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Improving Students' Understanding of Science Concepts: is there a Relationship Between Learning Models and Academic Ability?

Neni Hasnunidah[1*], Undang Rosidin[2], & Nina Kadaritna[3]
[1]Department of Biology Education, University of Lampung, Indonesia
[2]Department of Physics Education, University of Lampung, Indonesia
[3]Department of Chemical Education, University of Lampung, Indonesia

Abstract: The Argument-Driven Inquiry (ADI) learning model, which is considered appropriate for use in higher education, is still not able to overcome students' difficulties in developing argumentative discourse so that their understanding of concepts tends to be low. The management of the learning process for students with different academic abilities requires scaffolding in the ADI model which is implemented gradually from the class, group, and individual levels. This research has produced an Argument-Driven with Scaffolding (ADIS) model which is a modification of the ADI model with the addition of standpoints and phasing. Standpoint as a statement of claim functions in generating arguments through debate. Meanwhile, the phases consisting of initiation, development, and reinforcement function in the development of individual argumentation skills. This study aims to compare the understanding of the concept of students with different academic abilities by using ADI, ADIS, and conventional learning models. The design of a non-equivalent pre-test-post-test control group was used on 180 prospective science teacher students at the University of Lampung. The concept comprehension test is used to measure students' ability to understand the concepts taught from answers in the form of essays. The test questions relate to the level of thinking from Bloom's cognitive domain, namely remembering, understanding, applying, analyzing, evaluating, and creating. The results of the analysis of students' concept understanding data using ANCOVA showed that the achievement of concept understanding with the ADIS learning model was equivalent to ADI but higher than the conventional model. Students with high academic ability have a higher understanding of concepts compared to students with low academic ability. The highest average concept understanding was achieved by students with high academic ability in the ADIS class, while the lowest average was achieved by students with low academic ability in the Conventional class. The ADIS model has been proven to be able to train students' skills in drafting high-quality arguments and participating productively in scientific arguments in stages so as to improve understanding of concepts. Standpoint as a starting point in argumentation development and phasing (initiation, development, and reinforcement) in the ADIS model is effectively used as a scaffolding for students to develop argumentation skills both classically, in groups, and individually.

Keywords: academic ability, argument-driven inquiry, conceptual understanding, scaffolding.

▪ INTRODUCTION

Understanding a concept is the ability to absorb the meaning of matter or an abstraction that describes the general characteristics of a group of objects, events, or other phenomena being studied. This ability shows that students can grasp ideas in transferable ways, helping them take what they learn in class and apply it across domains. Moreover, meaningful student understanding of science concepts and topics is useful for science education programs to achieve their goals (Glynn & Duit, 2012). Understanding a concept involves elaborating on and adding new knowledge to previous knowledge, where new information is elaborated into an organizational structure that is already in memory. When

Neni Hasnunidah
*Email: neni.hasnunidah@fkip.unila.ac.id

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students learn, they often act on their prior knowledge, assumptions, and understanding that they have about certain situations. This is where developing conceptual understanding and associations comes in. We must prepare our students to be able to make decisions and use deeper understanding to process new information. Many researchers have shown that the development of understanding concepts can improve natural science achievements (Chiang et al., 2014; Widiyatmoko & Shimizu, 2018).

The results of a preliminary study in science learning revealed that an understanding of science concepts in Indonesian students was still low (Hasnunidah, 2016). The conceptual understanding of students of science concepts has not been comprehensive or is still separate from each other. Most students have not achieved a good way of utilizing science concepts to sort through and give meaning to new ways of thinking. Students still find it difficult to internalize the concepts obtained as a basis for thinking. Science should be taught by an approach experienced by researchers or scientists as they develop the knowledge themselve. When scientists defend theories and explanations by offering evidence and arguments, this is called argumentation.

Several studies have examined the relationship between argumentation and conceptual understanding. These studies can be conceptualized into two lines of research: (1) studies investigating the impact of argumentative activities on students’ conceptual understanding. Student involvement in argumentation contributes to improving the understanding of the concept (Chen et al., 2016). The argument can provide a strong foundation for understanding a concept and fact (Shestack, 2017). The goal of the thinking process in argumentation is the truth about the subject being argued (Makhene, 2017). Through argumentation, one can show statements (theories) that are expressed correctly or not by referring to the facts and evidence. (2) The effect of content of knowledge on the argumentation. Students’ understanding of a concept may influence the quality and quantity of the argumentation they construct (Cetin, 2014).

Conceptual understanding, based on the dimensions of Bloom’s cognitive processes, which were revised by (Anderson & Krathwohl, 2001) is a cognitive process for reading and understanding images, reports, tables, diagrams, directives, and regulations. In other words, understanding is the ability to communicate ideas in various forms of communication. Understanding a concept is the ability to absorb material meaning or an abstraction that describes the general characteristics of a group of objects, events, or other phenomena studied. The study of understanding important concepts is performed to determine how to understand and develop appropriate material. Meaningful understanding of students’ science concepts and topics is useful for science education programs to achieve their goals (Kılıç & Sağlam, 2014).

