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Mind mapping in the Argument Driven Inquiry (ADI) Model to Improve Students' Cognitive Learning Outcomes on Reaction Rate Topic

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Abstract: The purpose of this study was to determind the effect of mind mapping with Argument Driven Inquiry (ADI) model on student's cognitive learning outcomes (CLO) in the rate of reaction material. This study was a quasi-experimental design with a 2x2 design factorial. The results showed that: (1) there were differences in CLO for students who were learned using ADI-mind mapping and ADI in the rate of reaction material; (2) there were differences in CLO for students with high initial abilities and students who have low initial abilities learned using ADI-mind mapping and ADI in the rate of reaction material; (3) there weren't interaction between students initial abilities and learning models towards student's CLO.

Key Words: *Argumen Driven Inquiry* (ADI); *mind map;* student's cognitive learning outcomes (CLO); initial abilities

Abstrak: Tujuan dari penelitian ini adalah untuk mengetahui pengaruh *mind mapping* dalam model *Argument Driven Inquiry* (ADI) terhadap hasil belajar kognitif (HBK) pada materi Laju Reaksi. Penelitian ini merupakan eksperimen semu dengan rancangan penelitian *factorial 2x2 design.* Hasil penelitian menunjukkan bahwa: (1) terdapat perbedaan HBK untuk siswa yang dibelajarkan dengan model ADI-*mind mapping* dan ADI saja; (2) terdapat perbedaan HBK untuk siswa dengan kemampuan awal tinggi dan siswa dengan kemampuan awal rendah yang dibelajarkan dengan model ADI-*mind mapping* dan ADI saja; (3) tidak terdapat interaksi antara kemampuan awal siswa dengan model pembelajaran terhadap HBK siswa.

Kata kunci: *Argumen Driven Inquiry* (ADI); *mind map;* hasil belajar kognitif; kemampuan awal

INTRODUCTION

According to Ministry of Education Regulation Number 36 of 2018 concerning High Schools/Madrasah Aliyah, the sort of learning that should be implemented in schools is active and critical learning. This regulation applies to all high school subjects, including chemistry as a branch of science. Chemistry is a branch of science that investigates a material's composition, properties, and changes (John McMurry, 2015). Chemistry learning requires students to not only memorize theory, but also to demonstrate a strong grasp of chemical concepts. Understanding chemical concepts requires a strong ability to integrate students' mental models at three different representational levels, notably macroscopic, sub-microscopic, and symbolic (Lewis, 2007; Schmuckler, 2009). The Reaction Rate material, which is taught in class XI SMA, is one of the chemistry materials that covers the three levels of representation. The material on reaction rates covers a number of critical concepts, including the definition of reaction rates, the law of reaction rates, the factors that affect reaction rates, collision theory, and reaction orders (Speyers, 2010). Due to the fact that the reaction rate material encompasses numerous concepts, teachers must be innovative in their delivery of learning materials to ensure that students grasp the subject thoroughly. Field observations demonstrate that learning about the Reaction Rate material does not align with the established learning objectives. This statement is supported by research conducted at Brawijaya Smart School High School-Malang (Arviani, 2011) using conventional learning to the reaction rate material, which indicates that as many as 62.5 percent of students have

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difficulty understanding the reaction rate graph and 70.8 percent of students have difficulty understanding the factors that affect the rate of reaction. Other research (Rosita et al., 2013; Siswaningsih, 2016) indicates that students at SMA Negeri IV Malang continue to struggle with concepts contained in the Reaction Rate material, such as distinguishing between effective and ineffective collisions, defining activation energy and kinetic energy, defining the collision theory concept to explain the factors that affect reaction rates, and understanding the mechanism of action.

Several issues were identified during the learning of the Reaction Rate material as a result of this description, including a low value placed on student learning outcomes and a lack of understanding of students' concepts on a variety of topics. To address these issues, efforts must be made to improve the quality of learning in the Reaction Rate material. It is envisaged that by improving the quality of learning, the concepts in the Reaction Rate material can be conveyed more effectively and cognitive learning outcomes improve. One way to improve the quality of learning is through the implementation of appropriate learning in schools. One of the lessons considered in accordance with the characteristics of chemistry learning and the current 2013 curriculum is inquiry-based learning, because this approach allows for the integration of practicum activities and teacher-led instruction (Hasnunidah, et al., 2015). Additionally, inquiry-based learning has a beneficial effect on student learning outcomes (Anggareni, et al., 2013; Fitriani & Lestari, 2014). There are numerous approaches to inquiry learning, one of which is Argument Driven Inquiry (ADI) Model.

