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Analysis of Effectiveness Argument-Driven Inquiry to Improve Students' Argumentation Skill and Conceptual Understanding

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ABSTRACT

Objective: This study examined the effectiveness of the Argument-Driven Inquiry learning model in science learning in improving students' argumentation skills and conceptual understanding. **Method:** The techniques used are 1) searching articles on Scopus and Google Scholar using the keyword Argument-Driven Inquiry in science learning, 2) articles were selected focus on increasing conceptual understanding and argumentation skills, 3) the metadata was selected limited to 2015-2023, and 4) conducting the in-depth review. **Results:** The ADI model was able to improve students' argumentation skills. In general, students' argumentation levels are in levels 3-4. The quality of the arguments developed by students shows the understanding of the concepts possessed by students. Students can reach the cognitive level created (C6) by writing scientific reports. **Novelty:** This study reinforces previous research regarding the effectiveness of the ADI model in improving argumentation skills and conceptual understanding taken from recent articles. Therefore, this article can be the basis for developing learning tools for the ADI model.

INTRODUCTION

Learning science is essential in preparing future generations for various aspects of life, such as thinking logically, making decisions about their choices, and engaging in social communication. For this reason, science learning is currently expected to be packaged in an inquiry process so that students can be directly involved in the process of obtaining information. The goal is to facilitate students in understanding science concepts as a whole and strengthen process skills. Communication skills are one of the process skills required in learning the new paradigm. Communication skills, including argumentation skills, are essential points that students must have as basic skills in learning and socializing.

Argumentation skills become essential competencies for students in understanding science concepts. This skill explains the nature of scientific processes often carried out by scientists (Grooms et al., 2015). Students learn to acquire knowledge by observing, collecting data, evaluating, and making decisions as a scientific process, like what scientists do (Christenson et al., 2014; Faize & Dabar, 2018). It aligns with Fadly & Miaturrohmah (2021) and Walker & Sampson (2013). Learning by building arguments trains students to identify several opinions and analyze the truth of opinions rationally and critically (Felton et al., 2015). So that students learn how to build a valid and robust argumentation structure by evidence and theory (Foutz, 2013; Kulatunga et al., 2013). Through argumentation, students learn to build on their knowledge so that it can be assumed that student arguments describe their understanding of concepts (Hasnunidah et al., 2015). According to the statement of Walker & Sampson (2013), when student learning science with a lack of argumentation skills usually reflect their misunderstanding of science concepts.

The role of argumentation in learning provides opportunities for students to be involved in scientific discussions and opportunities to evaluate various alternative information obtained. There are five reasons why argumentation skills are essential to apply in classroom learning; 1) Argumentation skills support cognitive and metacognitive development; 2) support the development of communication skills and critical thinking; 3) increase scientific literacy and improve scientific writing skills; 4) support the understanding of scientific epistemology; 5) support the development of reasoning, especially theories related to science (Aldahmash & Omar, 2021; Cetin, 2014; Drury et al., 2019; Hunaidah et al., 2019; Paramita et al., 2019). Argumentation is a statement that contains claims, data support, and attempts to influence someone in the context of disagreement (Inch & Tudor, 2014). Scientific argumentation consists of 1) claims as conclusions from a problem; 2) evidence collected from data which is supporting the claims; and 3) reasons from theories or principles to support claims (Faize et al., 2017).

Conceptual knowledge is an understanding of principles and their interrelationships. Good conceptual understanding supports students to be processing information efficiently and effectively (Widiyatmoko & Shimizu, 2018). Besides that, understanding scientific concepts is obtained through more than just a scientific investigation (O'Dwyer et al., 2015). However, conceptual understanding can also be obtained by analyzing scientific phenomena that are issued in society (Paramita et al., 2019). The obstacle experienced by students in understanding concepts caused a lack of understanding of the content, which leads to misconceptions (Soeharto & Csapó, 2022). An improved understanding of the concept can be realized by applying learning models. Through learning activities, students are involved in problem-solving activities, conducting analysis, writing agreements, and discussing answers. Therefore, students build their understanding of concepts related to the studied topic (O'Dwyer et al., 2015).