Students’ conceptual understanding, which differs by student, requires a learning condition that involves a learning experience so that the potential for argumentation skills can be developed (Larraín, 2017). Argumentation skills can be incorporated into learning by teachers, so teachers should be able to carry out the mandate of developing students’ argumentation skills. Through the application of argument-based learning models, students showed an increase in terms of understanding concepts about science (Aslan, 2019; Chen et al., 2016; Effendi-Hasibuan & Bakar, 2020; Memiş, 2016). Students need to learn how to construct an argument, choose supporting evidence, and compile a rebuttal. Argument-based learning models for students are based on theoretical concepts that education aims to facilitate students to achieve an understanding that can be expressed verbally, numerically, and in a frame of mind (Neal, 2017; Rapanta, 2019; Soysal, 2021).

One of the argument-based learning models is Argument-Driven Inquiry (ADI). Various advantages have been found in using the ADI learning model to improve student's knowledge and skills through their participation in scientific arguments through inquiry activities. However, facing the problem of underdeveloped discourse of argumentation among students, the practicing of oral and written argumentation skills by each student through investigation is a difficult job. Some researchers also explained the difficulties in using the ADI learning model: (1) some students had difficulties in discussing ideas in participating in scientific arguments and many of them did not use scientific explanations as a tool to solve problems or to evaluate claims (Sampson et al., 2011); (2) students tend to use the minimum evidence needed to describe their conclusions (Walker et al., 2011); and (3) students can provide arguments with accurate claims and strong evidence, but still did not use the relevant rationale (scientific theories, models, or laws) (Sampson et al., 2012). Hence, this study can be considered as one of the first attempts to develop and implement the ADI instructional model with Scaffolding (ADIS) in Indonesia. A lecturer needs to develop scaffolding for his students to develop their argumentation skills It is supported by opinions.

ADIS is a modification of the ADI learning model, incorporates tiered arguments guided by standpoints at each level (Amelia et al., 2020; Hasnunidah et al., 2015). Arguments serve to defend or refute the standpoint in debates, promoting critical thinking and dialogue among students. Creating explicit debates with complete arguments including claims, evidence, and rationale is crucial for educators. Quality arguments include refutations, indicating a high level of argumentation ability and student involvement. Refutations demonstrate students' ability to provide evidence against others' claims, fostering dialogical conversations (Crowell & Kuhn, 2014). The ADIS model encourages active student participation in inquiry, argumentation, writing, and reviewing activities at the class, group, and individual levels. It follows a tiered guidance approach with initiation, development, and strengthening phases.

Students in a classroom naturally have variations of academic abilities, namely, high, medium, and low abilities. The polarization of students with high or low academic ability in a school has an impact on teachers' teaching patterns. This condition related to the numerous differences found on the students having high academic ability and those having low academic ability. Students with high academic ability have better learning orientation and learning habits, a high need for achievement, hope for success, and a higher persistence as well as perform better at completing problem-solving tasks and in consequence tests (Rezaee et al., 2022). Meanwhile, students with low academic ability are often associated with failure in education (Al-Zoubi & Younes, 2015).

As there is a marked difference between students with high academic ability and those with low academic ability, and the teacher's teaching patterns, the gap between these two types of students is wider. The gap between students with high and low academic abilities should be taken into consideration, and it was expected that the gap becomes smaller in the learning process and learning results. Therefore, efforts must be made to minimize the gaps among students based on their academic ability to improve students' learning quality and increase the potential of their creative thinking abilities. The gaps between the students with high and low academic abilities can be minimized by the integration of the ADI and ADIS learning models. Therefore, several questions need to be asked, namely: 1) Is there an influence of the learning model on students' understanding of concepts?; 2) Is there an influence of academic ability on students' understanding of concepts?; 3) Is there an influence of interaction between ADI, ADIS, and Conventional learning models with academic ability on students' understanding of concepts? The results of this research are expected to be considered by teachers to implement the ADI and ADIS learning models to improve the learning quality and thinking abilities, especially creative thinking, of students with low academic abilities.

▪ METHOD

Participants

The population in the study was all students of the Department of Mathematics and Natural Sciences Education, Faculty of Teacher Training and Education, University of Lampung who were taking the Science Biology course when the research was conducted. The entire population is divided into 6 classes from 3 different study programs (Biology, Physics, and Chemistry Education). Each study program has two classes (Grades A and B). The determination of the sample class consisting of 180 students was selected using a random sampling technique. There were 60 student participants in the ADI group, 60 in the ADIS group, and 60 in the conventional group. A total of 86.1% were female students and 13.9% were male students.

Research Design and Procedures

In this study, we used the pre-test–post-test non-equivalent control group design (Table 1). The first class used the ADI learning model, the second class used the ADIS learning model, and the third class used the conventional model. There were two 220-minute sessions per week for each group and the program was conducted over 16 weeks.

Table 1. Quasi-experimental research design

Pre-test	Group	Post-test
O1	X1A1	O2
O1	X1A2	O2
O1	X2A1	O2
O1	X2A1	O2
O1	CA1	O2
O1	CA2	O2

X1 = ADI model; X2 = ADIS model; A1 = low academic ability; A2 = high academic ability; C = conventional; O1= pretest score; O2 = posttest score

Before the treatment of ADI, ADIS, and Conventional learning models is used, a class equivalency test is first carried out with test techniques. The equivalency test aims to find out the initial ability of students from all three classes. The class equivalency test in this study uses grouping data derived from 60% of the UN score and 40% of the placement test score. The class equivalency test uses variance analysis (ANOVA). Based on the results of the ANOVA test on the average UN score and grouping data, it is known that the statistical value is F = 0.01 with a significance number = 0.99, so there is no significant difference in ability between students in the three classes (ADI, ADIS, and Conventional). This means that the three classes selected have relatively homogeneous initial abilities so that all of these equivalent classes can be used as classes for the implementation of experimental research.

