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Effectiveness of argument-driven inquiry (ADI) learning model on students' creative thinking skill: Environmental pollution

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ABSTRACT

ADI learning model supports the syntax of the learning process through investigative activities of environmental pollution problems and their impact on the ecosystem. The model implements practicum to challenge students' creativity in presenting the results of practicum through students' arguments. The purpose of this study was to analyze the influence of the ADI learning model and evaluate the students' creative thinking skills. This was a quasi-experiment study with a pretest-posttest non-equivalent control group design. The sample was taken with cluster random sampling technique, 42 students were divided into 2 classes in 7th junior high school at Global Madani School, Bandar Lampung. Results were analyzed using covariance analysis and the effect size was measured by the partial eta-squared value. Aspects of creative thinking skills that were measured: fluency, flexibility, originality, elaboration, and metaphorical thinking. The result shows the application of the ADI learning model had a significant effect in improving students' creative thinking skills with a significance value of 0.013 (sig.<0.05). The effect of implementing the ADI learning model had high effectiveness in improving the students' creative thinking skills with a partial eta squared value of 0.147 which was categorized as large (sig ≥ 0.14). Therefore, the ADI learning model affects improving students 'creative thinking and had an impact on high effectiveness in improving students' creative thinking. Finally, the learning model is recommended for Biology teachers to increase students' creative thinking skills effectively.

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INTRODUCTION

21st-century education is faced with the global challenge to prepare quality human resources. This challenge requires the education world to produce highly qualified graduates. US-Based Partnership for 21st Century Skills identifies the competencies needed in the 21st century, namely "The 4C's" -communication, collaboration, critical thinking, and creativity (P21, 2008). However, the condition of human resources in Indonesia is not fully competitive, so this can show that the quality of education in Indonesia is still low (Daryanto & Karim, 2017; Trisdiono & Muda, 2013).

The Central Statistics Agency reports that Indonesia is facing a demographic bonus gate in 2020-2037 (Budiati et al., 2018). The demographic bonus is a phenomenon where the population of productive age is higher than the population of non-productive age (Nugroho et al., 2017). If the Indonesian government doesn't immediately prepare a quality young generation, then the demographic bonus will only become a burden for the country due to the increasing unemployment rate (Maryati, 2015; Sukmaningrum & Imron, 2017). National graduates will be unable to compete with graduates from foreign countries who are more skilled and trained so that the Indonesian younger generations can lose good job opportunities.

The prosperity and glory country is very dependent on creative contributions, such as new ideas, inventions, or technology through the creative thinking of younger generations which should be nurtured from an early age. Creativity is a talent that is potentially owned by everyone (Sumarni, Setiandi, & Sunandar, 2020; Kisti & Nawangsari, 2012). The cognitive realm in creativity is called creative thinking skill (Treffinger et al., 2002). Creative thinking is a problem-solving process that can be expressed in unique ways as an attempt to connect previously unconnected ideas to form various alternative answers (Abraham, 2016; Blegur & Tlonaen, 2017; Rawlinson, 2017). Various aspects of creative thinking have been revealed by some experts. However, in a reality, creative thinking is a skill to see various alternative answers from different points of view in solving an increasingly complex problem that has not yet received special attention in the education world (Munandar, 2012). Meanwhile, the development of creative thinking skill is needed in the learning process so that students have not difficulty solving various problems and facing life's challenges in the future which are dynamic and full of uncertainty (Juanengsih et al., 2018; Mulyasa, 2009; Şeyihoğlu & Kartal, 2010; Sternberg, 2012).

Based on the preliminary study results toward 23 science teachers from 20 Junior High Schools in Bandar Lampung, Indonesia that has implemented the 2013 Curriculum are known that 87% teachers have developed students' creative thinking skill. The results of teachers assessment of their students show that students abilities on fluency aspect are medium category (61%), flexibility is a medium category (61%), originality is a low category (56%), elaboration is a medium category (49%), and metaphorical thinking is a low category (43%), so it can be stated that the empowerment of creative thinking skill in JHS Bandar Lampung, Indonesia has not been ideal and needs to be improved.

