Available online at http://journal.um.ac.id/index.php/jps
ISSN: 2338-9117 (print)/2442-3904 (electronic)

Jurnal Pendidikan Sains
Volume 8, Number 2, June 2020, pp. 45–52

Comparing Cognitive Learning Outcomes as the Impact of ADI-S and ADI Learning Models with Different Scientific Reasoning Abilities

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Abstract: This aims of the study to compare the cognitive learning outcomes of students who learned with Argument Driven Inquiry-Scaffolding (ADI-S) and Driven Argument Inquiry (ADI) with different scientific reasoning abilities. This research is a quasy experimental design. The instruments were used cognitive learning outcomes test and the test of scientific reasoning abilities. Data were analyzed using two way ANCOVA (2x2 factorial). The results showed: (1) learned with ADI-S on the reaction rate material get cognitive learning outcomes higher than learned with ADI, (2) student with high scientific reasoning abilities have better cognitive learning outcomes rather student with low scientific reasoning abilities both in ADI-S's class and ADI's class.

Key Words: ADI; ADI-S; scientific reasoning abilities; cognitive learning outcomes

Abstrak: Penelitian ini bertujuan untuk mengetahui perbedaan hasil belajar kognitif siswa yang dibelajarkan menggunakan model *Argument Driven Inquiry-Scaffolding* (ADI-S) dan model *Argument-Driven Inquiry* (ADI) dengan kemampuan penalaran ilmiah berbeda. Rancangan penelitian yang digunakan adalah *quasy eksperimental design*. Instrumen yang digunakan yaitu tes hasil belajar kognitif dan tes kemampuan penalaran ilmiah. Data dianalisis menggunakan ANCOVA dua jalur (faktorial 2x2). Hasil analisis menunjukkan: (1) pembelajaran dengan model ADI-S pada materi laju reaksi memberikan hasil belajar kognitif yang lebih tinggi jika dibandingkan dengan model ADI, (2) siswa dengan kemampuan penalaran ilmiah tinggi memberikan hasil belajar kognitif lebih tinggi dibandingkan kemampuan penalaran ilmiah rendah baik pada kelas ADI-S maupun ADI.

Kata kunci: ADI; ADI-S; kemampuan penalaran ilmiah; hasil belajar kognitif

INTRODUCTION

It turns out that numerous students still experience difficulties in learning the reaction rate topic. Supasorn and Promarak (2015) explained that students still find it difficult to distinguish between object size and surface area. Students consider that large objects have a large surface area. This might be correct when comparing small objects and large objects, regardless of the mass of the substance. Kurt and Ayas (2012) in their research reported that students still consider that catalysts could increase the rate of reaction by increasing the number of collisions. In fact, students understand that temperature and catalyst could increase the rate of the reaction, but do not understand how the process was done. Kolomuç and Tekin (2011) found that there are still numerous students who cannot distinguish between activation energy and collision theory. Students assume that activation energy is formed from collisions between particles.

In terms of the characteristics of the material, these difficulties occur due to, 1) The rate of reaction involves a mathematical calculation. To solve this quantitative problem, proportional ability is required. All quantitative problems in chemistry, especially those concerning reactions, always require proportional ability (Effendy, 1985); 2) The rate of reaction involves three representations, specifically macroscopic, submicroscopic and symbolic. This requires students to have the ability to understand the shifting relationships between the three representations (Devetak et al., 2009). To be able to understand the relationship between the three repre-

Article received 20/11/2019; Approved 22/4/2020

sentations students must use correlational abilities. Students often have difficulty connecting the three levels of chemical representation therefore their ability to understand the correlation tends to be low (Talanquer, 2011); 3) The rate of reaction involves practicum in the laboratory hence students are exposed to several variables. Students who acquired good variable control skills would be able to change one variable as a manipulation variable to determine its effect on the response variable (Kurniawati, 2017); 4) The rate of reaction contains abstract concepts. Kean and Middlecamp (1985) state that the molecular or submicroscopic level are defined as abstract concepts. Abstract concepts could only be understood by students who have reached the level of abstract thinking (Coletta et al., 2007). The abilities needed to understand the reaction rate material with such characteristics are referred to as *scientific reasoning abilities*.

