Jurnal Pendidikan dan Pengajaran Guru Sekolah Dasar JPPGuseda

Volume 8 Issue 3 Year 2025 Pages 181-188
ISSN 2623-0941 | e–ISSN 2623-0232
https://jppguseda-fkip.unpak.ac.id
DOI: 10.55215/jppguseda.v8i3.21

The Role of Argumentation in Advancing Critical Thinking Skills Across Multiple Academic Levels in Science Learning

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Abstract: The aims of this research is to investigate critical thinking skills improvement of elementary school students in different level academic of students, there are excellent class and regular class in environmental pollution theme using Argument-Driven Inquiry (ADI) learning model. This research use method Quasi Experiment with design The Matching-Only Pretest-Posttest Comparison Group Design. Research subject are 65 students of fifth grader in elementary school. Data analysis are using N-Gain test to draw student's critical thinking skills improvement, student's real grade criteria analysis to draw the criteria of pretest and posttest average grade of student's critical thinking skills. The result of whole student's critical thinking skills in both of classes has the same result of improvement criteria, there is middle criteria, but for posttest real grade average criteria in both of classes has different result, in excellent class has high criteria and regular class has middle criteria. The lowest number of critical thinking skills aspect improvement for excellent class is information aspect with middle criteria, while regular class is assumption aspect with low criteria. The greatest number of critical thinking skills aspect improvement for both of classes is implementation and consequences aspect with high criteria. It can be conclude that critical thinking skills in excellent class and regular class has the improvement to the positive way after implementation of Argument-Driven Inquiry (ADI) learning model, but excellent class has outperformed than regular class.

Keywords: argumentation, critical thinking skills, elementary school, science learning, students' academic level

Article info: Submitted October 22, 2025 | Revised November 8, 2025 | Accepted November 22, 2025

Recommended citation: Nurramadhani, A., & Nurcahyo, M. A. (2025). The role of argumentation in advancing critical thinking skills across multiple academic levels in science learning. *Jurnal Pendidikan Dan Pengajaran Guru Sekolah Dasar (JPPGuseda)*, *8*(3), 181–188. https://doi.org/10.55215/jppguseda.v8i3.21

Introduction

Science instruction in the classroom is not only the teacher giving a concept but also the students are able to find its by their own as the results of learning process, for instance their discover of theory in their experiment and they use their higher order thinking for make them practice about that. One of the higher order thinking (HOT) that can be developed in science learning is critical thinking skills. Critical Thinking as the intellectually disciplined process of actively and skillful of conceptualizing, applying, analyzing, synthesizing, and evaluating information, or generated by, observation, experience, reflection, reasoning, and also communication, as a guide to belief and action (Azar et al., 2021; Alkhatib, 2019). Critical thinking has also been referred as metacognition or can be said as the process of "thinking about thinking" (Șchiopu, 2018; Veenman, 2015; Fisher. 2025). Critical thinking skills are important because they are enabling students "to deal effectively with scientific, social, and practical problems in surrounding" (Santos, 2017; Veenman, 2015; Alkhatib, 2019).

In this 21st century era, almost people feel free to deliver their opinion openly through the discussion or debate activity as one of embodiment of democracy. In debate activity has a meaning how people can confince others with their opinion (Healey & Leatham, 2022; Cooke, 2018). A good debate can be supported by data, information, and valid, accurate, trusted evidence. Nowdays, people can access information easily through internet, print media, television, social media. Those information can be digested by reasoning that students must have critical thinking (Reid et al., 2016; Cladis, 2020). So, that is why in this 21st century era every single student must have critical thinking skills especially in sceince learning. Because science learning include in

higher order thinking (HOT) that is involve in 21st century skills which is can be shown if practiced in scientific approach learning. Critical thinking skills has a meaning based on Dewey (2022) and Williams (2017) as active consideration, simultaneously, and be careful about knowledge beliefs or forms that is taken for granted with the reasons that support and rasional conclusions.