An appropriate learning model is needed to practice argumentation skills. The Argument-Driven Inquiry (ADI) learning model has been widely used to train students' argumentation skills. The ADI model facilitates teachers to be able to design laboratory-based learning. Therefore, students experience authentic learning (Dwiretno & Setyarsih, 2018). Teaching learning process-based laboratory helps students validate science aspect that they learn as theory. The stages of learning the ADI model include the following eight stages: 1) the stage of identifying tasks and guiding questions; 2) method design and data collection; 3) data analysis and developing tentative arguments; 4) argumentation session; 5) reflection discussion; 6) Prepare reports; 7) peer review stage; and 8) the stage of report revision and collection (Sampson et al., 2014). This learning model refers to personal and social learning theory. Personal learning theory, according to Piaget, states that the individual himself forms knowledge through continuous experience. In addition, Vygotsky's theory of social constructivism states that knowledge is formed as a process in social interaction (ŞenyiĞiT, 2021).

Based on the description above, argumentation skills are able to build cognitive development and communication skills and increase students' scientific literacy. On the other hand, argumentation skills can be trained by applying learning models such as ADI. For this reason, it is necessary to study the relationship between the ADI model in improving students' argumentation skills and understanding of concepts. In addition, this study serves as a basis for the development of teaching materials for the ADI model related to the effectiveness of the ADI model. However, it is devoted to improving argumentation skills and understanding concepts in science learning.

RESEARCH METHOD

The research method used in this research is library research. Data collection was carried out by reviewing several articles as secondary data. According to Ramdhani et al. (2014), the secondary data collection technique consists of several stages as follows:

1) Choose a topic and search for relevant articles for the topic to be studied. The selected articles are articles published in the 2015-2021 range. Article searches were carried out on Scopus and Google Scholar, focusing on the ADI learning model in science.
2) Analysis and synthesis of the literature. Conduct an in-depth review and extract data from various articles as a data source discussed in the study. At this stage, all the data is reviewed to obtain the main points in improving argumentation skills and conceptual understanding of the impact of ADI learning. The next step is to select articles based on the article data obtained related to the application of the ADI model. These articles will become data to be developed in the discussion.
3) Synthesis and combining data. Therefore, it becomes a holistic information unit. **Figure 1** is the flow of the research method used.

