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The Effect of Argument Driven Inquiry (ADI) Model on the Scientific Argumentation Ability of High School Students on the Topic of Light Waves

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Abstract

Scientific argumentation is the process of strengthening claims through critical analysis based on supporting evidence and logical reasons, where the evidence can include facts that can be accepted as truth. This study aims to describe the improvement of students' scientific argumentation abilities on the topic of light waves after applying the ADI learning model. This research uses the type of True Experimental with a Control Group Pretest and Posttest design. The data collection technique in this study was the test method. The results of this study indicate an increase in scientific argumentation abilities on the topic of light waves after applying the ADI learning model. The results of the scientific argumentation ability of experimental class students were higher than the control class, the experimental class got an n-gain of 0.60 with a medium category, while the control class got an n-gain of 0.26 with a low category. In the pretest, experimental, and control classes, students were at levels 1, 2, and 3. The posttest results of experimental class students who experienced increased scientific argumentation at levels 4 and 5. Meanwhile, the posttest results of students in the control class were relatively the same as the pretest results, namely at levels 1, 2, and 3. In addition, the Cohen's Effect Size analysis results showed a value of 0.88 in the strong criteria. It can be concluded the ADI learning model affects learning to improve students' scientific argumentation abilities of senior high school students on the topic of light waves.

Keywords: ADI Learning Model, Scientific Argumentation Abilities, Light Waves

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INTRODUCTION

Twenty first century education aims to encourage students to have abilities that support them to be responsive to changes along with the times (Sutrisna, 2021). The challenge of education is to produce a generation that is competitive in the 21st century era (Susilowati et al., 2017), so learning in the curriculum must be oriented towards 21st century learning. One of the curricula in force in Indonesia is the 2013 Revised curriculum. Learning in the 2013 Revised curriculum requires varied learning experiences, ranging from simple to complex. The concept of 21st century learning in the 2013 Revised 2018 curriculum requires students to have 4C (Creative, Critical Thinking, Communicative, and Collaborative) abilities, namely creative, critical thinking, communicative, and collaborative (Arnyana, 2019). The 2013 Revised Curriculum has objectives, one of which is for students to have the competence to develop the ability to reason, think inductive and deductive analysis using physics concepts in order to explain various phenomena in everyday life, solve problems both qualitatively and quantitatively. One of the methods that can be used in learning physics is to train argumentation abilities.

Argumentation is the process of strengthening claims through critical analysis based on supporting evidence and logical reasons, where the evidence can include facts that can be accepted as truth (Datun et al., 2019). Scientific argumentation abilities are very important to be applied to physics learning so that students have logical reasoning, clear views and rational explanations of things learned, and critical thinking (Osborne, 2015). Argumentation abilities also play an important role in building understanding, models and theories of the concepts learned. Training argumentation abilities means training cognitive and affective abilities that can be used to understand physics concepts (Siswanto et al., 2014).

Physics learning activities integrated with scientific argumentation will stimulate students to provide valid evidence, data, and theories to support opinions (claims) in solving a problem (Robertshaw & Campbell, 2013). Therefore, alternative solutions are needed in order to design learning that can guide students to be actively involved in learning activities. The selection of the right learning model will affect the quality of learning which has implications for students' scientific argumentation abilities. However, the availability of learning models that can be applied to students in teaching scientific argumentation abilities is still limited. An alternative learning model developed to train scientific argumentation abilities is the Argument Driven Inquiry (ADI) learning model (Andriani, 2023). The Argument Driven Inquiry (ADI) learning model is basically inquiry-based learning by focusing on the argumentation process. The goal is to enable students to develop their own methods of collecting data, conducting experiments, using data to answer guided questions, writing, and reflective thinking (Manurung et al., 2020). ADI is a development of the inquiry and discussion model. ADI aims to create laboratory activities that are informative and involve the development of scientific argumentation through guided questions on experiments (Demircioglu & Ucar, 2015). In addition, the ADI model can be a basis for teachers to redesign laboratory activities that can provide students with more authentic learning experiences.

The results of preliminary observations that have been made by researchers at SMAN 16 Surabaya on 26 October 2022, from interviews with physics teachers and questionnaire answers of 95 students show that physics learning is still focused on delivering teaching materials by teachers and solving problems. From the results of interviews with physics teachers show that laboratory activities have been carried out by completing a Learner Worksheet (LKPD) in groups. In physics learning, there is no activity of exchanging opinions with other students regarding the methods and results or findings they use and obtain during experimental activities. Supported by the results of students' questionnaire answers as many as 61% of respondents indicated that there were no activities that appealed to students in the activity of arguing about the results they obtained from experimental activities. As many as 83% of respondents indicated that they had difficulty in understanding physics concepts, because previously they only memorized formulas to solve problems. This fact shows that in physics learning, the knowledge aspect is still prioritized and has not practiced argumentation abilities.