Research over the past decade shows that the implementation of critical thinking in elementary schools is recognized as an important necessity, but its implementation still faces various challenges. Studies in various countries have found that the critical thinking skills of elementary school students are generally still low, influenced by student factors (such as a tendency to memorize, misconceptions, and unsystematic answers) and teacher factors (such as the dominance of lecture methods, lack of understanding of the material, and minimal pedagogical training) (Sarwanto et al., 2021; Trisnani et al., 2024; Khalid et al., 2021). Curricula in many countries do place critical thinking as a key competency, but it is often not explicitly defined and has not been fully integrated into cross-subject learning (Lombardi et al., 2021a; Aktoprak & Hursen, 2022). Therefore, critical thinking skills of students still not well trained especially in elementary school for science learning.

From the observation of several elementary school science teachers in Indonesia, said that mostly science learning activity at school only lecturing or common experiment without habituation to ask first, or make them free to decide what problem that they will choose to solve, and rarely practiced in debate activity or argument. All that reason because of time alocation, or they have only limited time to teach some topics in science learning. So, that unfortunately, students are not typically taught to think or learn independently, and they rarely develope their HOT's skills on their own (Seman et al., 2017; Nasution & Afrianti, 2022). Specifically their critical thinking skills are not developed well. Beside that, there are skills also not develop well such as lack of training, lack of information, preconceptions, and time constraints (Seman et al., 2017). Actually most of teacher has good at their competences, readiness for the content, context, methode, and model in general learning, but they are not has habituation to how teach critical thinking skills in order to develop in their students. Therefore, it is important for teachers to be trained and to continuously understand how to integrate learning so that students' critical thinking skills are well developed, especially in elementary schools (Kinoshita, 2022; Gelerstein et al., 2016).

Train the students critical thinking skills in learning process using some model and method has been done by several researcher, for instance using problem solving methode, online discussion, communication with argument using computer media, and etc (Akbar et al., 2025; Dermawan et al., 2025 ; Lombardi et al., 2021b; Abrami et al., 2015). Nowdays, science learning asks the students find the solution for the environmental problem in their surrounding with evidence, information, and data processing skills suported. Proven strategies for fostering critical thinking include group discussions, cooperative learning, brainstorming, debates, the use of interactive modules, and the use of technologies such as augmented reality (Sulthon et al., 2025; Radiansyah et al., 2023; Hayati et al., 2023; Rodriguez-Dono & Hernández-Fernández, 2021; Ichsan et al., 2019).

Thus, the learning that will be applied to improve students critical thinking skills is using learning model that based on experiment activity with argument, one of them is ADI (Argument-Driven Inquiry). ADI is one of leaning model based on argument in inquiry experiment activity. Experiment activity has important role in science learning because it can be developed higher order thinking of students, especially critical thinking. Through experiment, students are able to decide the variable, formulate a problem and purposes, arrange the procedures, interprate the data, and make a conclusion. Using experiment, the students are able to state their argumentation from the problem that is given, and it can answer the hypothesis, changing the methode, and a reciprocity from what have been done during the experiment activity (Hasnunidah et al., 2015). Through ADI learning model, the students are able to state their opinion openly about the problem, in this case is environmental problem.

Students also can decide their hypothesis, doing the experiment, and present their result compare it with their own friends, and respond their friends' result freely. Therefore, students pratice to arrange the argument in science experimental activity can train a students critical thinking skills, so their skills will be improved. Although in different characteristic of students. The characteristic itself means that different academic level, i.e. higher, middle, and lower achiever. That things are really important to be considered because different level academic of students can affect to the differences of how to compile the argument, their motivation to learn, and their critical thinking skills. In a line of the research from some researcher that different academic level of students that gained from their academic test can be effect to how they deliver the argument, their motivation, confidence, and their higher order thinking, specifically critical thinking skills (Fadhlullah & Ahmad, 2017;Zetriuslita et al., 2016).