Science learning should be carried out by scientific inquiry which emphasizes direct learning experiences to foster thinking skills, work, be scientific, and communicate them as an important aspect of life skills (BSNP, 2006). All of the JHS science teachers in Bandar Lampung, Indonesia who were surveyed said that they had implemented an inquiry learning model based on a scientific approach in science learning. However, the implementation has not run optimally because several obstacles are still found, namely: most students have difficulty formulating a concept of science learning material systematically and communicating it straightforwardly in arguing, and tend to be passive during discussions.

Communication and argumentation are important parts that cannot be separated from science because they play a role in argumentation activity which can underlie students for learning to think and act like a real scientist (Probosari et al., 2016). Argumentation activity

encourages students to analyze evidence of the investigation, consider alternative answers, assess the truth of arguments from various points of view, produce arguments in unorthodox ways, and repair or improve the answers given during discussion forum to solve problems so be able to train creative thinking skills (Kadayifci et al., 2012; Laius & Rannikmäe, 2014).

A new learning strategy is needed so that students have creative thinking skills as one of the necessary competencies in the 21st century with applying an inquiry learning model that can handle students' obstacles in arguing. One learning model that is believed can facilitate students to improve argumentation and creative thinking skills is the Argument-Driven Inquiry (ADI) learning model. The ADI model is laboratory-based learning that can increase the knowledge and skills of students by participating in four main activities, namely: investigation, argumentation, writing, and reviewing investigation reports (Sampson et al., 2011). The ADI learning model gives students the opportunities to design and find experimental results, collect and analyze data, and be actively involved in the argumentation process so that they can exchange ideas, correct answers, and try to defend their thinking (Demircioglu & Ucar, 2015).

Several research results prove that the ADI learning model can facilitate learning to improve creative thinking skills. The application of the ADI learning model in the chemical environment topic has been proven effective for improving the students' creative thinking skills in senior high school at Phitsanulok, Thailand (Kumdang et al., 2018). The creative thinking skills of prospective mathematics teacher students in Cimahi, Indonesia who carry out learning using the ADI model have also increased (Hidayat et al., 2018). In addition, the application of the ADI learning model in research conducted in a chemistry class at a university in Turkey can overcome the weaknesses of students in argumentation and low creativity (Kadayifci et al., 2012).

The results of the JHS science teachers' survey in Bandar Lampung, Indonesia showed that only 26% had applied the ADI model to science learning. However, the creative thinking skill needs to be trained in early age because it is one of the important skills required in the 21st century. At this time, JHS students are ≥ 11 years old which is starting to enter the formal cognitive operational development stage. At this stage, students should start to develop skills in systematic thinking with an abstract, logical, and hypothesize reasoning design in solving complex problems experimentally (Crain, 2007; Piaget, 2005). So, the ADI learning model as described needs to be applied and developed in JHS science learning activities.

This research focuses on how much the effectiveness of the application of the ADI learning model for improving students' creative thinking skills in junior high schools on the environmental pollution topic. Environmental pollution is one of the science topics in VII grade JHS which requires deep understanding. The ADI learning model presents a syntax that can support the learning process in achieving the competencies needed by students through investigation activities related to environmental pollution problems and their impact on the ecosystem by conducting experiments to solve problems, then giving alternative solutions when presenting research results in argumentation activities on forums discussion so that they can find conclusions from some of the possibilities that occur, and write down the findings and ideas for completion the problem on individual investigation reports so that students are designed to think actively.

Based on the descriptions that have been stated, it seems that the ADI learning model can increase students' creative thinking skills effectively, especially for science learning about environmental pollution topics in junior high school. Therefore, it is necessary to conduct research that aims to determine (1) the effect of the ADI learning model in improving students' creative thinking skills; and (2) the effectiveness level of the effect of the ADI learning model in improving students' creative thinking skill.

METHODS

Research Design

This research type was a quasi-experiment using a pretest-posttest non-equivalent control group design. The Independent variable is the learning model (Argument-Driven Inquiry and Discovery), while the dependent variable is students' creative thinking skills. This study used two groups. The experimental group was given an Argument-Driven Inquiry learning model, while the control group was given the Discovery learning model. The application of learning model in control class according to result survey of JHS science teachers Bandar Lampung, Indonesia which is mostly applied on environmental pollution topic as 78%. The description of this research design is shown in Table 1.