Sampson and Gleim (2012) developed the ADI model as an integrated learning unit to encourage students to engage in interdisciplinary activities in order to improve their understanding of discipline-specific concepts. As the name implies, the ADI learning model is one of several designed to improve students' ability to argue scientifically (Demirciolu & Uçar, 2012). Additionally, Walker et al. (2011) argue that the ADI model can help students develop critical thinking skills by emphasizing the critical role of argumentation and knowledge validation. Walker et al. (2011) also explain that the ADI model is comprised of a series of learning activities, particularly laboratory-based learning, that can increase students' active participation in argumentative discourse while simultaneously improving their scientific argumentation skills. Argumentation ability is critical for students studying chemistry, as it serves as a barometer of students' comprehension of the material being studied. This model was developed with the intention of being applicable not only to laboratory-based learning, but also to conceptual-based learning. Among them is research conducted by (Grooms, 2011) that indicates that ADI learning is used not only in laboratory-based learning, but also in non-laboratory learning involving molecular shape and polarity. The ADI learning model can be used if students can actively communicate their arguments against a material during the learning process. Apart from enhancing students' scientific argumentation abilities, the ADI learning model has been shown to improve students' HBK. This is supported by Mumpuni (2017), who found that students taught using the ADI model achieved higher average learning outcomes than students taught using guided inquiry on Salt Hydrolysis material.

As with other learning models, the ADI model has deficiencies. Sampson et al. (2011) explain one of them by stating that students frequently struggle with discussing and presenting their arguments both orally and in writing. Indeed, the goal of ADI learning is to increase students' comprehension and knowledge of the subject matter through active argumentation activities. As a result, ADI is considered more effective when combined with a learning medium that assists students in communicating their arguments (Darusman, 2016). A mind map is an example of an appropriate learning medium.

According to Polat et al. (2017), mind maps enable students to practice a variety of skills, including counting, establishing cause-and-effect relationships for a problem, classifying, detailing, and consciously using colors and shapes as a learning medium. Additionally, Long and Carlson (2017) stated that students' difficulties stem from their inability to take notes and connect concepts in learning materials. The difficulties associated with processing and organizing information from school subject matter can be overcome through the use of a mind map. Chemistry education that incorporates mind mapping has been shown to improve students' cognitive and affective outcomes (O'Connell, 2016; Rizal, 2014).

Another factor to consider when teaching chemistry is the students' initial ability. The term "initial ability" refers to the ability that students possess prior to moving on to the next level or material (Rosita et al., 2013). Initial ability can be determined by examining the test scores for the preceding material. The initial ability of a student is critical to the smooth operation of a learning activity because it indicates the students' readiness to receive the subject matter being delivered (Ali, Ardiansyah, Irwandi, & Murniati, 2016; Rustaman, 2005; Syahbana, 2012). This statement is also supported by research conducted by, which found that while students with a high initial ability can solve problems effectively, those with a low initial ability can also improve their abilities through teacher-provided strategies based on an analysis of student difficulties in previous material.

A study was conducted based on this description to determine the effect of the ADI-mind mapping model on the cognitive learning outcomes of students with varying initial ability for reaction rate.

METHOD

The research design used in this study was a quasi-experimental research design. The quasi-experimental design used in this study used a factorialized (2 x 2) version of the non-equivalent control group design. The 2x2 factorial design shows the possible influence of the moderator variable and the treatment variable (independent variable) on the results of the study (the dependent variable). The independent variable in this study was ADI-mind mapping, the dependent variable was cognitive learning outcomes (HBK), and the moderator variable was the student's initial ability score which in this study was taken from data on daily test scores on Thermochemistry material. Schematically, the research design a factorialized (2 x 2) version of the non-equivalent control group design is presented in Table 1.

Table 1. A factorialized (2 x 2) version of non-equivalent control group design

KA	Learning Model	
	Experiment ADI + *Mind mapping* (X_1)	Control ADI (X_2)
High (Y_1)	X_1Y_1	X_2Y_1
Low (Y_2)	X_1Y_2	X_2Y_2

Remark:

X_1Y_1 : Cognitive learning outcomes using the ADI-mind mapping model for students with high initial ability.

X_1Y_2 : Cognitive learning outcomes using the ADI-mind mapping model for students with low initial ability.

X_2Y_1 : Cognitive learning outcomes using the ADI model for students with high initial ability.

X_1Y_1 : Cognitive learning outcomes using the ADI model for students with low initial ability.