This study was conducted over 16 weeks of the basic biology course. The ADI, ADIS, and conventional groups were assigned to carry out this quasi-experimental study. The conventional group was taught by using traditional basic biology instructions, whereas the experimental groups were instructed by using the ADI and ADIS instructional methods. The ADI process was defined as follows: (1) identification of a research question; (2) generation of data through systematic observations or experimentation; (3) production of tentative arguments; (4) argumentation session; (5) creation of a written investigation report; (6) double-blind peer review; (7) revision of the report based on the peer review; and (8) reflective discussion (Sampson et al., 2011). The ADIS process included three stages: initiation, development, and reinforcement, as described in Table 2 (Hasnunidah et al., 2015).

Table 2. Student activity in the argument-driven inquiry with scaffolding (ADIS) model

Syntax	Lecturer Activity	Student Activity
The Initiation Phase		
Stage 1. Development of class standpoint	Explain the learning model, logistics, and how to implement it. Deliver the learning objectives. Propose the phenomena related to the emergence of class standpoints. Encourage students to develop their class claims, whether to approve or refute the class standpoint. Guide students to take up research assignments in the student worksheet.	Pay attention and record learning objectives. Develop the class claims that approve or resent the class standpoint. Observe the research tasks in the student worksheet.
Stage 2. Collecting the data class	Organize the student groups into two camps: the camp that agreed to the standpoint and the camp that denied the standpoint. Guide students in laboratory investigations to look for evidence and a sound basis to support claims that approve or refute the standpoint.	Condition yourself by the camp that approves or refutes the standpoint. Investigate evidence and look for a sound basis to support claims that approve or refute the standpoint according to the student worksheet.
Stage 3. Production of tentative class argument	Guide students to process and analyze the data collected. Facilitate students to build arguments and to write them down in argumentation schemes.	Analyze data obtained from the research process. Produce works in the form of argumentation schemes written in the student worksheet and blackboard.
Stage 4. Interactive session of class argument	Guide debates to criticize the arguments and refine the rationale between agreeing fortresses and opposing standpoints.	Debate to criticize arguments and improve the basic reason between the two camps that approve or refute the standpoints.

Stage 5. A written investigation of class report	Help students to plan and prepare the investigation reports as directed in the student worksheet. Assign students to compile an investigation report.	Compile individual research reports that explain the investigation purpose and steps and provide sound arguments.
Stage 6. Peer review of class report	Guide students to evaluate the investigation report's quality through review sheets.	Evaluate the investigation reports by using the review sheet.
Stage 7. Revising the process of class report	Encourage students to revise the investigation report.	Revise the report based on the peer review results.
Stage 8. Reflective discussion	Help students to reflect on the investigation process and results.	Reflect on the research process and results.
The Development Phase		
Stage 1. Development of group standpoint	Deliver the learning objectives. Propose the phenomena related to the emergence of group standpoints. Encourage students to develop their class claims, whether to approve or refute the group standpoint. Guide students to take up research assignments in the student worksheet.	Pay attention and record the learning goals. Develop the group claims into the group of approving or refuting the standpoint. Observe the research tasks in the student worksheet.
Stage 2. Collect and analyze the group's data	Organize students into groups that approve or refute the standpoint. Guide students in laboratory investigations to look for evidence and a sound basis to support claims that approve or refute the standpoint.	Condition yourself in a group to approve or refute the standpoint. Conduct group investigations to look for evidence and a sound basis to support claims that approve or refute the standpoint according to the student worksheet.
Stage 3. Production of group tentative argument	Guide students to process and analyze the collected data. Facilitate students to build arguments and to write them down in argumentation schemes.	Analyze data obtained from the research process. Produce works in the form of argumentation schemes written in the student worksheet and blackboards.
Stage 4. Interactive session of group arguments	Guide debates to criticize arguments and improve the basic reason between the camps that approve and refute the standpoint.	Debate to criticize arguments and improve the basic reason between groups that approve or refute the standpoint.
Stage 5. Reflective discussion	Help students reflect on the investigation process and results.	Reflect on the investigation process and results.
The Reinforcement Phase		
Stage 1. Development of individual standpoint	Deliver the learning objectives. Propose the phenomena related to the emergence of individual standpoints.	Pay attention and record learning objectives.

	Encourage students to develop their class claims, whether to approve or refute the individual standpoint. Guide students to take up research assignments in the student worksheet.	Develop the class claims that approve or refute the individual standpoint. Observe the research tasks in the student worksheet.
Stage 2. Collect and analyze individual data	Facilitate individual students in laboratory investigations to look for evidence and a sound basis to support claims that approve or refute the standpoint.	Conduct individual investigations to look for evidence and a sound basis to support claims that approve or refute the standpoint according to the student worksheet.
Stage 3. Production of individual tentative argument	Facilitate individual students to build student arguments according to data and results of data analyses.	Produce works in the form of argumentation schemes written in the student worksheet according to data and results of data analyses.
Stage 4. Interactive session of individual arguments	Guide debates to critique arguments and refine the rationale between agreeing individuals and strongholds that oppose standpoints.	Debate to criticize arguments and improve the basis of reason between individuals who approve or refute the standpoint.
Stage 5. Reflective discussion	Help students reflect on the process and results of the investigation.	Reflect on the research process and results.