Table 1
Design of Pretest-Posttest Non-equivalent Control Group.

Group	Treatment		
	Pre-test	Learning	Post-test
E	Y_1	X	Y_2
C	Y_1	O	Y_2

Note:
E = Experiment group Y_1 = Pre-test X = Argument-Driven Inquiry Learning Model
C = Control group Y_2 = Post-test O = Discovery Learning Model

Population and Samples

The population in this study were all students of VII grade JHS GM Bandar Lampung, Indonesia which amounted to 84 people. The research sample was selected using the cluster random sampling technique, namely by randomizing the class in a large population without taking random subjects individually (Hasnunidah, 2017; Sugiyono, 2015). The sample chosen for the experiment group is VII(3) and the control group is VII(4). Every research group had 21 students. The research was conducted on February 25th - March 13th in the 2019/2020 school year.

Instrument

This study used a test to measure students' creative thinking skills. The test form is an essay with 15 questions. The test was given to students include five aspects of creative thinking skill, namely fluency, flexibility, originality, elaboration, and metaphorical thinking (Treffinger et al., 2002). Students work on the test with environmental pollution topic that is suitable from basic competency according to interpretation (Kemdikbud, 2017). The assessment scheme is shown in Table 2.

Before being used, the instrument was tested for validity and reliability. The content and construct validity were analyzed by expert lecturers from Universitas Lampung, while the empirical validity and reliability used statistics due to the results of 43 sample students' answers in VIII grade. The validation results of the testing instrument were stated to be valid on all questions with medium and high categories. Meanwhile, the results of the reliability test were stated reliable on all questions with a reliability value of 0.861 which was categorized as very high.

Table 2
Assessment Scheme of Environmental Pollution and Creative Thinking Skill

Basic Competency	Indicator of Basic Competency	Aspects of Creative Thinking Skill	Question Number
3.8 Analyzing the occurrence of environmental pollution and its impact on the ecosystem.	3.8.1 Finding the characteristics of environmental pollution.	**Fluency** The ability to generate ideas, ways, suggestions, questions, and alternative answers smoothly within a certain time.	1, 6, 11
	3.8.2 Describing the factors that cause environmental pollution.	**Flexibility** The ability to generate various ideas, answers, or questions, where the ideas or answers are obtained from different viewpoints by changing the ways of thinking and the approaches used.	2, 7, 12
	3.8.3 Describing the process of environmental pollution.	**Originality** The ability to generate phrases, ways, or ideas to solve a problem or make a combination of parts or elements unusually and uniquely was unthinkable by others.	3, 8, 13
	3.8.4 Classifying the sources of environmental pollution.	**Elaboration** The ability to enrich, develop, increase, describe or specify details of the object, idea, product, or situation to make it more interesting.	4, 9, 14
	3.8.5 Predicting the impact of environmental pollution on the ecosystem.	**Metaphorical Thinking** The ability to use a comparison or analogy to make a new connection.	5, 10, 15

Procedure

This research began with school, population, and sample determination. The next step was the development of an instrument test that refers to aspects of creative thinking skills in biology concepts. After the instrument test has finished, it must be measured the validity and reliability. Instrumen test that fulfills validity and reliability test could be used to measure creative thinking skill twice, namely before learning (pre-test) and after learning (post-test). A teacher implemented both learning models due to research design during three weeks. The experimental group was given the ADI learning model through 8 steps, namely identification of task, generation of data, production of tentative argument, interactive argumentation session, written investigation report, double-blind peer review, the revision process, and reflective discussion (Sampson & Gleim, 2009).