As explained above that the reaction rate topic understanding requires scientific reasoning skills, whereas it turns out that research conducted by Kartika (2017) found that as many as 88 percent of students remain at the concrete thinking stage. This thinking stage is categorized in the lowest criteria of scientific reasoning. It means the the development of scientific reasoning abilities for most students is underdeveloped. In addition, it is said that one of the factors that causes many students to have difficulty learning the material reaction rate is because students have not reached scientific reasoning abilities. Oloyede (2012) states that students with low levels of scientific reasoning ability experience difficulty in understanding chemical concepts. Because most students still have not reached scientific reasoning skills, a learning model is needed whose learning process can help students develop scientific reasoning skills, namely by applying the model *Argument-Driven Inquiry* (ADI).

The ADI learning model basically employs an inquiry approach. Yet, in the ADI model the process of communicating knowledge is carried out through arguing activities to writing scientific reports. ADI learning model is based on inquiry-based learning activities combined with an argumentation process between students (Walker et al., 2012). In learning with an inquiry approach, students are facilitated to experience thinking activities such as observing, predicting and classifying, classifying and communicating findings. Such a learning process can support students' scientific reasoning abilities. This is supported by Zimmerman (2007), scientific reasoning ability is the ability to inquire, conduct experiments, analyze facts and make conclusions. Therefore, it can be stated that through the application of learning with the ADI model, students are expected to be able to practice scientific reasoning skills. Bao et al., (2009) revealed that learning accompanied by the development of scientific reasoning abilities can affect the achievement of student understanding. With the increase in scientific reasoning abilities, it is expected that students' understanding of concepts can increase, therefore their cognitive learning outcomes also increase. This is supported by Kartika (2017) who states that there is a correlation between scientific reasoning abilities and student learning outcomes. Several previous studies have examined that it turns out that the application of the ADI model can improve concept understanding and develop cognitive processes (Heng et al., 2014; Katchevich et al., 2013). Kalay (2017) further found that the ADI model applied to the field of chemistry can improve cognitive learning outcomes and students' retention of conceptual understanding.

In addition to the advantages of the ADI model that improve cognitive learning outcomes, Amin and Aloysius (2016) reported that based on the survey results, it was found that 86.96 percent of lecturers experienced problems in implementing the ADI model, the obstacles found included: 1) students lack of understanding and motivation; 2) interactive sessions were only dominated by a few students with high academic abilities; 3) students were still familiar with the conventional lecture model; and 4) relatively insufficient science content mastery factor. For this reason, the teacher needs to provide the necessary skills to motivate and guide students to justify many sources of information or guide students to determine what knowledge should be considered, specifically by applying *scaffolding*. According to Thalib (2010), *scaffolding* means giving individuals a large amount of assistance during the early stages of learning and then reducing the assistance and giving students the opportunity to take over greater responsibility as soon as they are able to do it themselves. This assistance can be in the form of instructions, warnings, encouragement, deciphering the problem into learning steps, giving examples or others to enable students to learn independently. Bruner (in Seifert & Sutton, 2009) states that when *scaffolding is* provided, students seem more competent, smarter and can learn more.

Hannafin and Land (2000) classifies *scaffolding* into four types, specifically: *conceptual, metacognitive, procedural* and *strategic scaffolding. Conceptual scaffolding*, helps students build concepts about what they have learned. *Metacognitive scaffolding*, helps students remember by managing thinking processes individually. *Procedural scaffolding*, guiding students how to use resources or tools. *Strategic scaf-*

folding provides guidance in analyzing and focusing an approach to a task or problem to identify and select the information needed to solve a problem.