Study by Pujianto et al. (2023) showed an increase in the ability of scientific argumentation in physics education students in attending research methodology lectures. From the results of data analysis, the average value of initial scientific argumentation was 70.67% and increased to 84%. So, it can be concluded that the application of the ADI learning model can improve the scientific argumentation abilities of physics education students. In line with research by Nasution (2019) states that there is an influence on students' scientific argumentation abilities by using the ADI learning model, where there is an increase in scientific argumentation abilities in students with the ADI learning model higher than using conventional learning, where the experimental class obtained data on improving students' argumentation abilities 76.06 and the control class 70.66. This is also in accordance with research conducted by Firdaos et al. (2021), namely that there are differences in students' argumentation abilities using ADI learning model. This shows that ADI learning model has a greater average value than classes that use conventional learning to increase student argumentation even though both are in the medium category. Another study by Putri et al. (2020) stated that the ADI learning model proved effective in improving students' scientific argumentation abilities. This can be seen from the average total score of students' scientific argumentation abilities test, where the ADI class is the highest among the guided inquiry class and confirmation class. Most of the students in the ADI class were able to organize arguments strongly and correctly even reaching the highest level (level 5). This is supported by research conducted by Siregar & Pakpahan (2020) which shows that the ADI learning model has a significant effect on the science argumentation abilities of junior high school students. The results of the argumentation level have increased in the experimental class to reach level 4, while the control class is dominant at levels 1 and 2 which are above 25%. The findings on students' scientific argumentation abilities are in accordance with research conducted by Dulim & Madlazim (2022) which states that in argumentation-based learning, students' scientific argumentation abilities are able to reach level 5 for indicators of providing ideas (claims), level 4 on indicators of analyzing data, providing rational justification and being able to validate or reject claims based on scientific evidence. This is also in accordance with research conducted by Amiroh & Admoko (2020) which states that the argumentation abilities of students on average increase from level 1 to level 3, but there are some who can reach level 4. Increased argumentation abilities also affect the improvement of understanding of physics concepts. Another study by Utami et al. (2022) showed an increase in the level of argumentation at pretest at level 1, namely students were only able to mention claims, then at posttest at levels 3 and 4, namely students were able to express claims, data, warrant, and backing. This is because the ADI model learning aims to create a classroom atmosphere that can help students in building understanding and providing scientific evidence, thus making students better understand how to compile good scientific argumentation.

There are many variations of the use of the ADI model in the learning process, especially in the scientific argumentation component studied. One of them is research conducted by Yuli Andriani (2023) which shows that the application of the Argument Driven Inquiry learning model can significantly improve students' written argumentation abilities compared to learning with guided inquiry. The study used 4 indicators of scientific argumentation components, namely claim, data, warrant, and backing. Therefore, the researcher used 6 indicators of scientific argumentation components namely claim, data, warrant, backing, qualifier, and rebuttal as a research novelty. This is supported by suggestions from previous research conducted by Nur Hanifah and Setyo Admoko (2019), namely the need for a more complex scientific argumentation integrated question instrument at level 5 or consisting of 6 indicators of scientific argumentation in order to stimulate students in scientific argumentation at level 5. The novelty of this research is the use of 6 indicators of scientific argumentation components, namely claim, data, warrant, backing, qualifier, and rebuttal as well as the use on the topic of of light wave that has never been done before. Based on the background description, a study was compiled with the aim of describing the improvement of students' scientific argumentation abilities on the topic of light waves after the application of the ADI learning model. Through the ADI learning model, it is hoped that it can improve the scientific argumentation abilities of students in physics learning, and produce students who are competent in 21st century learning, and can be used as an alternative to physics learning in the future.

METHOD

The type of research used is True Experimental Design, so that in this study a comparison group (control) is presented so that the results obtained from the treatment can be known with certainty (Arikunto, 2013). This research design uses Control Group Pretest and Posttest.

Table 1. Research Design *Control Group Pretest and Posttest*

Group	*Pretest*	Treatment	*Posttest*
Experiment	O_1	X	O_2
Control	O_1	-	O_2

(Arikunto, 2013)

Description:

O_1 : Pretest (initial test) conducted in experimental and control classes aims to describe the initial ability of students before being given treatment.