This research ended with the posttest at the end of learning using the same questions as the pretest questions. Posttest is carried out to measure concept understanding after students are given learning treatment with ADI, ADIS, and Conventional models. Furthermore, a response questionnaire was given to students to explore information about the learning experience after learning was carried out. In the final stage, the data from the pretest and posttest results of student concept understanding and student response questionnaires in both ADI, ADIS, and Conventional classes are processed. Furthermore, an analysis of the data from the student response questionnaire was carried out and conclusions were made based on the results obtained from the analysis of the concept understanding data.

Instruments

The Conceptual Understanding Test (CUT) is an instrument used in this study both as a pre-test and post-test. This test is in the form of an essay with 28 questions. The test questions related to Bloom's cognitive level of thought, which were revised by (Anderson & Krathwohl, 2001), namely, remembering, understanding, applying, analysing, and creating. The Conceptual Understanding Test (CUT) questions are related to 10 main materials, namely: 1) Exploring Plant Tissues and Organs; 2) Exploring Human Tissues and Organs; 3) Mitosis; 4) Meiosis; 5) Photosynthesis; 6) Respiration; 7) Mendel's Law; 8) Patterns of inheritance of traits in humans; 9) Interaction of Organisms with the Environment; 10) Evolution. The scoring rubric of the CUT with a score range of 0–4.

Before the CUT is used, the validity and reliability test of the questions is first carried out. The validity of the question items is calculated by the product moment correlation formula. The results of the validity test obtained are compared at $\alpha = 0.05$, to determine whether the question item is valid or invalid, with the criterion: if the p value < 0.05, the question item is said to be valid, on the other hand, if $p > 0.05$, the question item is said to be invalid. Meanwhile, the formula used to measure the reliability of the test in this study is the Alpha Cronbach formula. The rvalue obtained is compared with the rtable to determine whether or not the CUT is reliable or not. If the rvalue is > rtable, the test instrument can be said to be reliable, on the other hand, if the rvalue is < rtable, then the test instrument is not reliable. The results of the validity test on the question items of the CUT showed that p value of each question item (from items 1 to 28) > 0.05, was greater than the p table (0.254 for α=0.05 or 0.330 for α=0.01) with N=59. Thus, all test questions are valid. Furthermore, the score of Alpha Cronbach's CUT (rvalue) is 0.832 > rtable (= 0.2564), so it can be stated that the reliability of this test question is categorized as very high.

Data Analysis

The descriptive statistics were measured for each variable and presented as scores of the ADI, ADIS, and conventional groups: the means, standard deviations, skewness, kurtosis, minimum, and maximum values. For the inferential statistics, analysis of covariance (ANCOVA) was conducted with three dependent variables, which were the post-CUT scores for the three groups; one independent variable, which was the program and students' academic abilities; and one covariate, which was the pre-CUT score. As the aim was to generalize results obtained from the sample to the population, ANCOVA with a significant value of 5% was appropriate. Before conducting ANCOVA, all variables were checked for assumptions of ANCOVA, which were normality and homogeneity of variances, and all assumptions were met.

▪ RESULT AND DISSCUSSION

Test Scores

The descriptive statistics with scores of the pre-test and post-test for the ADI, ADIS, and conventional groups are shown in Table 3. The minimum score for the pre-test was 7 and the highest score was 14 for all groups. Scores of this test were used to compare whether students display differences in previous learning of the conceptual understanding of science in the ADI, ADIS, and conventional groups. For example, can be seen in Table 3 below.

Table 3. Descriptive statistics for the variables

Descriptor	Learning Model	Academic Ability	N	Min	Max	Mean	SD	Skewness	Kurtosis
Pretest	ADI	High	30	14	35	22.69	5.44	0.615	−0.369
		Low	30	7	38	18.61	7.40	0.640	0.097
	ADIS	High	30	8	37	22.84	8.41	0.050	−0.984
		Low	30	9	33	17.55	5.33	0.755	0.846
	Conventional	High	30	7	43	20.82	8.09	0.504	0.341
		Low	30	10	27	17.76	4.45	0.274	−0.592
	Mean	High	30	10	38	22.12	7.31	0.390	−0.337
		Low	30	9	33	17.97	5.73	0.556	0.117

Posttest	ADI	High	30	59	93	77.45	9.44	−0.247	−0.775
		Low	30	45	90	72.90	10.30	0.686	0.633
	ADIS	High	30	58	94	77.85	8.77	−0.402	−0.166
		Low	30	43	81	66.88	8.87	−0.912	0.824
	Conventional	High	30	44	82	67.37	10.33	−0.816	−0.051
		Low	30	30	80	58.72	12.2	−0.152	−0.180
	Mean	High	30	54	90	74.22	9.51	−0.488	−0.331
		Low	30	39	84	66.17	10.46	−0.126	0.426