Previous research conducted by Rimadani (2015) states that applying *scaffolding* classified by Hannafin and Land (2000) improve students' conceptual understanding and reasoning abilities. Hasnunidah (2016) uses other type of *scaffolding* in ADI learning. The finding indicated that the ADI model with *scaffolding* improve conceptual understanding and critical thinking of students. However, so far, there has been no research that integrates *scaffolding* according to Hannafin and Land (2000) on the ADI model in Chemistry subject, especially the reaction rate topic. Therefore, researchers were interested to; 1) identify the differences in cognitive learning outcomes between students who are taught using the ADI-S model and the ADI model; 2) observe the differences in cognitive learning outcomes between students with different scientific reasoning abilities.

METHOD

This research employed quasi experimental research design with 2 x 2 factorial design on two groups with different learning model on reaction rate topic (Table 1). Each group was divided into two categories of students based on the average score of scientific reasoning ability test; high and low scientific reasoning ability. The research was conducted on SMAN 6 Malang and involved the eleventh grade of Natural Science classes. It took 34 students, from XI MIPA 1, as the experimental class which was taught by ADI-S learning model and 32 students from XI MIPA 3 as the control class which was taught by ADI learning model. The sample of the research was selected by using cluster random sampling.

The ADI model taught in the control class in this study included the stages: (1) *Identification of the task*, (2) *Generation of data*, (3) *Production of a tentative argument*, (4) *Interactive argumentation session*, (5) *Creation of a written investigation report*, (6) *Double-blind group peer review*, (7) *The revision process*. Meanwhile, the ADI-S model that was taught in the experimental class was the ADI model which was integrated with scaffolding. The scaffolding used refers to the classification scaffolding according to Hannafin and Land (2000). Scaffolding were given at the following stages: (1) Data collection and analysis would be given conceptual scaffolding and strategic scaffolding, (2) Development of tentative arguments would be given metacognitive scaffolding. (3) The argumentation session would be given metacognitive scaffolding.

The instruments used include, (1) Scientific Reasoning Ability Test given before treatment, adopted from the Classroom Test of Scientific Reasoning (CTSR): Multiple Choice Version revised 2000 edition developed by Lawson, in the form of multiple choice of 24 questions, (2) The Cognitive Learning Outcomes Test given after the treatment, developed by the researcher in the form of an open description of 20 items. All items have been declared valid, both in terms of content validity and item validity, the reliability test results show that the reliability coefficient is 0.799 with high criteria. KPI test which has been translated into Indonesian has a reliability coefficient of 0.76 (Kartika, 2017). The reliability coefficient of the Indonesian translation is the same as the reliability coefficient translated into Turkish and other languages, which is in the range 0.61-0.78 (Lee & She, 2010).

The research data obtained were the posttest scores of the Cognitive Learning Outcomes test results (as the dependent variable) and the Scientific Reasoning Ability scores (as moderator variables) which were statistically tested using the two-way ANCOVA analysis test with a significance value of 5 percent. The results of the normality test showed that the distribution of Cognitive Learning Outcomes and Scientific Reasoning Ability data for students in the ADI-S class and ADI class were normally distributed, as well as the results of the homogeneity test showing that the variants of Cognitive Learning Outcomes and Scientific Reasoning Ability data were said to be homogeneous, but for the

Table 1. The 2 x 2 Factorial Design of Research

Scientific Reasoning Ability	Learning Model	
	ADI-S (X_1)	ADI (X_2)
High (Y_1)	X_1Y_1	X_2Y_1
Low (Y_2)	X_1Y_2	X_2Y_2

Annotation:

X_1Y_1 = KAI uses the ADI-S learning model for students with high KPIs
X_1Y_2 = KAI uses the ADI-S learning model for students with low KPIs
X_2Y_1 = KAI uses the ADI learning model for students with high KPIs
X_2Y_2 = KAI uses the ADI learning model for students with low KPIs

two average Scientific Reasoning Ability similarity test it was said that there were differences between the two classes thus the Scientific Reasoning Ability score was used as a covariate in the two-way ANCOVA hypothesis test.