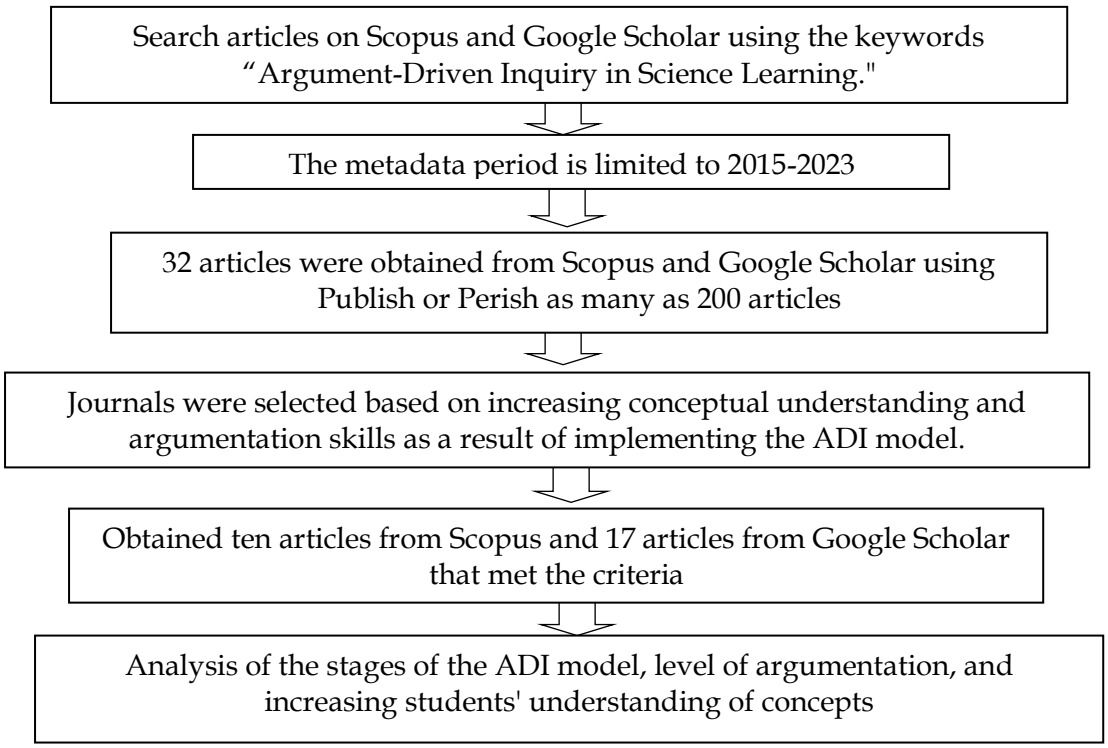

Figure 1. Research flowchart.

RESULTS AND DISCUSSION

Results

This study focuses on the effectiveness of applying the ADI model in improving students' argumentation skills and conceptual understanding in science learning. Based on the article search found, 27 articles related to the ADI model. The summary of articles is described in **Table 1.**

Table 1. Summary of article review ADI model.

Author	Title	Findings
Howitz et al. (2023)	A Specifications-Graded, Sports Drink-Themed General Chemistry Laboratory Course Using an Argument-Driven Inquiry Approach	Students can develop arguments independently based on the data presented.
Arslan et al., (2023)	Exploring the effect of argument-driven inquiry on pre-service science teachers' achievement, science process, and argumentation skills and their views on the ADI model	The ADI model positively impacts prospective teachers in improving argumentation skills, understanding concepts, and increasing the level of argumentation.
Hosbein et al., (2021)	Tracking Student Argumentation Skills across General Chemistry through Argument-Driven Inquiry Using the Assessment of Scientific Argumentation in the Classroom Observation Protocol	There is an increase in cognitive aspects and argumentation skills. The quality of the Argument increases in line with the increase in students' conceptual understanding.
Kaçar & Balim, (2021)	Investigating the effect of the ADI method in science courses on secondary school student's level of conceptual understanding	There are significant differences regarding the understanding of concepts in science learning as a result of implementing the ADI model.
Amelia et al., (2021)	The Effectiveness of Argument-Driven Inquiry in Promoting Students' Argumentation Skills about Colloids	There is a significant difference between the argumentation skills of students in the ADI class and the inquiry class. The argumentation skills of the ADI class students are higher than those of the inquiry class students. Based on the data, the mean ADI class is 4.42> 4.04
Parno et al. (2021)	Building conceptual understanding of students on the laws of Newton through argument-driven inquiry	Based on the data, the N-gain value for the experimental class was 0.42, which was in the medium category, which was higher than the control class with an N-gain value of 0.06. This shows that the ADI learning model can improve students' understanding of concepts in Newton's Law material.
Pan et al. (2021)	The effect of the argument-driven inquiry (ADI) based on science, environment, technology, and society (SETS) to students' concept understanding and	The results showed that students' understanding of concepts applied to the SETS-based ADI model improved more than the ADI model. In addition, students' argumentation skills are generally at level 3.