Based on data presented in Table 3, the mean post-test scores of the ADI, ADIS, and conventional groups between the two academic abilities (high = 74.22; low = 66.17) were higher than the mean pre-test scores (high = 22.12; low = 17.97). The mean post-test scores of the ADI group between the two academic abilities (high = 77.45; low = 72.90) were higher than those of the conventional group (high = 67.37; low = 58.72). Similarly, the mean post-test scores of the ADIS group between the two academic abilities (high = 77.85; low = 66.88) were higher than those of the conventional group. Meanwhile, the mean post-test score of students with high academic ability in the ADIS group (77.85) was higher than that in the ADI group (77.45). Conversely, the mean post-test score of students with low academic ability in the ADI group (72.90) was higher than that in the ADIS group (66.88). Although the mean post-test scores of ADI and ADIS between the two academic abilities (high and low) were higher than the mean pre-test scores, the amount of increase in the ADI and ADIS groups was much higher than that in the conventional group. This also shows that the ADIS learning model benefits the students.

The Effect of Learning Models on Students' Understanding of Science Concepts

The ANCOVA results are given in Table 4. The ANCOVA analyses indicate that there was a significant mean difference (F=24.266; p=0.000) between the ADI, ADIS, and conventional learning models regarding the collective dependent variables of the post-test between groups when the pre-test was controlled. In other words, there was a statistically significant influence of the learning models on the dependent variable.

Table 4. ANCOVA test results on the effect between subjects

	Type III Sum of Squares	**df**	**Mean Square**	**F**	***p***	**Partial Eta Squared**	**Noncen Parameter**	**Observed Power^b**
Corrected Model	10.731.505a	6	1.788.584	20.822	0.000	0.419	124.931	1.000
Intercept	59.911.456	1	59.911.456	697.459	0.000	0.801	697.459	1.000
Pretest Conceptual Understanding	2.720.616	1	2.720.616	31.672	0.000	0.155	31.672	1.000
Learning Models	4.168.844	2	2.084.422	24.266	0.000	0.219	48.532	1.000
Academic Ability	1.302.708	1	1.302.708	15.165	0.000	0.081	15.165	0.972
Learning Models*Academic Ability	262.070	2	131.035	1.525	0.220	0.017	3.051	0.321
Error	14.860.627	173	85.900					
Total	910.787.020	180						
Corrected Total	25.592.132	179						
Note: p < 0.05								

The comparison of the average value corrected for concept understanding for the three learning models can be seen in Table 5. In the table, the average value corrected for concept understanding in the ADI model is higher than that of the Conventional model. Likewise, the average corrected value of concept understanding in the ADIS model is higher than that of the conventional strategy. It can be said that in achieving concept understanding, the ADIS learning model is as effective as ADI, but both are more effective than the Conventional model.

Table 5. Comparison of mean corrected scores of understanding of science concepts between the three models

Learning Model	Pre-test	Post-test	Difference	Corrected	Statistic Notation
ADI	20.65	75.18	54.53	74.00	A
ADIS	20.19	72.37	52.17	72.14	A
Conventional	19.29	63.05	43.76	63.94	B

The results of this study support the hypothesis that students’ conceptual understanding is associated with the use of the learning model. The post-test scores of both the ADIS and ADI groups of students were statistically equal in terms of understanding science concepts, but both were higher than the post-test scores of the conventional group of students. This result is similar to those of several studies focusing on the effects of argumentation-based instruction using a pre-test–post-test design, which documented that students who were taught with argumentation-based instruction developed better conceptual understanding than those taught with the traditional instruction (Tsemach & Zohar, 2021).

The results indicate that activities such as investigation, argumentation, scientific writing, and peer review contribute to improved conceptual understanding. ADI and ADIS models enable students to construct concepts independently through laboratory investigations. Problem-based learning facilitates knowledge construction and reasoning skills compared to traditional teaching approaches, as it involves transferring concepts to new situations and integrating them (Wang et al., 2013). Our findings support this claim, as the identification task in ADI and standpoint development in ADIS present open-ended problems. These problems stimulate curiosity and motivate students to solve them, enhancing their concept mastery. Lecturers should make science relevant to students' lives, promoting understanding through direct experience and application in daily situations. Social interaction with peers during the knowledge construction process plays a crucial role in students' intellectual development (Jiang et al., 2023; Yücel & Usluel, 2016). Engaging in communication, criticism, debate, and revision of investigation results within the ADI and ADIS models contributes to improved conceptual understanding. Through these interactions, students clarify and reorganize their ideas. Scientific argumentation enhances science concept understanding (Hsu et al., 2015). Argumentation fosters knowledge-building through conversation, writing, listening, and reading. Concept elaboration occurs as new knowledge is integrated with existing organizational structures in memory (Jonassen et al., 2013).