X : Application of ADI learning model to improve students' scientific argumentation.

\- : Application of learning models commonly practiced in schools.

O_2 : The posttest (final test) conducted in the experimental and control classes aims to describe the scientific argumentation abilities of students after being treated.

In this study using a population that is all students of class XI MIPA at SMAN 16 Surabaya. This class consists of eight classes that get physics material (XI MIPA 1, XI MIPA 2, XI MIPA 3, XI MIPA 4, XI MIPA 5, XI MIPA 6, XI MIPA 7, XI MIPA 8). By using the cluster random sampling technique, 2 classes were obtained as samples, namely class XI MIPA 7 as the experimental class and class XI MIPA 6 as the control class. In collecting data to measure students' scientific argumentation abilities, researchers used a test method in the form of a pretest-posttest on students. The pretest-posttest was carried out using question instruments and scientific argumentation assessment rubrics that had been prepared by researchers. The category of students' scientific argumentation ability is based on the level of scientific argumentation according to Inch (2006), are shown in **Table 2.**

Table 2. Toulmin Model Argument Scoring Matrix (Adapted from Inch Framework)

Level	Criteria
1	Consists only of claims
2	Consists of claim, data, and/or warrant
3	Consists of *claim, data, warrant, and backing/qualifier/rebuttal*
4	Consists of *claim, data, warrant, backing,* and *qualifier/rebuttal*
5	Consists of *claim, data, warrant, backing, qualifier and rebuttal*

(Inch, 2006)

Data testing was carried out using the data analysis prerequisite test which consisted of normality test and homogeneity test. Normality test and homogeneity test were conducted from pretest and posttest results. Normality testing was carried out using the chi squared test equation, while homogeneity testing was carried out using the bartlett test equation. Tests on the learning process according to the analysis of its implementation refer to the assessment of paired t-test, one paired t-test, n-gain analysis, and effect size. The scientific argumentation ability of students can be said to increase in terms of the n-gain score reaching value of $\geqslant 0.30$ with a minimum category of medium. The effectiveness of the ADI learning model can be said to have an effect on improving students' scientific argumentation skills in terms of the effect size value of $\geqslant 0.51$ with a minimum category of strong.

RESULTS AND DISCUSSION

Before implementing physics learning with the Argument Driven Inquiry (ADI) model which aims to analyze the effect of the ADI model on scientific argumentation abilities, researchers hope that the results obtained are in accordance with predetermined objectives. Before being given treatment by applying the ADI model, students take the initial scientific argumentation ability test (pretest). After being treated, students will be given questions again, namely the final scientific argumentation ability test (posttest). The test consists of 4 essay questions, each of which has fulfilled 6 indicators of scientific argumentation abilities including claim, data, warrant, backing, qualifier, and rebuttal.

Previously, the normality test and homogeneity test were carried out as prerequisite tests for hypothesis testing. Normality test is used to describe whether the research data is normally distributed or not. The results of the normality test calculation are shown in **Table 3.** Based on **Table 3**, can be known that the value of $\chi^2_{\text{count}} < \chi^2_{\text{table}}$, so H_0 is accepted, it can be concluded that the pretest and posttest results from both classes are normally distributed.

Table 3. Results of Normality Test Calculation

Data	Class	α	dk	χ^2_{count}	χ^2_{table}	Conclusion
Pretest	Experiment	0.05	6	6.91	12.59	Normal
	Control			4.54		
Posttest	Experiment			5.52		
	Control			7.60		

Homogeneity test is used to describe that the research data is homogeneous or not. The results of the homogeneity test calculation are shown in **Table 4.** Based on **Table 4**, can be known that the value of $\chi^2_{\text{count}} < \chi^2_{\text{table}}$, so H_0 is accepted, it can be concluded that the pretest and posttest results of the two classes are homogeneous.