This research was conducted at SMA Brawijaya Smart School- Malang in the odd semester in the 2018/ 2019 academic year. The research was carried out from October 8 to October 29, 2018. The research was conducted on learning activities and data collection of values. Samples were taken at random with the cluster random sampling method with the entire population of class XI MIPA in the high school. Class XI IPA 3 was designated as an experimental class taught by ADI-mind mapping and class XI IPA 4 was designated as a control class which was taught using the ADI model only. The integration of the ADI model and mind mapping is shown in Figure 1.

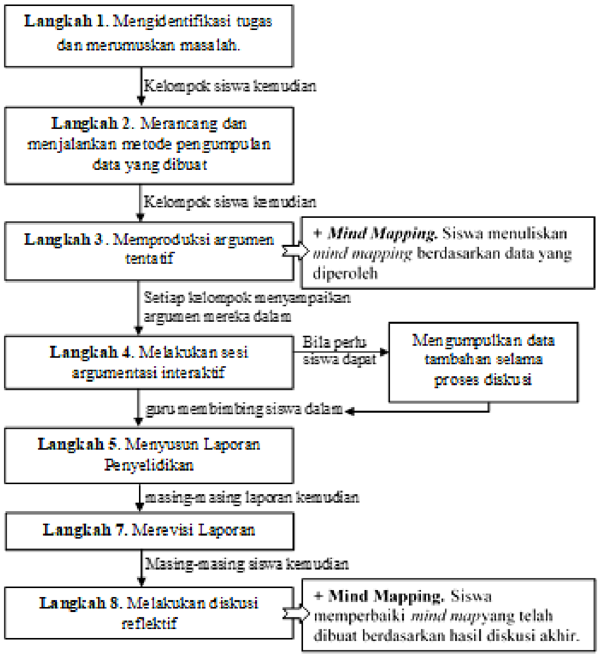

Figure 1. Argument Driven Inquiry (ADI) with mind mapping learning syntax (modified by Walker & Sampson, 2013)

The instruments in this study were classified into two, specifically treatment instruments and measurement instruments. The treatment instruments used were syllabus, lesson plans, and worksheets, while the measurement instruments used included the cognitive learning outcomes test in the form of multiple choice questions.

There are three hypotheses formulated in this study. The most suitable analytical method for this research design was Two Way ANOVA. Hypothesis testing in this study was carried out at a significance level of 5% or = 0.05. Decision making on the hypothesis can be seen based on the p-significance value obtained from the analysis based on the following criteria:

- P(sig) > 0.05 then H_0 is accepted
- P(sig) < 0.05 then H_0 is rejected

RESULTS

In accordance with the syntax of the ADI-mind mapping model previously mentioned, in this study students were asked to be proficient in conveying their arguments both orally and in writing. Written arguments are made in the form of mind mapping with the following steps: (1) determine the topic, (2) determine the main idea and write it in the middle of the paper, circle with shapes according to creativity, (3) add several branches that are connected with the main idea for each point you want to discuss, (4) write keywords or phrases in each branch, (5) add appropriate symbols, pictures, and illustrations to make it easier for students to remember the material being studied (Crowe & Sheppard, 2012; Darusman, 2016; Ristiasari, et al., 2012). The following is an example of a mind map made by students in the experimental class, which is shown in Fig. 2.

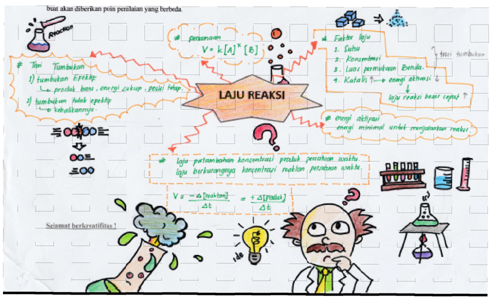

Figure 2. The Example of Student's Mind Mapping

Before testing the hypothesis, it is necessary to ensure that the data are normally distributed and homogeneous. Normality and homogeneity tests were carried out on the initial ability and cognitive learning outcomes value data obtained through the posttest results. From the results of the normality and homogeneity test of the initial ability and learning outcomes data, the following results were obtained. Normality for students' initial ability value data was a significance value of 0.184 and students in the control class have a significance value of 0.200 with a 95% confidence level. As for the data on the learning outcomes test scores, the results were 0.200 for the two experimental classes. For the homogeneity test, a significance value of 0.216 was obtained for the initial ability data and 0.348 for the cognitive learning outcomes data. These results indicate that both value data have been tested for normal and homogeneous distribution.

The HBK test was carried out on the same day for the two sample classes, namely on October 25, 2018. The cognitive learning outcomes test questions were in the form of 17 multiple-choice questions that had been declared eligible through content and item validity tests. This study uses initial ability as a moderating variable. For this reason, each sample class is divided into groups of students with high initial ability and low initial ability. The grouping of cognitive learning outcomes based on initial ability can be seen in Table 2.