Author	Title	Findings
	scientific argument skill in buffer solution learning: Studied from cognitive style	
Antonio & Prudente, (2021)	Metacognitive Argument-Driven Inquiry in Teaching Antimicrobial Resistance: Effects on Students' Conceptual Understanding and Argumentation Skills	Students' understanding of concepts and argumentation skills increased significantly after applying the MADI learning model. In addition, student self-confidence increases.
Divena et al., 2021	Effectiveness of Argument-Driven Inquiry (ADI) on students' concept mastery and argumentation skills in the reproduction system	ADI learning model was improving students' mastery of concepts, specifically on applying (C3) of Bloom's category. Students capable of developing warrants when developing argumentation
Putri et al. (2020)	The effectiveness of Argument-Driven Inquiry to improve scientific argumentation skills on the material Reaction rate	The ADI model can improve students' argumentation skills compared to the guided inquiry model and confirmation classes. The quality of the arguments of most of the ADI class is at level 4, while for the guided inquiry class, it is at level 2. This means that at level 2, students can provide simple explanations without further alternative explanations, whereas at level 4, students can provide explanations accompanied by a rebuttal.
Amelia et al., (2020)	Promoting the scientific argumentation skills of students using ADI-S and ADI models in chemical kinetics teaching	The percentage of students' argumentation skills at level 2 (providing claims, backing, and warrants) The r-ADI learning model is higher than the ADI model. Meanwhile, the ADI model only concentrates on level 1 student arguments.
Suliyanah et al., (2020)	The Process of Developing Students' Scientific Argumentation Skill Using Argument-Driven Inquiry (ADI) Model in Senior High School on The Topic of Elasticity	Students' argumentation skills increased at level 3. Students were able to provide claims with support warrants. However, Students still need to be more confident in expressing opinions.
Hanifah & Admoko, (2019)	Application of the ADI learning model to train the scientific argumentation skills of high school students	The ADI model increases the level of student argumentation from levels 1 to 3 and 4.
Salsabila et al., (2019)	Using Argument driven inquiry to promote students' concept mastery in learning global warming	The results showed an increase in students' understanding of concepts with an N-gain value of 0.45 in the experimental class compared to the control class with an N-gain value of 0.28. Thus, the ADI model effectively increases

Author	Title	Findings
		students' understanding of concepts.
Songsil et al. (2019)	Developing Scientific Argumentation Strategies Using Revise argument-driven inquiry (rADI) in Science Classrooms in Thailand	Students using the rADI model are able to improve their scientific argumentation skills even though they still need to improve in establishing supporting arguments. Based on the rADI model data, the quality of student arguments increased by 10% and supporting arguments by 11%. In comparison, the traditional learning model increased the quality of student arguments by 2% and supporting arguments by 1%.
Chen et al. (2019)	Bridging the gender gap of children's engagement in learning science and argumentation through a modified argument-driven inquiry	The application of the ADI modification (experimental class) for male and female study groups showed a significant increase in the quality of argumentation from the beginning to the middle of the semester. Students with high involvement have more quality arguments than students with low involvement.
Nikmah et al., (2019)	Effectiveness of Learning Media Using Argument-Driven Inquiry (ADI) Learning Model to Increase Students' Learning Outcomes and Self Efficacy	The result showed that the ADI model improved students' self-efficacy and learning results in the high category. Students' self-efficacy was 0,6 as medium criteria and learning result was 0,74 as a high category.
Dwiretno & Setyarsih, (2018)	Physics learning uses the ADI model to train students' scientific argumentation skills	Students' argumentation skills after participating in the ADI model learning have argumentation abilities with an average value of 77.62 which means they are at level 3
Septyastuti et al., (2018)	The effect of learning the buffer solution of the Pogil model and ADI on scientific argumentation skills	The ADI model improves the quality of scientific argumentation better than the Pogil model. The quality of the students' arguments in the ADI model was 47.09% higher than in the Pogil model, which was 32.26%.
Kalay et al. (2017)	EfeActivity of the ADI Learning Model in Improving Student Concept Understanding on Molecular Form and Polarity Material	Applying remedial using the ADI model is more effective in increasing students' understanding of concepts from 5.2% to 71.2%.
Hadiwidodo et al., (2017)	Development of Learning ToolsChemistry Model Argument-Driven Inquiry to Improve Argumentation Skills and Student Learning Outcomes	Implementing learning with the ADI model effectively improves argumentation skills and student learning outcomes in the redox reaction material.

