty should be directed to deliver students to have scientific reasoning skills to supports scientific literacy. Of course, lecturers within the FTE in the University of Mataram need to design and to implement teaching models that challenge students to think critically and creatively such as inquiry-based, project based, and problem based learning models.

CONCLUSION

Based on the results of research and discussion above, it can be concluded that: (1) the scientific reasoning ability of the prospective student's teacher in the FTE of University of Mataram is categorized as low. More than 90% students are classified as concrete and transitional reasoners. Only 4.3% students reached the formal operational phase of thinking; and (2) there is a significant difference in the aspects of the student's scientific reasoning ability within semester and within study programs.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the Excellence Program of Mathematics and Science Teacher Education, theFaculty of Education, Mataram University, Indonesia, for a financial support and opportunities in conducting the research and presenting this paper.

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