RESULTS

The results of Cognitive Learning Outcomes and Scientific Reasoning Ability tests are presented in Table 2. Based on the results, the average score of Cognitive Learning Outcomes of class taught by ADI-S is higher than the class taught by ADI. In addition, the average score of Cognitive Learning Outcomes of class taught by ADI-S with high and low Scientific Reasoning Ability is higher than the class taught by ADI.

To find out the difference in the distribution of scores, the students' Cognitive Learning Outcomes data were then analyzed based on the reaction rate sub material between the ADI-S class and the ADI class. From a total of 20 Cognitive Learning Outcomes test questions, broadly speaking, it includes the evaluation of learning achievement from four sub-materials on the subject of reaction rates, including questions number 1-4 evaluating the sub-material on the concept of reaction rates; question number 5-6 evaluates the sub material of the collision theory; questions 7-13 evaluate the sub-material factors that affect the reaction rate; 14-20 evaluates the sub-matter of order and reaction equations. The percentage distribution can be seen in summary in Table 3. There is a difference in the percentage of students who answered correctly between the ADI-S class and the ADI class, the difference in the percentage difference between the two classes is not too big. In the collision theory sub-material, the factors that affect the rate of reaction as well as the order and reaction equations, the percentage of ADI-S class students who answered correctly was higher than the ADI class, but for the sub-material on the concept of reaction rate, ADI class students showed a higher percentage than the class. ADI-S.

A summary of the two-way ANCOVA results from the influence of learning models (ADI-S and ADI) and scientific reasoning abilities on cognitive learning outcomes can be seen in Table 4. It can be concluded that: (1) the learning model has a significant effect on cognitive learning outcomes, this can be seen in column "MODEL"; (2) differences in scientific reasoning abilities also have a significant effect on cognitive learning outcomes.

Table 2. The Average Score Obtained

Class	The Average Score of Cognitive Learning Outcomes	The Average Score of Scientific Reasoning Ability	Scientific Reasoning Ability Classification	Total Number of Students	The Average Score of Cognitive Learning Outcomes
ADI-S	77,6	8,05	Tinggi	19	78,7
			Rendah	15	76,3
ADI	62,5	6,63	Tinggi	15	67,7
			Rendah	17	67,1

Table 3. Percentage of Students Who Answer Correctly Based on Reaction Rate Sub Topic

Sub Topic	Percentage (%)	
	ADI-S	ADI
Reaction rate concept	69,11	70,3
Collision theory	66,17	50
Factors affecting reaction rate	79,4	59,38
Order and equation of reactions	84	78,13

Table 4. Two-Way ANCOVA Results

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
MODEL	1460,654	1	1460,654	14,151	0,000
KPI	1124,773	1	1124,773	10,897	0,002

DISCUSSION

The Effect of Learning Model on Cognitive Learning Outcomes

In general, this study shows that the use of scaffolding which was integrated with the ADI model offers a better effect on cognitive learning outcomes on reaction rates when compared to the ADI model without scaffolding. In this research, conceptual scaffolding was given in the form of short questions about the concepts to be taught to stimulate students' basic concepts. The form of conceptual scaffolding in the form of instructions or questions was used as an supplementary approach to stimulate students' memory and attention to the concepts that underlie the problems given, thus students connect the concepts in their memory (Pucangan, 2017). Providing short questions that allows students to recall previous concepts to relate to new concepts is expected to enhance the cognitive load of students. Having a good understanding of the concept is still lacking in dealing with complex problems. Complex problems often involve a great deal of concepts, thus in addition to having a good understanding of concepts, students also need to understand the relationship between concepts. Therefore, conceptual scaffolding was given in order to help students understand the relationship between the concepts in the reaction rate material.