Data Analysis Techniques

The results of students learning are mean scores of both classes and every aspect of creative thinking skill that were categorized according to the interpretation of Purwanto (2008), namely very high [86 ≤ A ≤ 100], high [76 ≤ B ≤ 85], moderate [60 ≤ C ≤ 75], low [55 ≤ D ≤ 59], and very low [E ≤ 54]. After that, the learning outcomes data were tested for normality and homogeneity tests. Hypothesis testing is carried out with belief that data is normally and homogeneously distributed. The ANCOVA (Analysis of Covariance) test was conducted to analyze the effect of the differences of application from two learning models on students' creative thinking skills. Then, the value of partial eta-squared in the Ankova test is used to represent the effect size. The effect of application from learning model on creative thinking skill can be categorized to small [0,01 - 0,05], medium [0,06 - 0,13], and large [≥ 0,14] (Pituch & Stevens, 2016). Furthermore, the Least Significant Difference (LSD) test was carried out when a significant difference was found. This test aimed to determine the learning model that had a

significant influence with a certain amount of contribution (effectiveness value) to improve creative thinking skills.

RESULTS AND DISCUSSION

The research results on descriptive statistics related to mean scores of pre-test and post-test students' creative thinking skills are presented in Table 3.

Table 3
Average Value of Creative Thinking Skill.

Learning Model	Subject	N	Average and Standard Deviation	Category
Argument-Driven Inquiry	Pre-test	21	28,57 ± 9,39	Very Low
	Post-test	21	60,38 ± 17,57	Medium
Discovery Learning	Pre-test	21	27,56 ± 11,35	Very Low
	Post-test	21	49,52 ± 19,47	Very Low

Based on Table 3, it is known that the mean score of students on the pre-test and post-test in the experimental group is higher than the control group. This research is found that the ADI learning model can improve students' creative thinking skills in science learning from very low to medium. This is in line with the previous research that state Argument-Driven Inquiry (ADI) has a positive influence on the achievement of mathematical creative thinking skill (Hidayat et al., 2018). This achievement is a contribution from the increasing average value of creative thinking skill in each aspect which is presented in Table 4.

Table 4
Average Value of Each Aspect of Creative Thinking Skill.

Aspect	Subject	Argument-Driven Inquiry		Discovery Learning	
		Value	Category	Value	Category
Fluency	Pre-test	35,87	Very Low	39,05	Very Low
	Post-test	71,11	Medium	60,32	Medium
Flexibility	Pre-test	40,63	Very Low	40,32	Very Low
	Post-test	61,90	Medium	55,87	Low
Originality	Pre-test	24,13	Very Low	20,00	Very Low
	Post-test	55,56	Low	40,32	Very Low
Elaboration	Pre-test	19,68	Very Low	16,83	Very Low
	Post-test	55,24	Low	47,62	Very Low
Metaphorical Thinking	Pre-test	22,54	Very Low	21,59	Very Low
	Post-test	58,10	Low	43,49	Very Low

Based on Table 4, this research finds that the application of the ADI learning model can increase the fluency and flexibility aspects into a medium category even though the aspects of originality, elaboration and metaphorical thinking are still low, while Discovery Learning only increases the fluency aspect. ADI learning model can develop five aspects of students' creative thinking skills, namely fluency, flexibility, originality, elaboration, and metaphorical thinking because of its ability to increase creative thinking skill categories from the beginning. This means that the application of the ADI learning model is better than the Discovery learning model in improving the students' creative thinking skills. This result is in line with the previous research that states the use of the ADI learning model can develop every aspect of students' creative thinking skills (Kumdang et al., 2018).

Students who learn with the ADI learning model are more able to think fluently (fluency), so they can provide various ideas. They can identify the type of pollution that occurs and explain several observed characteristics according to the question discourse well. This result is in line with the previous research that states the development of students with the ADI learning model

is very rapid on the fluency in three cycles (Kumdang et al., 2018). If students are given more ideas so they have a higher level of fluency (Firdaus et al., 2018).

Students who learn with the ADI learning model are more able to think flexibly (flexibility) so that they can provide various ideas by including the approach used. They can identify factors that caused environmental pollution by providing the reasons about how those factors can influence it well. This result is in line with the previous research that states the development of students with ADI learning model is very rapid on the flexibility in three cycles (Kumdang et al., 2018). For students who have a higher level of flexibility, their mindset is not limited in one side to response problems (Firdaus et al., 2018).