Table 2. Cognitive Learning Outcomes Based on Initial Ability

Class	Grpup KA	Total Students	Mean	Max Value	Min Value
Experiment	High	11	83.45	96	72
	Low	7	73,71	90	54
Control	High	9	75,33	84	66
	Low	9	63,78	78	34

Based on the data in Table 2, it can be seen that the average cognitive learning outcomes score for the group of students with high initial ability in the experimental class is 83.45 and in the control class is 75.33. Meanwhile, in the group of students with low KA, the average value of learning outcomes was 73.71 in the experimental class and 63.78 in the control class.

Hypothesis testing

After confirming that the cognitive learning outcomes data has been normally distributed and homogeneous, then the analysis can be continued at the hypothesis testing stage. The hypotheses tested for the cognitive learning outcomes variable are as follows:

(1) $H_{1(1)}$: there is a difference in cognitive learning outcomes in the reaction rate material between students who are taught with the ADI-mind mapping learning model and ADI only.

(2) $H_{1(2)}$: there is a difference in cognitive learning outcomes in the reaction rate material between students who have high KA and students who have low initial ability for the two research classes.

(3) $H_{1(3)}$: There is an interaction between ADI-mind mapping and ADI only. with initial ability on students' cognitive learning outcomes.

Hypothesis testing was carried out using the two way ANOVA analysis method with a significance level of 0.05. The results of the hypothesis test can be seen in Table 3.

Tabel 3. Two Way ANOVA Results

	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1678,844[a]	3	559,615	4,572	,009
Intercept	194245,404	1	194245,404	1586,873	,000
Kelas	613,404	1	613,404	5,011	,032
Kemampuan	873,927	1	873,927	7,139	,012
Kelas * Kemampuan	,509	1	,509	,004	,949
Error	3917,045	32	122,408		
Total	207796,000	36			
Corrected Total	5595,889	35			

a. R Squared = ,300 (Adjusted R Squared = ,234)

Based on the results of hypothesis testing with two way ANOVA listed in Table III, it can be interpreted as follows.

The Effect of Learning Models in Both Classes on Cognitive Learning Outcomes

The results of the hypothesis test are shown in the “Class” data with an F_{count} of 5.011. This value is greater than the F_{Table} value of 4.49 with a significance value of (0.032) <0.05. It was concluded that there were differences in the cognitive learning outcomes for students who were taught the ADI-mind mapping model and ADI only on the reaction rate material (H_1 was accepted/H_0 was rejected).

These results indicate that H_1 is accepted and H_o is rejected, in other words there are differences in the cognitive learning outcomes of students who are taught with and without mind mapping in the ADI learning model. This can be proven based on the cognitive learning outcomes test score data obtained in the study, which shows that the cognitive learning outcomes class taught by mind mapping in the ADI model learning is higher than the class taught by the ADI model only (control class). The difference in cognitive learning outcomes is thought to be caused by the different learning processes carried out in the control and experimental classes. The difference in the average cognitive learning outcomes of the two classes is shown in Figure 3.

Based on Figure 3. it can be seen that the class taught with the ADI model assisted by mind mapping (experimental class) has a higher average cognitive learning outcomes than the class taught with the ADI model only.

According to (Dwani, et al., 2015; Purtadi & Sari, 2007) all syntax in inquiry learning can improve students’ cognitive learning outcomes. The difference in treatment for the two sample classes lies in the application of mind mapping. This shows that apart

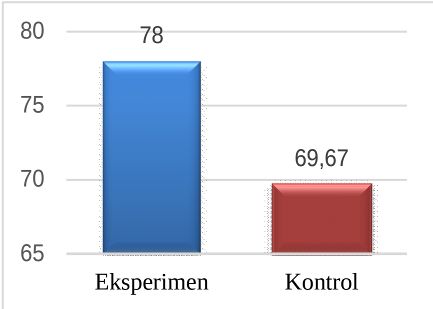

Figure 3. Average Score of Cognitive Learning Outcomes on Both Experimental and Control Classes

from the syntax of ADI learning itself, mind mapping plays an important role in improving cognitive learning outcomes. This statement can be explained as follows: Mind mapping activities invite students to do several activities at once, namely taking notes, making sentences in appropriate and easy-to-understand language, and connecting important concepts using pictures, shapes, branches, and colors. (Purtadi & Sari, 2007) explains how these activities can help students improve their cognitive learning outcomes. This can be briefly seen in Table 4.