Strategic scaffolding guides students to analyze and focus an approach to a task or problem to identify and select the information needed to solve a problem (Prediger & Krägeloh, 2015). Strategic scaffolding is used to assist students analyze, plan and make decisions. In this research, strategic scaffolding was given at the stage of data collection and analysis. It aimed at assisting students when analyzing and interpreting data or findings during the concept formation process therefore it makes it easier for students to draw conclusions based on the data obtained.

Metacognitive scaffolding facilitates students to know what they know and how to use their knowledge during the learning process (Friday & Tasir, 2016). Rahayu (2018) states that metacognitive scaffolding increases metacognitive skills when students solve problems. Metacognition skills are included in the main skills that help students organize their understanding, thinking and learning. In this study, metacognitive scaffolding which is given at the stage of forming tentative arguments and the argumentation session is to help students think metacognitively in terms of evaluating arguments. Students are expected to be able to interpret the arguments that have been formed. This interpretation is done to show the extent to which students understand the concepts that have been learned. The provision of scaffolding in the form of assistance in constructing concepts, analyzing data and assistance in evaluating arguments in the learning process with the ADI model allowed students to understand the concept of reaction rate. If students easily understand the concept of reaction rate, their learning outcomes will also be enhanced (Nurdiansyah, 2018). The results of this study are supported by several researchers such as Rahayu (2018), Pucangan (2017) and Rimadani (2015) that the use of scaffolding in learning improve student learning outcomes.

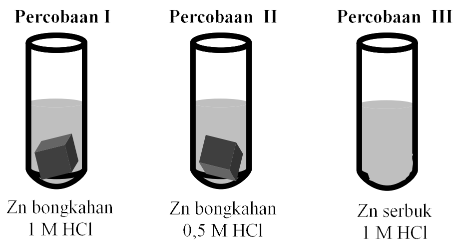
The use of scaffolding in learning is based on Vygotsky's theory of cognitive development. According to Suyono and Harianto (2014), the use of scaffolding in learning is a process or way of providing assistance by adults or more competent peers, therefore students move from the zone of actual development (ZAD) to the zone of proximal development (ZPD). According to Vygotsky (in Suyono & Harianto, 2014) there is a difference between what students can do without the help of others or often called ZAD and what students can do with the help of others or often called ZPD. Bruner (in Seifert & Sutton, 2009) believes that students can learn more as long as they are given the right guidance and resources, knowing as scaffolding. Furthermore Bruner believes that it is very important to provide guidance in the right way and at the right time. When scaffolding is provided, students appear to be more competent and are able to learn more.

The Effect of Different Scientific Reasoning Ability on Cognitive Learning Outcomes

To identify the effect of different scientific reasoning ability on cognitive learning outcomes, it is observable from students' ability in completing the exercises. One example of exercises that measures cognitive learning outcomes and requires scientific reasoning ability is presented as Figure 1.

The reasoning ability needed to solve these problems is correlational reasoning ability. Students need to use correlational reasoning in order to determine the relationship between the total surface area of zinc (Zn) and the concentration of HCl and the likelihood of an effective collision, so as to explain their effect on the reaction rate. Students who are not capable at using correlational reasoning will not be able to determine that with the same mass the smaller the size of the

Consider the following experiment, each tube contains the same mass of zinc (Zn) and 10 mL of hydrochloric acid (HCl).



The order of reaction rates from fastest to slowest is ....

a. I > II >III
b. II > I > III
c. III > I > II
d. III > II > I
e. II > III > I

Figure 1. Example of Exercises

substance, the greater the total surface area of the substance, the greater the probability of an effective collision so that the reaction rate is faster. Figure 2 shows that the percentage of students categorized as having high Scientific Reasoning Ability who answered correctly in answering the questions above was compared to the percentage of students categorized as having low Scientific Reasoning Ability. This shows that students in the High-Scientific Reasoning Ability group are more capable at using correlational reasoning than the Low-Scientific Reasoning Ability.