So, in this research aims to examine how the improvement of students critical thinking skills using ADI learning model involve the environmental issue in different academic level of students. The novelty of this research lies in its comprehensive examination of argumentation as an instructional approach using ADI model that simultaneously enhances critical thinking skills across multiple academic levels in science learning. Unlike

previous studies that tend to focus on a single grade level or specific age group, this study provides a comparative analysis that reveals how students with different academic backgrounds engage with and benefit from structured argumentation processes. The integration of multi-level learner data enables a deeper understanding of the developmental progression of critical thinking, while also offering new insights into how argumentation-based learning can be adapted to varying cognitive stages. This cross-level perspective represents a unique contribution to the field, advancing current knowledge on differentiated pedagogical strategies for fostering higher-order thinking in science education.

The significance of this study lies in its potential to inform science educators in elementary school, curriculum designers, and policymakers about effective instructional practices that universally support critical thinking development across diverse student populations. By demonstrating that argumentation-based learning can meaningfully enhance critical thinking at multiple academic levels, the research provides strong empirical evidence for adopting this approach as a core component of science instruction. The findings highlight the adaptability and scalability of argumentation activities, making them relevant for improving instructional quality in both resource-rich and resource-limited educational contexts. Ultimately, the study contributes to strengthening scientific literacy and reasoning skills among students, which are essential competencies for navigating complex real-world issues in the twenty-first century.

Methods

This research employed a quasi-experimental method using a matching-only pretest–posttest comparison group design. This is beginning with the pretest, then implement the ADI learning in both classes, after that giave the posttest (Creswell & Creswell, 2017) The study involved 65 fifth-grade students from an elementary school in Indramayu, who were assigned into two groups based on their academic level: an excellent class consisting of 32 higher-achieving students and a regular class consisting of 33 middle–lower achievers. The sample was selected through purposive sampling to ensure representation of different academic levels. Data were collected through the implementation of the Argumentation Driven Inquiry (ADI) learning model, which integrates experimental activities with structured argumentation and inquiry processes within environmental science topics. This design enabled the researchers to examine the differential impact of argumentation-based science learning on students' critical thinking skills across academic levels.

The critical thinking skills of students were taken by several instruments. For instance, critical thinking skills test with 6 cases and 20 questions of environmental issue. The test based on adaptation Inch & Tudor (2014) with 8 indicaors of critical thinking skills, i.e: questions of issues, purposes, informations, concept, assumptions, point of view, interpretation and inference, implication and concequeces.The questionnaire based on their learning experiences using argumentation by using likert scale, and observation sheets of students' activity in the class during the lessons.

Then, those data will be analysed. For critical thinking skills test will be analysed by using N-Gain test to draw student's critical thinking skills improvement, student's real value criteria analysis to draw the criteria of pretest and posttest average grade of student's critical thinking skills in real scoring. Percentage for questionnaire based on students learning experiences, and description of observation as additional data. The critical thinking test based on [9] with eight aspect that relate each others. There are question of issue, purposes, information, concept, assumption, point of view, interpretation and inference, and implication and concequence.

Result and Discussion

Student's Critical Thinking Skills in General

Students' critical thinking skills are gained from the pretest and posttest in science learning using ADI leaning model. Then, it will be examined that improvement during the lesson from the beginning until the last lessons between excellent class and regular class. The value of the students critical thinking skills' improvement are gained from the average of N-gain. The excellent class got middle criteria (0,66) of N-gain, meanwhile the regular class also got the middle criteria of N-gain with different value (0,51). Both of classes has the same criteria of N-gain or the improvement, with different value. It means that both of classes make the critical thinking skills improved to the positive way. Although it is different with former research that said the improvement criteria of students critical thinking skills in higher achiever different with lower achiever, higher achiever has higher criteria than lower achiever (Hasnunidah et al., 2015).

Nevertheless, the results contradict with Mahanal et al. (2019) that higher level students got high improvement criteria in critical thinking skills than lower level students. This is most likely because in the initial critical thinking abilities in that study, high-achieving students were already better, whereas in this study, critical

thinking skills were not significantly different. This can also be caused in this study, the learning model which is applied are constant and equal. Because of the same criteria of N-gain in the students critical thinking improvement but has different value, that is shown excellent class has higher value than regular class, so there are the significant different test using t test (**Table 1**) for make sure that there is really has significant differences between excellent class and regular class in critical thinking skills after science learning using ADI learning model.