Table 4. Results of Homogeneity Test Calculation

Data	Class	S^2	S^2_{combined}	B	χ^2_{count}	χ^2_{table}	Conclusion
Pretest	Experiment	16.61	15.70	80.13	0.11	3.84	Homogeneous
	Control	14.77					
Posttest	Experiment	34.68	28.06	97.02	1.98		
	Control	21.24					

After the prerequisite test is carried out and the data is declared normal and homogeneous. Next, a paired t-test was conducted which aims to describe the differences in the pretest and posttest scores of students' scientific argumentation. This test is conducted to describe whether or not there is a difference in the results of research before and after being treated using the ADI learning model on students' scientific argumentation abilities. The results of the paired t-test calculation are shown in **Table 5.**

Table 5. Result of Paired t-test Calculation

Class	t_{count}	t_{table}	Conclusion
Experiment	6.60	2.03	H_0 rejected
Control	1.65		H_0 accepted

Based on the results of the paired t-test shown in **Table 5**, can be known that the t_{count} value in the experimental class is greater than the t_{table} value. This shows that in the experimental class H_0 is rejected, so H_1 is accepted, namely there is a difference from the pretest and posttest scores. In the control class, the t_{count} value is smaller than the t_{table} value. This shows that in the control class H_0 is accepted, that is, there is no difference from the pretest and posttest scores.

The one paired t-test was used to describe whether the average results of the scientific argumentation abilities of experimental class students who used the application of the ADI model were better than the average results of the scientific argumentation abilities of students in the control class without using the application of the ADI model in learning activities. This one paired t-test was conducted on the posttest value of students' scientific argumentation. Table 6 shows the results of the one paired t-test**.** Based on **Table 6**, can be known that $t_{count} > t_{table}$, so H_0 is rejected, it can be concluded that the average scientific argumentation ability of experimental class students is better than the average results of the scientific argumentation ability of control class students.

Table 6. Result of One Paired t-test Calculation

Test Class	Comparison Class	t_{count}	t_{table}	Conclusion
Experiment Class	Control Class	12.72	1.65	H_0 rejected

The n-gain analysis aims to describe how much the students' scientific argumentation abilities have improved after applying the ADI learning model. The results of the pretest and posttest scores of scientific argumentation were calculated using the n-gain formula. The following are the results of the n-gain value in the experimental and control classes listed in **Table 7.** Based on **Table 7**, the average n-gain value of the number of students in the experimental class was 0.60 with a moderate category, while the control class obtained an n-gain of 0.26 with a low category. So, it can be seen that there are differences in the improvement of students' scientific argumentation abilities between the experimental and control classes.

Table 7. Result of *n-gain* Calculation

Class	*n-gain*	Category
Experiment	0.60	Medium
Control	0.26	Low

Effect Size analysis was conducted to describe the effectiveness of the learning model used in the study. Effect Size was conducted on the pretest and posttest scores of students' scientific argumentation. The results of the Effect Size calculation obtained are shown in **Table 8.** Based on **Table 8** shows that the ADI learning model is effectively used in learning and is included in the strong criteria.

Table 8. Result of *Effect Size* Calculation

Class	*n-gain score*	*Std. Deviation*	*Effect Size*	Criteria
Experiment	0.60	0.094	0.88	Strong
Control	0.26	0.087		

The analysis of students' scientific argumentation abilities was carried out by analyzing students' pretest and posttest answers based on the level of argumentation according to Inch (2006) in Table 2 can be seen in **Figure 1.**

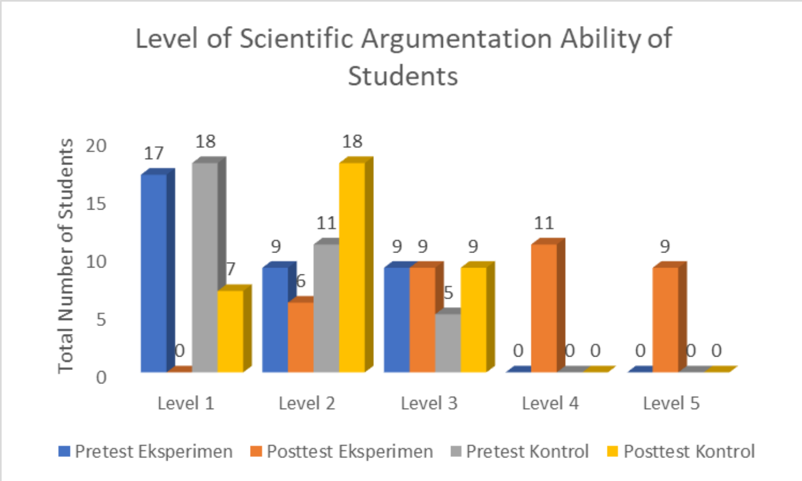

Figure 1. Level of Scientific Argumentation Ability of Students

Based on **Figure 1**, the results of the leveling analysis of students' scientific argumentation abilities, it shows that there is an increase in the level of scientific argumentation in the experimental class. In the pretest, experimental and control class students were at levels 1, 2, and 3. There was an increase in the scientific argumentation ability of students in the experimental class after applying learning with the ADI model. This is indicated by the posttest results of experimental class students who experienced an increase in scientific argumentation at levels 4 and 5. Meanwhile, the posttest results of students in the control class were relatively the same as the pretest results, namely at levels 1, 2, and 3.