Based on this analysis, students with low Scientific Reasoning Ability have the potential to experience difficulties in understanding the reaction rate material, so that they get lower Cognitive Reasoning Ability than students with high Scientific Reasoning Ability. The results of Nnorom's (2013) study on biology learning revealed that students with high Scientific Reasoning Ability were able to achieve higher learning outcomes than students with low Scientific Reasoning Ability. Students with low Scientific Reasoning Ability are less skilled at using their reasoning to analyze scientific facts and information so they have the potential to experience difficulties in understanding or solving problems. This is in accordance with Oloyede's (2012) statement that students with low Scientific Reasoning Ability levels will have difficulty understanding chemical concepts. On the other hand, students with Scientific Reasoning Ability will find it easier to make correlations between concepts, have good probabilistic skills when faced with problems and make conclusions when they are faced with facts or data in the process of concept building during learning. Students with low Scientific Reasoning Ability groups generally have the potential to experience difficulties in understanding the material, but this is not the case for students who are taught with the ADI-S model. This is because during the implementation of learning with the ADI-S model students are given *scaffolding* which can help students in constructing concepts, analyzing data and assistance in evaluating arguments therefore students with low Scientific Reasoning Ability can be supported to develop their thinking skills. Learning that involves students and students themselves constructing concepts, will make it easier for students to understand concepts and will be embedded in memory longer (Santiasih et al., 2013).

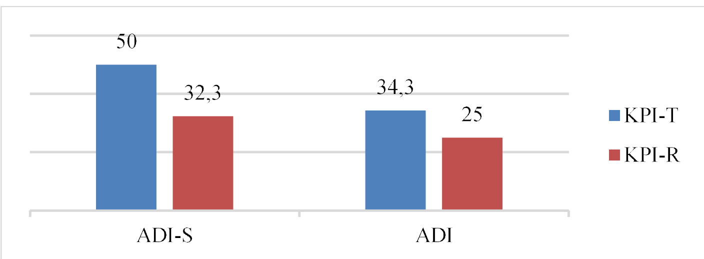


Figure 2. The Percentage of Students' Correct Answer

Based on the theory of cognitive development according to Piaget (in Seifert & Sutton, 2009), children at the age of 11 years and over, their cognitive development have entered the formal operational stage. Furthermore, Piaget (in Suyono & Harianto, 2014) states that the characteristics of this operational stage are characterized by children being able to think abstractly, in specific being able to think of ideas or alternative problem solutions, and being able to formulate scientific hypotheses and compose rules about matters which is abstract, thus theoretically, high school students should be able to employ scientific reasoning ability. Piaget (in Suyono & Harianto, 2014) also explains that the order of children's cognitive development is universal, meaning that every child around the world has to pass the sensory-motor stage to the formal operational stage. The difference in scientific reasoning abilities experienced by students is due to the varying speed of completion of each stage by each child and has various forms. At a certain stage of development, a certain cognitive structure will emerge whose success at each stage is highly dependent on previous achievements. According to Seifert & Sutton (2009), although this KPI is not the only main factor determining success in learning, because there are still other factors such as motivation. However, this scientific reasoning ability is a type of thinking skill that is needed to solve scientific problems or when students design a scientific experiment. Because in everyday life students rarely face problems of that nature, causing students to use these abilities only in certain fields, it is not surprising why numerous studies have found that students have not been able to reach the stage of formal thinking (the highest stage in scientific reasoning ability).

CONCLUSION

Based on the findings and discussion, first, the ADI-S learning model on reaction rate topic is able to improve students' cognitive learning outcomes compare to ADI learning model. Second, High scientific reasoning ability provides higher cognitive learning outcomes than low scientific reasoning ability in both ADI-S and ADI classes. Research related to the use of the ADI-S model needs to be carried out for a longer time (not only on reaction rates) or to examine its effects on other dependent variables besides cognitive learning outcomes. Students' scientific reasoning abilities also need to be considered because it is an important factor in the achievement of cognitive learning outcomes.

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