There are significant differences of students critical thinking skills in excellent class and regular class after science learning using Argument-Driven Inquiry (ADI) learning model in environmental issue based on table 1 bellow. The excellent class (higher achiever student) has better improvement than regular class (middle-lower achiever student). It is in a line with former research that there are significant differences in higher order thinking skills, such as compile argument, deliver the question, and critical thinking skills of whole academic level of students, but higher achiever students shown better improvement than middle-lower achiever (Mahanal et al., 2019; Fadhlullah & Ahmad, 2017; Zetriuslita et al., 2016).

It is caused by the students in excellent class mostly think more critically and deeply, bravely to ask question rather than students in regular class, so make the questions quality from both of them different. In a line with the statement of Tunga (2021) excellent class students think more critically, bravely to ask the questions during every lesson. For example, in science lesson using ADI learning model in environmental issue, one of the students in excellent class asks to the teacher about what is the factor that causes fish death beside acid or base pH and abnormal temperature? Can lack of oxygen cause fish to die?

Table 1. Significant differences Test of Excellent Class and Regular Class Critical Thinking Skills

	F	*Sig.*	t	df	Sig (2-tailed)	α
Equal variances Assumed	5.428	.023	5.654	63	.000	.05
Equal variances not Assumed			5.654	55.514	.000	.05

Meanwhile in regular class, students still ask about the term in the problem that is given. For example, what is the meaning of acid, H_2SO_4, pollution, pollutant. In this case, it can be drwan that the students in regular class (middle-lower achiever) still ask about the new terms in their ears. Because the students that has slow characteristic or in lower achiever will ask explanation about the words or terms that is new for them (Tunga, 2021).

All that results are supported from observation during the lesson, every meeting and cases in both of classes. First meeting, both of excellent class and regular class, the students still shy to ask questions. Second time, the students in excellent class begin to brave asking question critically based on context of their experiment activity. Their concept about pH, ecosystem, and temperature has develop well, while students in regular class, there are asks a questions about technique how they do the experiment. Their concept about pH still low, because they still can't distinguish between acid and base for the value. The last meeting, the students in both of classes has already ask critically to their friends about theirs opinion that has already delivered from the cases that is given.

It is sign that with applying ADI learning model in science learning can be "dig up" the critical thinking skills of students, so that it can improve, but it is not instantly improved. It takes time, because it needs a process habituation in every single meeting in science learning. Before using ADI learning model, in this science learning both of classes are rarely trained to think critically and asking a question. Instead students don't want to think critically, but they felt that things is hard for them, because the students are not used to it, like present analysis, solving problem, posing argument, and inquiry (Divrik et al., 2020).

Practiced the critical thinking skills one of them using learning that suitable with it, because students' critical thinking skill can be developed through learning that provide cases (Reid et al., 2016; Cladis, 2020). Such as like ADI learning model that provide issues or cases that has to be solved using experimental activity and research with inquiry. Learning with exploration and experiment can improve students critical thinking skills, enthusiasm, and belief in learning process (Akbar et al., 2025; Dermawan et al., 2025 ; Lombardi et al., 2021b).

Critical thinking is one of the important aspects in problem solving process because it is included in reflective thinking (Nuraini et al., 2020). Nevertheless, both excellent class and regular class reach the improvement criteria in middle criteria is good development, because they are junior high school students that has stage ages in adolescence. The thinking characteristic, such as reasoning and critical thinking of adolescence still developing. Age range of them betweeen 11-15 years old. They begin to the formal operation development, but it has to be considered is the transition phase from concret operational to the formal operational in reasoning or higher order thinking. In this phase studesnts realize about their thinking limitation, where they are begin to think about the concepts outside their experiences (Ziegler & Weger, 2019).

Nonetheless, the development of critical thinking skills in excellent class and regular class improve to the positive way.