Students who learn with the ADI learning model are still not optimal in the development of originality, elaboration, and metaphorical thinking aspects. They can't explain the process of environmental pollution by combining causal elements, classify and describe their ideas on the types of environmental pollution sources, and predict the impact of environmental pollution on ecosystems by making a related analogy of real conditions in the discourse. These are in line with the previous research that states the application of the ADI learning model for elaboration and originality aspects in cycle 1 have not yet developed, but have increased drastically in the two next cycles (Kumdang et al., 2018). Some aspects of creative thinking skill that are still underdeveloped can arise because students are not familiar with the new learning system which has different characteristics from previous learning so they find it difficult when challenged to carry out the learning process through self-investigation activities in finding answers from problems were given. In addition, implementing the ADI learning model also requires a lot of time to run the syntax so that it is possible to have time to adapt (Kumdang et al., 2018).

The pre-test and post-test results that have been obtained, they have analyzed the effect of application learning model on students' creative thinking skill with Ancova test and the magnitude effect of application learning model on students' creative thinking skill with effect size was represented by partial eta squared value in Ankova test are presented in Table 5.

Table 5
The Ancova Test and the Effect Size on Creative Thinking Skill Value.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	9580,283	2	4790,142	34,569	0,000	0,639
Intercept	1258,091	1	1258,091	9,079	0,005	0,189
Pre-test	8342,460	1	8342,460	60,205	0,000	0,607
Models	934,965	1	934,965	6,747	0,013	0,147
Error	5404,105	39	138,567			
Total	141815,583	42				
Corrected Total	14984,388	41				

The results of the Ankova test in Table 5 show that the learning model (ADI and DL) has a different effect on students' creative thinking skills by having an F value of 6.747 and a significance of 0.013 [sig. <0.05]. Furthermore, this research finds that the magnitude effect of the applied learning model students' creative thinking skill is a large category (Pituch & Stevens, 2016) with a partial eta squared value of 0.147.

After obtaining a different effect between the application of two learning models and the magnitude contribution from the application of the learning model, the LSD test was carried out with the result of the analysis is presented in Table 6.

The LSD test results in Table 6 show that the difference mean value of students' creative thinking skills between the ADI group and Discovery Learning group is 9.85 with a significance value of 0.013 [sig. <0.05]. The achievement of students' creative thinking skills who learn with

ADI is higher than the Discovery learning model. Therefore, the application of the ADI learning model has a significant effect on students' creative thinking skills in science learning with high effectiveness.

Table 6
LSD Test on Creative Thinking Skill Value.

Learning Model	Mean Value			Different Increment	Sig.	Notation
	Pre-Test	Post-Test	Difference			
Argument-Driven Inquiry	28,57	60,38	31,81	9.85	0,013	a
Discovery	27,56	49,52	21,96			b

The effect of the application ADI learning model is effective due to the contribution of syntaxes during learning activities. The syntaxes of the ADI learning model and the Discovery learning model were implemented properly. However, the ADI learning model presents more syntaxes that provide opportunities for students to learn actively and independently by conducting self-investigations to build their knowledge in solving a problem. Students can mobilize all their abilities and train their creative thinking skills. Meanwhile, Discovery learning has fewer main syntaxes that play a role in students' activities, namely data collection, data processing, and verification. The development of every aspect of students' creative thinking skills requires a creative learning climate, giving them the freedom to think, and expressing perceptions openly (Firdaus et al., 2018). In conclusion, the ADI learning model has superior syntaxes to support the development of creative thinking skills. This is in line with the previous research that state ADI learning model presents a learning process that can improve creative thinking skill by building scientific knowledge and explanation through self-investigation on four important syntaxes, such as in scientific investigations, argumentation, writing reports, and reviewing reports (Hidayat et al., 2018; Kumdang et al., 2018).

In data collection syntax, students carry out investigative activity to collect and analyze data in cooperation. This can be seen in Figure 1.

(a) (b) (c)

Figure 1. Data Collection Session in the Experiment Group (a) air pollution; (b) water pollution; (c) soil pollution.