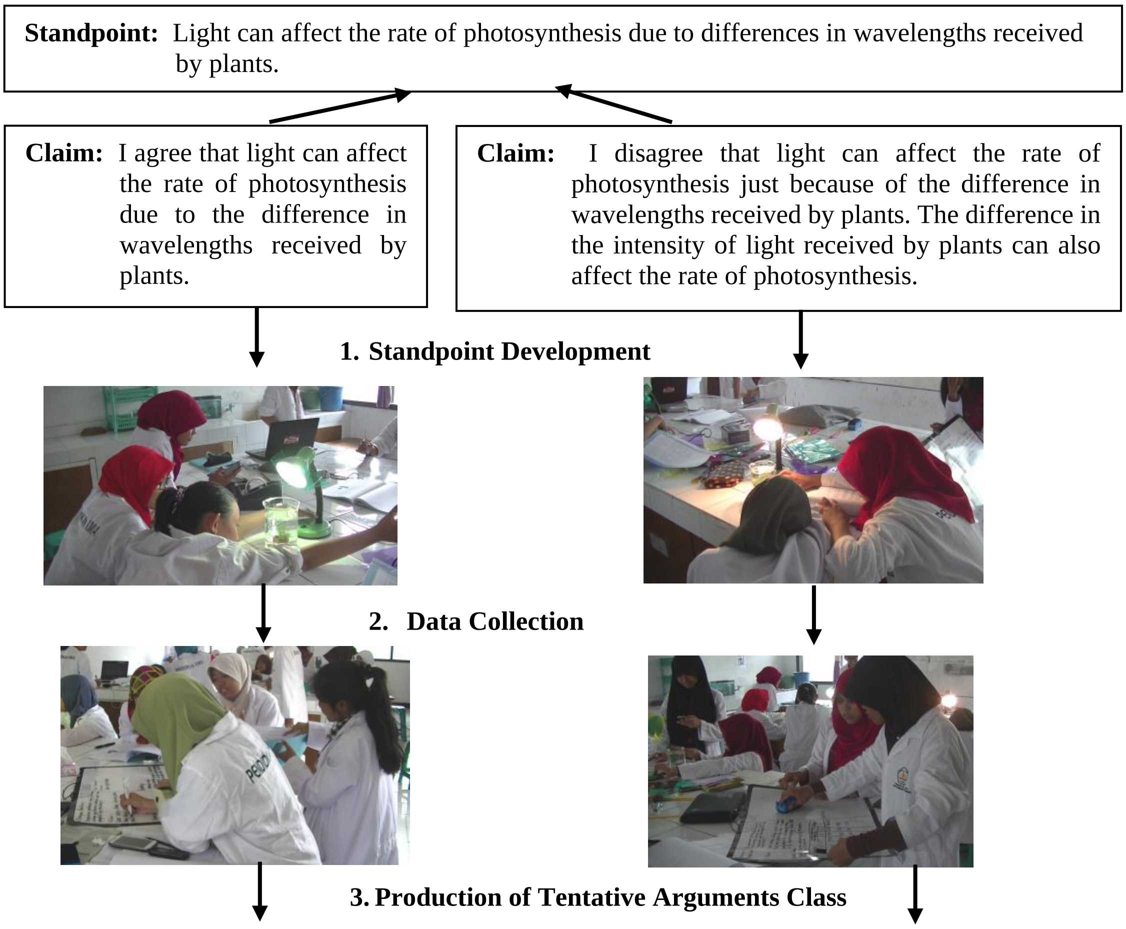
Students can display their knowledge about an object as they are listening, observing, and studying from other students in their group, based on the modification of their own results of understanding (Brown & Palincsar, 2018). We have seen how students have responsibility in their learning when they are given the opportunity to communicate. Students who use the ADI and ADIS models are given the opportunity to communicate both verbally and by writing, through “argumentation sessions.” Through this activity, cooperation between students in a group is involved, so that it enables them to influence and learn from each other. Reconstructing the concept in a small group is believed to greatly strengthen the learning process. Students are required to produce a report that answers three basic questions: What were you trying to do and why? What did you do and why? What is your argument? The aim of this report is to understand the goal of investigation and learn to write scientifically.

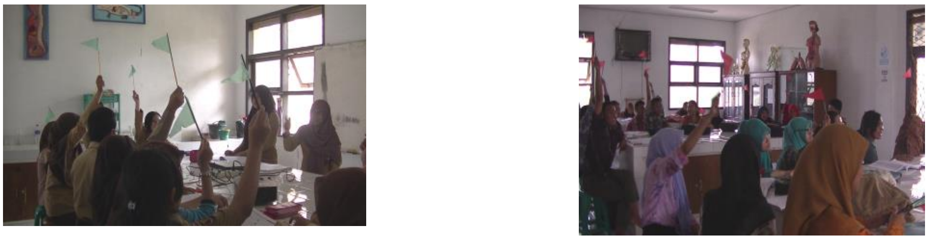
The writing process encourages metacognition, improves students’ understanding of the content, and develops a conceptual understanding for scientific inquiry. The ADI and ADIS learning models used in this study could enable students to integrate the writing activities as an important part of the scientific process. This finding supports that of (Sampson et al., 2011), who concluded that writing activities in the ADI model teach students the importance of sharing their research results through writing, reading, understanding other people’s writings, and evolving their values. This activity could help students to understand the topic and develop a better understanding of how to write scientific arguments.

The next learning activity in the ADI and ADIS learning models that made a major contribution to improving students’ conceptual understanding was reviewing, which ensures the quality of investigative reports. With the aim of engagement in the evaluation process added to the models, students assessed the other groups’ reports with a peer review sheet as part of a double-blind peer review. The double-blind peer review is expected to improve students’ metacognition, critical thinking skills, argumentation skills, and conceptual understanding (Erenler & Cetin, 2019). Reviewing activities can introduce students to educational feedback (Man et al., 2024), encourage the development and use of quality standards, help students become more metacognitive, and create a community that values evidence and critical and responsible thinking (Bae & Kwon, 2021); here, students can also see good examples of scientific argument, both strong and weak. Thus, through writing and reviewing activities, students are involved in scientific activities (Geithner & Pollastro, 2016) gain experience in the practice of the scientific community (Dogan et al., 2016; Geithner & Pollastro, 2016), receive feedback from the entire proces, and have the opportunity to learn from mistakes (Halim et al., 2018).