It can be seen that there is a positive improvement either in excellent class or in regular class after science lesson using ADI learning model. So, it can be said that using ADI learning model can improve the students critical thinking skills. It can be proved that during the learning process, especially in argumentation session and double-blind peer-review, students are motivated to tried criticize the argument or statement that delivered by their friends orally. Besides that, they tried to criticize their friend's argumentation by made a correction their friend's written argumentation. From that observation results, ADI learning model in science learning can develop students reasoning and critical thinking with emphasize in the role of argumentation itself, there are forming and validating scientific reasoning (Hasnunidah et al., 2015). Practicing the reasoning skills to the students can make the improvement in students critical thinking skills (Huhn, 2017).

Student's Critical Thinking Skills in Aspect

This research uses critical thinking aspect based on (Inch & Tudor, 2014) with eight aspect that relate each other's. There are question of issue, purposes, information, concept, assumption, point of view, interpretation and inference, and implication and concequence. It has already analyzed using N-gain.

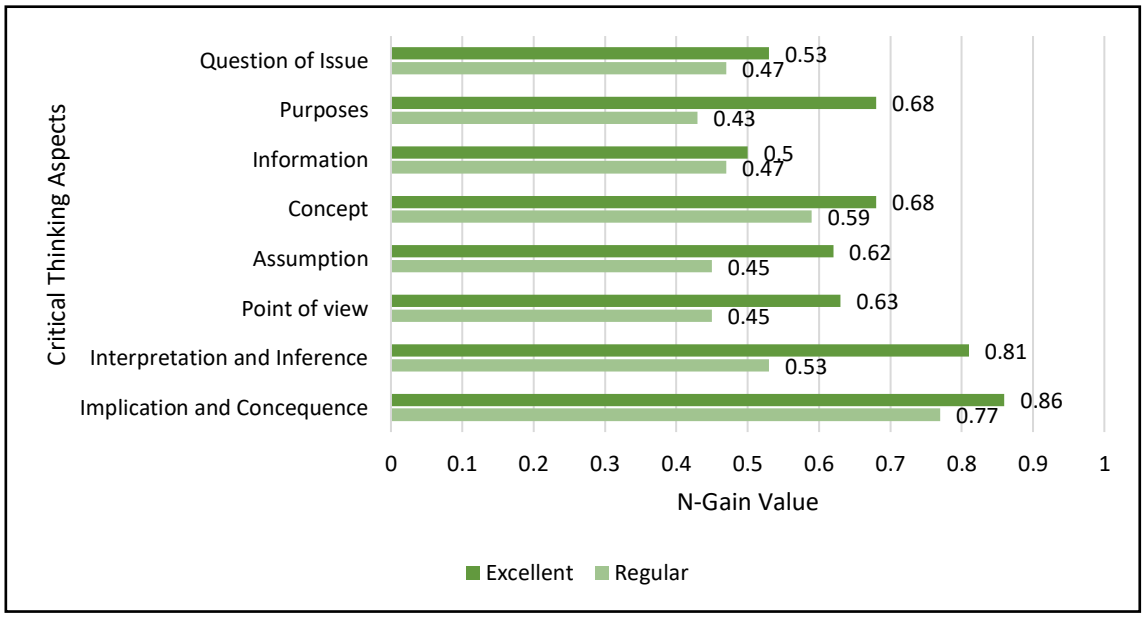

Figure 1. The Critical Thinking Improvement in Aspect of Excellent Class and Regular Class

From **Figure 1**, it can be described that there are the similarity of the critical thinking improvement criteria or criteria N-gain between excellent class and regular class in point of view aspect. There are 0,63 (middle) for excellent class and 0,45 (middle) for regular class. The other are purposes aspect, 0,68 (middle) for excellent class and 0,43 (middle) for regular class. Then Assumption aspect, 0,62 (middle) for excellent class and 0,45 (middle) for regular class. The last one is concept aspect 0,68 (middle) for excellent class and 0,59 (middle) for regular class.