In the first scientific argumentation component, namely claim, students are able to provide initial ideas related to the question in the form of a relationship between the slit-to-screen distance variable and the distance of the center of the first bright band from the central bright band. This is because the first syntax of the ADI model, namely identify the task and the guiding question, provides opportunities for students to develop initial ideas to find out how things work or why things happen (Grooms et al., 2015). So that by practicing indicators on the claim component can result in students being able to conclude the explanation that has been given during learning (Andriani, 2023).

In the second scientific argumentation component, namely data, students are able to provide appropriate evidence and support the initial idea in the form of a graph of the relationship between the slit-to-screen distance variable and the distance of the center of the first bright band from the central bright band, accompanied by variable information on the x and y axes, the scale value of the data provided, and the results of the relationship between the two variables. This is because the third syntax of the ADI model, namely analyze data and develop an initial argument, provides opportunities for students to interpret data to suggest data that can support claims (Grooms et al., 2015). So that by training indicators in the data component can result in students being able to provide appropriate evidence and support initial ideas. This is in line with Pritasari et al. (2015) who argued that aspects of argumentation can be developed through the right learning process.

In the third scientific argumentation component, namely warrant, students are able to explain the shape and description of the graph that has been made based on the data obtained from the questions given. This is because, in the third syntax of the ADI model, namely analyze data and develop an initial argument, it provides opportunities for students to compile explanations of investigation data and put forward evidence in science (Grooms et al., 2015). So that by practicing indicators on the warrant component can result in students being able to explain the relationship of evidence to the initial idea appropriately. Kuhn (2010) states that argumentation is said to be scientific if one's argument is not only in the form of a theory, but must also be proven in real terms.

In the fourth scientific argumentation component, namely backing, students are able to provide theoretical justification through appropriate related physics concepts, namely light interference and the equations used. This is because, in the fourth syntax of the ADI model, the argumentation session provides opportunities for students to evaluate data using one or more science concepts during the investigation to strengthen the arguments that have been made (Grooms et al., 2015). So that by practicing indicators on the backing component can result in students being able to provide rational theoretical justification so that initial ideas and evidence can be accepted. In line with Handayani (2015), it is argued that the low level of scientific argumentation can be due to students' lack of conceptual mastery. Students only issue opinions according to what is known, but not yet based on evidence or theory. Students will find it easier to make scientific arguments if they already have a good concept.

In the fifth scientific argumentation component, namely qualifiers, students are able to provide justification for the initial idea clearly, in the form of a way to increase the distance value of the center of the first bright band from the central bright band. This is because the fifth syntax of the ADI model, namely explicit and reflective discussion, provides opportunities for students to develop the arguments they use by identifying concepts related to evidence in situations that match the question (Grooms et al., 2015). So that by practicing indicators on the qualifier component can result in students being able to provide justification for the initial idea clearly. Kumala (2017) mentioned that scientific argumentation plays an important role for students to improve their ability to think critically, be able to solve problems, and make arguments that connect scientific logic so that arguments can be accepted by others.

In the sixth scientific argumentation component, namely rebuttal, students are able to provide statements that are exceptions or refutations of the initial idea, namely providing refutations related to factors that affect the distance of the center of the first bright band from the central bright band. This is because, in the seventh syntax of the ADI model, namely double-blind group peer review, it provides an opportunity for students to review each other's reports, by providing criticism and suggestions. Students must defend claims based on evidence and evaluate evidence that supports claims. If they cannot defend their claim, then students must provide a statement that is an exception / refutation of the claim appropriately (Grooms et al., 2015). Therefore, by practicing the indicators in the rebuttal component, students can provide a statement that is an exception/refutation of the initial idea. Students can be trained to express opinions and provide statements both support and refutation based on data and logical reasons (Sudarmo et al., 2018).