Table 4. The Relation of Mind Map Components with Cognitive Learning Outcomes (adapted from Sumanik, 2018)

HBK	*Mind Mapping*
C1-**Remember**	Notes Structure
C2-**Understand**	Notes Structure
	Use of Language and Terms
	Use of Symbols and Images
C3-**Apply**	Bentuk Branches and colors
C4-**Analyze**	Content of the Material
	Use of images and symbols
C5-**Evaluate**	Completeness of concepts

Based on Table 4. it can be concluded that mind mapping activities can improve students’ cognitive learning outcomes. cognitive learning outcomes includes 5 levels in Bloom’s Taxonomy, namely in C1-

C5. Mind mapping activities can assist students in improving students' cognitive abilities with these 5 levels, such as C1-C2 relating to the structure of notes and the use of language and terms, C3 relating to the use of branches and colors, C4 relating to the use of images and symbols, and C5 which relates to the completeness of the concepts written in the form of a mind map. This statement is in line with several related studies, such as that conducted by Rosita et al., (2013) which states that mind mapping can improve students' cognitive learning outcomes and affectiveness in chemistry because mind mapping activities are related to the cognitive structure of students in receiving learning material. This can be the reason why the average cognitive learning outcomes of students in the experimental class is higher than the average learning outcome in the control class.

The Effect of Initial Ability on Cognitive Learning Outcomes

The results of the hypothesis test are shown in the "Ability" data with an Fcount of 7.139. This value is greater than the FTable value of 4.49 with a significance value of (0.012) <0.05. It was concluded that there were differences in the cognitive learning outcomes for students with high initial ability and students with low initial ability who were taught using the ADI-mind mapping model and ADI only mapping on the reaction rate material (H1 accepted/ H0 was rejected).

Initial ability shows the level of student understanding of the material that has been and will be studied. The cognitive learning outcomes value data shows that students with high initial ability get a higher average cognitive learning outcomes when compared to the average learning outcomes of students who have low initial ability. Student initial ability is related to students' ability to receive a material. Characteristics of chemistry is mutually sustainable where the material to be studied is related to the material after it. Therefore, it can be assumed that how students understand the reaction rate material is related to their level of understanding in understanding the previous material, that is hermochemical.

Yuniarti, et al (2014) also mention that the identification of initial ability can be a determining factor in teaching new subjects in a learning system. As explained by Odja & Payu (2014) that new concepts will be more easily accepted or understood by students who have high initial ability. Students with high initial ability will more easily process the information being studied when compared to students with low initial ability. This could be because students with high initial ability already have a higher understanding of the material to understand the material afterwards than students with low initial ability. Thus, the cognitive learning outcomes value of students with high initial ability will be higher when compared to the cognitive learning outcomes value of students with low initial ability.

The Effect of Interaction between Initial Ability and Learning Model on Cognitive Learning Outcomes

The results of the hypothesis test are shown in the "Class*Abilities" data with an F_{count} of 0.004. This value is smaller than the F_{Table} value of 4.49 with a significance value (0.949)>0.05. It was concluded that there was no interaction between students' initial ability and the learning model of students' cognitive learning outcomes (H1 was rejected/H0 was accepted).

both classes experienced an increase when compared to their initial ability data, both in classes taught with the ADI model alone and those taught with mind mapping in ADI learning. An increase in cognitive learning outcomes can also be observed in students with high and low initial ability. Based on this, it can be concluded that students with different initial ability can experience an increase in cognitive learning outcomes if taught with the right learning model. This shows that the results of the study indicate that there is no interaction between the learning model and initial ability on cognitive learning outcomes.

These results are supported by research conducted by (Nurjannah, 2018) which states that there is no interaction between the learning model and interest in learning on learning outcomes, because according to him, each variable in the study has a role in influencing the dependent variable to be measured. In other words, the absence of interaction between the variables used in the study indicates that each variable plays an active role in influencing the variables to be measured.

CONCLUSION

The conclusions that can be drawn from the results of this study are: (1) There are differences in the cognitive learning outcomes for students who were taught the ADI-mind mapping model on the reaction rate material; (2) there are differences in the cognitive learning outcomes for students with high initial ability and students with low initial ability who are taught using the ADI-mind mapping learning model and ADI only on the Reaction Rate material; (3) There is no interaction between students' initial ability and the learning model of students' cognitive learning outcomes.

The ADI model can be said to be effective in increasing cognitive learning outcomes. Other researchers can try other research variables with the ADI model as the independent variable. Based on the facts on the ground, researchers can see the potential that this model can effectively improve other educational experimental research variables. In addition, the use of mind map media can be maximized by providing an introduction to making mind maps at least a day before learning is carried out, therefore the learning can run more efficiently both in terms of time and achievement of learning objectives.

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