Besides that, there are the differences of the critical thinking improvement criteria or criteria N-gain between excellent class and regular class in interpretation and inference, there are 0,81 (high) for excellent class and 0,53 (middle) for regular class. Interpretation and inference is the aspect that explain about providing data from phenomena which is observed, such as make an interpretation and draw a conclusion. When make a conclusion, the students asked to gathered the information that they have got as one of an evidence to draw a conclusion based on their purposes in experiment. In learning process, regular class (middle-lower achiever) students mostly still asking about what is the purposes of the experiment that they will do. Interpretation of evidence related to the purposes of making a claim. Usuallay most of lower achiever students have difficulty to make a right statement. So that, the purposes aspect is the most lowest aspect value for regular class.

Not only regular class that has the lowest value in critical thinking aspect, excellent class also has that one. Based on ctitical thinking test, excellent class has the lowest value among eight of them, there are question of issue and information aspect, there are 0,53 (middle) dan 0,50 (middle). It is caused when the students explain the informations, sometimes they reveald the information briefly but outside the context of issue that is given to them. In addition, they also complained they have to write much informations. Similar with the research

from Massey (2015), information aspect has the lowest percentage of the critical thinking improvement, there is only 33% with middle improvement or N-gain criteria. It is caused by the most of students accustomed to memorizing rather than analyze the information.

Question of issue aspect, students in both of classes have difficulty to construct the right question suitable with the issue. In learning process, students still shy to deliver their questions. That is in a line with the research result by (Hasnunidah et al., 2015) that students still shy to rise a questions and still have difficulty to define the problem, this can be make students critical thinking skills not developed well. Eventhough the result shown that both of classes have difficulty, but the questions that is delivered by students in excellent class has better than regular class. That is based on the characteristic of students itself. Nurramadhani et al. (2017) said that the ability of higher achiever students in deliver questions has better quality than middle-lower achiever students.

The other aspect result, like implementation and consequence aspect for both of classes has the same students critical thinking skills improvement criteria or N-gain criteria, there are in the higher criteria. In the teaching learning process, students asked to predict and relate the phenomena with the concept that they have been gotten. Implementation and consequence aspect itself have a meaning that make an implication from phenomena that is observed and relate them with the concept that is involved in it, then predict the consequences that will be happened from the phenomena. In this aspect, students are asked to predict what will be happened if something happen in the cases that given to them. From observations, both of classes can elaborate their opinion briefly and predict the phenomena clearly about one of the problem or cases in that issue. While, opinion and prediction in excellent class more directed than in regular class. This aspect is the last aspect that the statement are arranged from the rest of aspect before. Before this aspect, there are concept aspect, they also have good improvement. The concept aspect has relation with implementation and concequences aspect, so that is why this last aspect has high improvement criteria.

Critcal thinking skills is not instant skills, but it must be through habituation and repetation. So that, the improvement of students critical thinking skills in both of classes show to the positive way in every single aspect.Through this lesson, not only critical thinking skills of students that can be improved, but also students concept also can be reach by their experience in learning. For example, students must be comprehended and can applied their knowledge, they must be work hard to solve the problem, find everything for themselves, have an effort for their ideas (Tunjungsari & Takwin, 2021; Enciso et al., 2017). Critical thinking skills is also important because it will be applied in dialy life during teaching learning process or outside school to improve their quality life and professionalism in working environment (Enciso et al., 2017).

Conclusion

Students critical thinking improvement criteria in both of classes has similarity, there is middle criteria. But, the critical thinking improvement between excellent class and regular class has significant differences. Excellent class has outperformed rather than regular class. The highest improvement in excellent class and regular class is in implementation and consequences aspect, there are high criteria for excellent class and middle criteria for regular class. Both of classes also has the same criteria, there are middle criteria of critical thinking improvement in several aspect. For instance, point of view, purposes aspect, assumption aspect, and concept aspect. Nevertheless, the critical thinking skills of both of classes are improved to the positive way and the excellent classes has outperformed in critical thinking skills in generally and every single aspect rather than regular class.

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