Pictures A, B, and C in Figure 1 showed that investigative activities carried out during the research, namely sub-topics of air pollution, water pollution, and soil pollution. The investigative activity provides opportunities for students to find solutions in solving a problem by observing and analyzing the causes, processes, and results that occur on a phenomenon directly so that learning concepts are connected. This result is in line with previous research that state inquiry (investigation) activity can develop every aspect of creative thinking skill because students can express and explore ideas in various ways and points of view to solve problems (Zubaidah et al., 2017). Students' creative thinking can be developed through learning that facilitates experimental activities (scientific investigations) because students will know the process and reasons for something happening, and find solutions for existing

problems from natural phenomena in life (Rachmawati & Kurniati, 2011).

In interactive argumentation session syntax, students carry out group discussions by visiting and receiving guests. The interaction between each group's arguments was recorded in audio form and each question asked from the guest along with the answers given from the presenter group were written. This can be seen in Figure 2 and Figure 3.

(a) (b) (c)

Figure 2. Argumentation Interactive Session in the Experiment Class (a)-(c) Group 2-4

1. How do we know the occurrence of air pollution from dust that sticks?
   We can see the dots attached to the handbody which indicate dust. The more dust attached, the higher the pollutants in the area.
2. Why water that contaminated with detergent can cause fish to die?
   Because detergent become pollutants in the water. Detergent contains chemicals that can be harmful to organisms. These chemicals are destructive.
3. If the waste damages the soil, then how the plants' condition?
   It is clear that if the waste can damage the soil, the plants will slowly die because the soil conditions have changed or are not suitable for life, thus inhibiting plant growth.

Figure 3. Interactive Argument Results in the Experiment Class

Picture A dan B in Figure 2 showed that each group was active and conducive to discussion. Then, Figure 3 showed that their ability to argue. The argumentation activity allows students to exchange information by comparing the findings between groups, so that students can convey, correct, or refute the opponent's opinion with investigative evidence that is supported by various theories to obtain the truth problem-solving. Argumentation activity encourages students to analyze evidence of the investigation, consider alternative answers, assess the truth of arguments from various points of view, produce arguments in an unorthodox way, improve and increase the answers given during the discussion forum to solve problems so that be able to train students' creative thinking skill (Kadayifci et al., 2012; Laius & Rannikmäe, 2014).

In written investigation report and report review syntax, students compile investigation reports individually and evaluate the quality of the investigation report through peer review sheets. The results of the review will be returned to respective students and become self-reflection on their work. This can be seen in Figure 4.

In Figure 4, picture A showed that the teacher explained the preparation to start the investigation report, told the report answer key on picture B, and students corrected the other's people report on picture C. Written investigation report give students the opportunities to express their thoughts on the concepts that have been found and studied by putting them in writing. Report review activity gives students the opportunities to examine the results of friends' work and examine their work by comparing them to the answer key reports provided so that students can reflect on the extent to the truth of students understanding concept learning to solve problems. The results of the report review activity can be a self-reflection to improve, develop, and change ways or better-thinking strategies so that it can help improve creative thinking skills (Kumdang et al., 2018).

(a) (b) (c)

Figure 4. Written Investigation Report (a) and Report Review Session in the Experiment Class (b) Teacher activity; (c) Students activity

CONCLUSION

Based on the results of research and discussion, it can be concluded that the application of the ADI learning model is recommended for a Biology teacher to increase students' creative thinking skills effectively. The results of this research support the previous research that state ADI learning model effective for improving creative thinking skill (Hidayat et al., 2018; Kadayifci et al., 2012; Kumdang et al., 2018). This research showed that the ADI learning model had a significant effect in improving the students' creative thinking skills with a significance value of 0.013 [sig. <0.05]. Furthermore, the effect of implementing the ADI learning model had high effectiveness in improving students' creative thinking skills with a partial eta squared value of η_p^2 0.147 which was categorized as large [≥ 0.14]. ADI learning model presents a learning process that can train students to creative thinking through the primary syntaxes, such as data collection, argumentation interactive, writing report and report review on a laboratory study. This syntax gives opportunities for the students to get used to thinking actively for understanding science concepts by solving problems. The process of effective learning interaction between a teacher and students in constructing knowledge is an important determinant to reach learning goals successfully.

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