Author	Title	Findings
Marhamah et al. (2017)	Application of the ADI model in improving students' argumentation skills on the concept of environmental pollution in grade X of state SHS 1 Ciawigebang	Students' argumentation skill was increased based on N-gain score in the medium category (0,43). Students can write argumentation in levels 3 (34%) and 4 (18%) as the impact of the implementation ADI learning model.
Andriani (2016)	Increased understanding of student concepts through *Argument-Driven Inquiry* learning in integrated science learning for junior high school students in grade VII	Implementation of the ADI learning model increases students' conceptual understanding based on an N-gain score was 0,56 as a medium category
Chen et al. (2016)	Using a modified argument-driven inquiry to promote elementary school students' engagement in learning science and argumentation	The experimental class showed higher student involvement in science learning than the comparison class. In addition, the argumentation skills of the experimental class were higher with claims and warrants compared to the comparison class.
Hasnunidah et al., (2015)	Argument-Driven Inquiry with Scaffolding as the Development Strategies of Argumentation and Critical Thinking Skills of Students in Lampung, Indonesia	A significant difference exists in improving students' argumentation and critical thinking skills. The S-ADI learning model further enhances students' argumentation skills compared to ADI and conventional models.
Demircioglu & Ucar, (2015)	Investigating the Effect of Argument-Driven Inquiry in Laboratory Instruction	The instructional laboratory-based ADI model is more effective in improving learning outcomes and science process skills of prospective teacher students when compared to the fractionation laboratory model. However, at the argumentation level, the application of these two models is similar. The same thing also applies to the aspect of the quality of the argumentation, which is similar.

Discussion

The analysis was the impact of ADI model stages in improving argumentation skills during the learning process.

Argumentation Skill

The stages of learning in the ADI model affect students' argumentation skills. The stages are the development of tentative argumentation, argumentation skill, and writing a scientific report. A study by Amelia et al. (2021) shows that the ADI model improved student argumentation skills better than the inquiry-based learning model. The argumentation abilities score can see it. Students in ADI class reach level 4 and level 5 argumentation (25.3% and 58.8%). Compared with the Inquiry model, level

argumentation is level 3 (22.9%) and level 4 (41.2%). Research held by Putri et al. (2020) showed that the ADI model improved students' argumentation level if compared with the guided inquiry model and traditional model. Students in guided inquiry class reach level 4 of argumentation and none in level 5. However, generally, students in ADI class could build complete argumentation in levels 4 and 5. There were 38.9 % of students reached level 4 argumentation and 15.3% in level 5 argumentation. Research conducted by Pan, Marfu'ah, & Dasna (2021) presented that the ADI model based on Science, Environment, Technology, and Society (SETS) has improved students' argumentation skills mostly in level 3 and level 4 (51.8% and 25.9%) respectively. ADI-SETS model compares with the ADI model; only 43.7% reach level 4 of argumentation, and 18.5% on level 5. We can see slight differences in the percentage of students' argumentation skills. It was because both methods used the ADI model.

Based on data described before by Amelia et al. (2021), Putri et al. (2020), Pan et al. (2021), and Marhamah et al. (2017), the argumentation aspect has shown in **Table 2**.

Table 2. Students' argumentation level is based on research.

Author	Sample	Level of argumentation (%)				
		1	2	3	4	5
Putri et al., (2020)		2.8	39.6	3.5	38.9	15.3
Amelia et al., (2021)	35	-	-	21.6	14.3	64.1
Pan et al. (2021)	28	2.9	34.8	43.7	18.5	
Marhamah et al. (2017)	38	-	47.0	34.0	18.0	-

Table 2 shows the average of students' argumentation in levels 3 and 4. It is in line with Hanifah & Admoko (2019); Dwiretno & Setyarsih, (2018); Suliyanah et al., (2020). Students can provide simple explanations and arguments according to the theory at this level. However, some research found that students can produce a high level of argumentation, such as level 5. Students can provide strong and complete argumentation in these range levels (3 to 5). Students can associate data for supporting claims where the specified data and claims are valid. In addition, students can give warrants and involve rebuttals in their argumentation. The higher level of students' arguments represents the complexity of argumentation developed by students. The complexity of students' argumentation shows the level of understanding of students' concepts (Putri et al., 2020). So that students' argumentation abilities can provide an overview of students' cognitive levels (Aydeniz & Dogan, 2016; Devi et al., 2018).

Students' ability gives arguments supported by the learning stages in the ADI model. Some of the ADI stages are the development tentative argumentation stage, the argumentation session stage, the written investigation report stage, and the revised report stage (Amelia et al., 2021). The ADI model facilitates students to share ideas and provide explanations in groups freely and creatively (Amielia et al., 2018). Based on the data in Table 1, the quality of student arguments at levels 4 and 5 is still a tiny percentage. It is because students are at the stage of learning to argue and need to practice more to develop better-quality arguments continuously (Cetin, 2014). Students sometimes need help in determining the relationship between data and theories of science. They can use scaffolding to help students develop arguments by providing certain topics and specific questions (van de Pol et al., 2015). The ADI model provides an improvement in argumentation skills both orally and in writing (Auliyah & Nurita, 2019; Hosbein et al., 2021).