Based on the data from the results of Ancova in Table 5, it can be seen that the posttest scores of students in the ADIS group are higher than those in the ADI group. Several other reasons as to why ADIS is better than ADI in improving conceptual understanding in high school students can also be described based on their learning activities. This can be seen in the example of ADIS activities in learning about Photosynthesis in Figure 1. These findings indicate that students with high academic abilities can optimally improve their thinking processes through inquiry, argumentation, writing, and review activities carried out in a scaffolding way from the class to individual level compared to students with low academic abilities. The ADIS learning model is considered appropriate to be used in science learning, because arguments can be built through investigative activities in which all activities carried out by students are directed toward finding out and discovering their own answers from something that is questioned on a class, group, and individual scale (Hasnunidah et al., 2015). Science learning by using the ADIS model emphasizes on the student activities maximally to design and carry out investigations, argue, write, and review.

Argumentation in ADIS guide promotes critical thinking by encouraging students to generate ideas, evidence, and reasoning, evaluate different perspectives, and arrive at the most valid explanation. Critical thinkers ask relevant questions, effectively combine information, reason logically, and draw reliable conclusions. Standpoints serve as a starting point for developing tiered arguments in ADIS, facilitating the initiation, development, and strengthening of classical argumentation skills in classrooms and groups. Standpoints play a vital role in classical dialectics and are a functional element in Ferretti's argument (Ferretti, 2019). The ADIS learning model enabled science educators to integrate inquiry-based laboratory experiments with other subjects, such as reading and writing, in developing gradual scientific arguments at the class, group, and individual levels. The ADIS model had the potential to empower critical thinking skills through science learning. With all its advantages and disadvantages, we believe that the ADIS model can be implemented in science learning at the elementary, middle, and higher education units. Science educators can use the ADIS model as an alternative in designing science learning processes in the classroom.





4. Class Argument Interactive Session

5. Research Report Review **6. Report Revision Process** **7. Reflective Discussion**

Figure 1. Implementation of ADIS learning model

A factor that reduces the conceptual understanding of students who follow learning with conventional models is the lack of empowerment of students to learn optimally (E. Lee & Hannafin, 2016). According to the researchers, students have become "accustomed" to receiving knowledge transfer from lecturers, doing assignments (if any), and then studying the questions as the exam approaches. In other words, students' mindsets and learning styles, both in and out of lectures, have not involved high mental activity (Collings, 2019). Meanwhile, concept understanding is a key aspect of learning. One of the important learning objectives is to help students understand the main concepts in a subject, not just remember separate facts. Overall understanding allows students to learn more meaningfully rather than simply re-memorizing without meaning, then they can apply it in everyday life and carry out higher mental processes (Grove & Bretz, 2012).

The Effect of Academic Ability on Students' Understanding of Science Concepts

ANCOVA for the academic ability variables were also used to investigate whether there was any significant mean difference between high and low in terms of post-test scores. ANCOVA analyses showed a significant mean difference (F = 15.165; p = 0.000) between students with high and low academic abilities in terms of post-test scores (Table 4). This result showed that students with high and low academic abilities had a different understanding of science. For the high and low academic ability variables, LSD results were also used to investigate whether there was a statistically significant mean difference between the mean corrected scores. The results of the LSD test are presented in Table 6. LSD analyses showed that the mean corrected scores of students with high academic ability were higher than those with low academic ability. This result showed that the achievement of students with high academic ability was better than those with low academic ability.

Table 6. Comparison of mean corrected scores of understanding of basic biology concepts between the two academic abilities

Academic Ability	Pre-test	Post-test	Difference	Corrected	Notation
High	22.11	74.22	52.11	72.93	a
Low	17.97	66.17	48.19	67.32	b

The results also showed that academic ability significantly influenced students' conceptual understanding. Students with high academic ability have significantly better understanding of science concepts compared to students with low academic ability. The results of this study support previous relevant research. The success of the learning process is strongly influenced by the characteristics possessed by students, both as individuals and as groups. Students with the best academic ability tend to think critically more easily and make decisions faster (Kallet, 2014).

Grouping students based on academic ability is crucial for effectively educating a diverse student body. The analysis of this study results confirms the significant impact of academic ability on conceptual understanding, consistent with previous research findings. The academic ability has the significant influence on conceptual understanding (Almulla & Alamri, 2021). Students' initial academic ability greatly affects their participation in lecture activities (J. Lee et al., 2022). This study reveals higher conceptual understanding among academically capable students compared to underachieving students. Aligning with similar previous studies, (Zubaidah et al., 2020) research on reciprocal teaching-learning models found higher average scores in cognitive learning outcomes for students with higher academic ability. Intelligence significantly contributes to learning success (Mandelman et al., 2016). Intelligent students comprehend and retain lessons more easily than less intelligent or slower learners. Higher-ability students possess better initial states and greater confidence, influencing their success in the learning process (Fong & Krause, 2014). The academic ability of students strongly influences their critical thinking skills and decision-making abilities, as supported by the referenced literature (Lin et al., 2021; White, 2018).