In line with the results of research by Andriani (2023) that the application of learning with the ADI model can significantly improve students' written scientific argumentation abilities compared to the guided inquiry learning model. This is because the ADI model aims to create a classroom atmosphere that can help students in building understanding and providing scientific evidence, thus making students better understand how to compile good scientific argumentation (Sampson et al, 2011). Another study by Utami et al. (2022) showed an increase in the level of argumentation at pretest at level 1, namely students were only able to mention claims, then at posttest at levels 3 and 4, namely students were able to express claims, data, warrant, and backing. This is supported by research conducted by Siregar & Pakpahan (2020) which shows that the ADI learning model has a significant effect on the science argumentation abilities of junior high school students. The results of the argumentation level have increased in the experimental class to reach level 4, while the control class is dominant at levels 1 and 2 which are above 25%. The findings on students' scientific argumentation abilities are in accordance with research conducted by Dulim & Madlazim (2022) which states that in argumentation-based learning, students' scientific argumentation abilities are able to reach level 5 for indicators of providing ideas (claims), level 4 on indicators of analyzing data, providing rational justification and being able to validate or reject claims based on scientific evidence. This is also in accordance with research conducted by Amiroh & Admoko (2020) which states that the argumentation abilities of students on average increase from level 1 to level 3, but there are some who can reach level 4. Increased argumentation abilities also affect the improvement of understanding of physics concepts.

Another study by Pujianto et al. (2023) showed an increase in the ability of scientific argumentation in physics education students in attending research methodology lectures. From the results of data analysis, the average value of initial scientific argumentation was 70.67% and increased to 84%. So, it can be concluded that the application of the ADI learning model can improve the scientific argumentation abilities of physics education students. In line with research by Nasution (2019) states that there is an influence on students' scientific argumentation abilities by using the ADI learning model, where there is an increase in scientific argumentation abilities in students with the ADI learning model higher than using conventional learning, where the experimental class obtained data on improving students' argumentation abilities 76.06 and the control class 70.66. This is also in accordance with research conducted by Firdaos, et al. (2021), namely that there are differences in students' argumentation abilities using ADI learning model. Based on the results of the n-gain test, it was revealed that the improvement in argumentation abilities in the experimental and comparison classes had an increase in the moderate category. However, the average n-gain value of the experimental class was 0.67, which was greater than the improvement in argumentation abilities obtained by the comparison class.

This shows that ADI learning has a greater average value than classes that use conventional learning to increase student argumentation even though both are in the medium category. Another study by Putri et al. (2020) stated that the ADI learning model proved effective in improving students' scientific argumentation abilities. This can be seen from the average total score of students' scientific argumentation abilities test, where the ADI class is the highest among the three classes, namely the average score of Argument-Driven Inquiry class students is 14.70; guided inquiry class is 10.28; confirmation class is 8.58. In addition, the quality of scientific argumentation abilities of students taught with ADI learning model is the best among the three classes. Most of the students in the ADI class were able to organize arguments strongly and correctly even reaching the highest level (level 5). Although the majority of students' answers in the three classes were level 2, but in the guided inquiry and confirmation classes only a few students were able to reach level 4, and none were able to reach level 5.

Researchers train students' scientific argumentation on the sub topics of light dispersion, light interference, light diffraction, and light polarization. Based on the findings, it can be seen that there are differences in the scientific argumentation abilities of students in experimental and control classes. In the experimental class that used the ADI learning model, there were differences in the scientific argumentation abilities of students before and after learning, this was due to the advantages of the ADI model which could make students learn to argue. The scientific argumentation abilities of students who are given the application with the ADI learning model are able to reach the high category, namely at level 4 to 5 argumentation. The limitations of this study only discuss on the topic of light wave, and there are no technology-based learning tools such as Augmented Reality (AR) and Virtual Reality (VR). Then, the implementation of the ADI learning model which requires a relatively long time, so that the number of meetings of two meetings is still insufficient to improve the scientific argumentation skills of students. In addition, a good time allocation is needed in the syntax of the ADI learning model so that its implementation can be carried out optimally. It can be ascertained that the results of this study have positive implications for various parties involved in this study. from the results of research on the average difference in the results of significant scientific argumentation abilities between the control class sample group and the experimental class provides implications that must be observed, where with the application of an argumentation-based learning model that has never been applied in schools before, namely the ADI learning model, students get different results and have positive developments.

CONCLUSION

Based on the results of the research that has been done, it is concluded that the scientific argumentation ability on the topic of light waves of students increases as a result of the application of the Argument Driven Inquiry (ADI) model. The increase in argumentation abilities can be seen from the average n-gain value in the medium category in the experimental class, while in the control class the average n-gain value is obtained in the low category, this is because learning in that class uses the usual lesson plan applied at school. In the effect size analysis, the value is obtained in the strong criteria. Thus, it can be concluded that the ADI learning model can improve students' scientific argumentation abilities and is effective to be implemented.

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