The Impact of Interaction Between Learning Models with Academic Ability on Students' Understanding of Science Concepts

The ANCOVA results, as seen in Table 4, there was no statistically significant interaction between the program and academic ability on the post-test scores (F = 1.525; p = 0.220). This result indicates that the ADI, ADIS, and conventional learning models did not make any difference in the understanding of science by students with high and low academic abilities. From the results described above, it is known that there is no significant interaction effect between the learning model and academic ability and conceptual understanding.

The absence of an interaction was found between the learning model (ADI, ADIS, and conventional) and academic ability on conceptual understanding because of the strong influence of each learning model and academic ability on the learning outcome variables. In other words, there was no significant interaction between learning model and academic ability on conceptual understanding, as there was no dominant effect of learning model based on academic ability on conceptual understanding. Conversely, the effect of academic ability was not more dominant than the learning model on conceptual understanding. The absence of interaction between learning models (Contextual Direct and Direct Learning) and achievement motivation on cognitive learning outcomes and motor skills is due to the strong influence of each learning model and achievement motivation variables on learning outcome variables (Suprapto, 2015).

Although there was no effect of the interaction of the learning model with academic ability on the student's understanding science concept. We tried to compare students' understanding concept using the ADI and ADIS models. The results showed that the ADIS model is more effective in improving conceptual understanding among high-ability students compared to low-ability students. Several reasons contribute to this finding. Firstly, high-ability students have better initial conditions and higher self-confidence (Ku et al., 2014), leading to greater academic success. Secondly, academic abilities are influenced by study habits, and high-ability students exhibit good study habits, enhancing their academic performance (Vialle et al., 2015). ADIS provides a tiered learning experience that fosters good study habits in high-ability students. Conversely, low-ability students struggle with developing effective learning habits. Thirdly, debate is a key aspect of the ADIS model, as seen in figure 2. Based on Figure 2, it can be seen that student argumentative debates in the ADIS class show very complex interaction patterns, argumentative discourse develops with claims and counter claims that are equipped with more than one warrant and backing. Apart from that, this score also develops disputes over other students' data, warrants or backing. High-ability students excel in debates due to their strong conceptual understanding. Engaging in scientific debate requires solid prior knowledge. However, must be confirmed effective teacher facilitation ensures meaningful student participation and contributes to their conceptual development (E. Lee & Hannafin, 2016).

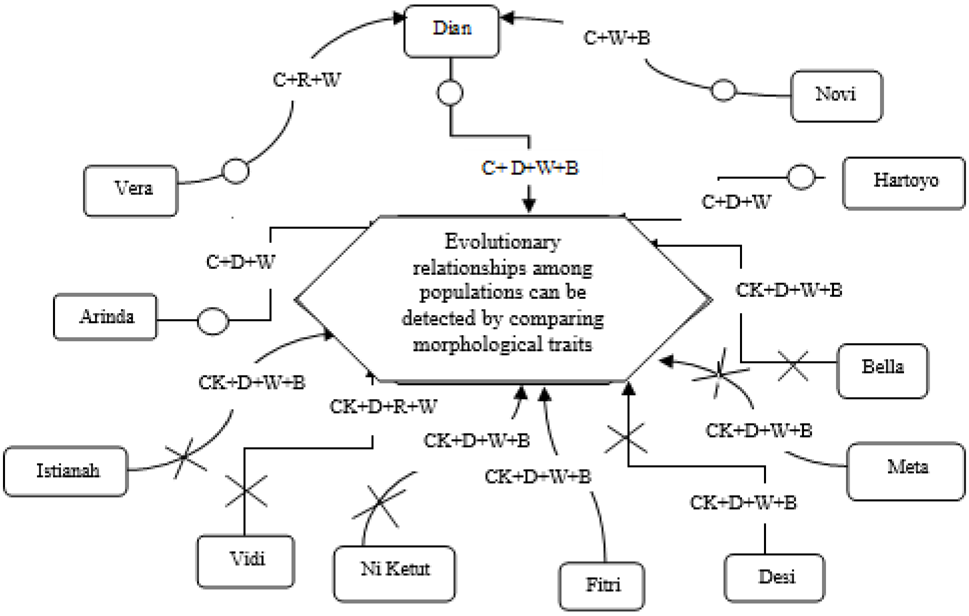


Figure 2. Examples of discourse patterns that develop in *ADIS* classes show high quality debate

▪ CONCLUSION

The learning model affects students' understanding of concepts. The ADIS model is just as effective as ADI in improving concept understanding compared to conventional models. Academic ability affects students' understanding of concepts. The understanding of the concept of students with upper academic ability is higher than that of students with lower academic ability. The ADIS model is inclined having a higher potency in enhancing the achievement of students with high and low academic abilities, in terms of understanding concept. It is believed that the ADIS model has appropriate learning stages needed by students with both high and low academic abilities, to enhance their achievements. Being involved in an argumentation and in the production of spoken and written argument in this study, the students improved their understanding concept. This study provides a contribution to science teachers and lecturers to implement learning models that involve scaffolding in classroom argumentation to develop the science and writing abilities of the students.

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