Conceptual Understanding

Understanding concepts in science learning will help students understand the application of chemistry in responding to global problems (Dewi & Rahayu, 2022; Holme, 2020; Sjöström & Talanquer, 2014). Teaching the learning process using the ADI model improved students' conceptual understanding. Based on research conducted by (Parno et al., 2021) shows that students' conceptual understanding of Newton's law has increased significantly. It saw by N-Gain value in a total of as much as 0.42 for the ADI model. The syntax of the ADI model can develop students' conceptual understanding better than the conventional model.

Each stage in the ADI model is designed to increase students' understanding of concepts. The first stage trains students to study the phenomena presented, referring to the level of remembering (C1). The second stage of designing the method refers to the level of understanding (C2). The third stage is related to data analysis and building arguments referring to the C3 level, namely the application of students' understanding. Up to the 6th stage, writing reports trains students to present their work in the form of scientific writing (Parno et al., 2021). Students have reached the understanding of creating (C6) level at this stage. The same thing was stated by Walker et al. (2016); students who use ADI learning have a broad conceptual understanding because they independently design to collect data and develop arguments based on data.

On the other hand, similar research held by Salsabila et al. (2019) described that students' conceptual understanding was increased significantly than Inquiry based-learning (IBL). The N-gain score for ADI class was 0,45, categorized as medium improvement in conceptual understanding. Meanwhile, IBL class of as much as 0,28 is classified as a low improvement. Another research conducted by Nikmah et al. (2019) showed that students' conceptual understanding improved as the impact of implementing teaching material based on the ADI model. Based on data described by Parno et al. (2021), Salsabila et al. (2019), Nikmah et al. (2019), and Andriani (2016) for improving conceptual understanding aspect shown in **Table 3**.

Table 3. Students conceptual understanding

Author	Sample	The average score		
		Pre-test	Post-test	N-gain
Parno et al., (2021)	23	41.1%	55.0%	0.4
Salsabila et al., (2019)	26	37.3%	66.3%	0.5
Kalay et al., (2017)	30	5.2%	71.2%	-
Andriani, (2016)	33	36.0%	72.0%	0.6

Data represented in **Table 2** and **Table 3** showed that the ADI model is competent for improving students' argumentation skills and expanding students' conceptual understanding. The conceptual understanding average majority on the medium level refers to the N-gain score. Students must expand argumentation skills as crucial competency to support conceptual understanding of science concepts (Safitri et al., 2020). Research conducted by Antonio & Prudente (2021) explained that ADI learning stages with a metacognitive approach positively impact students' argumentation skills. This model allowed expanded students' argumentation based on investigation data and information.

Moreover, in the tentative argument stage, students learn to reflect on their conceptual understanding. Students' argumentation level establishes a valid claim and is supported by data. Even though the argumentation still lacks a reasoning aspect.

Related research developed by Divena et al. (2021) claimed that factors for expanding students' conceptual mastery are the argumentation tentative stage and argumentation session from the ADI learning model. Argumentation tentative stages help students to interact directly with data and information. In this stage, students learn to make claims based on the data obtained and train students to build arguments based on concepts (Sampson et al., 2014). An article from Bukifan & Yuliati (2021) explained that the implementation of ADI grows students' mastery of concepts on thermodynamic topics. Students can answer the question with difficult indicators, for instance, level C4 (analysis) and level C5 (synthesis) of Bloom's taxonomy. Based on the interview process with students held by Andriani (2016), the stages in the ADI model help students understand concepts before developing arguments. Engaging students in discussions and developing argumentation helps students understand concepts better.

CONCLUSION

Fundamental Finding: The ADI learning model can improve students' argumentation skills and conceptual understanding. The stages of the ADI model facilitate students in practicing building logical arguments based on data. The main steps in the ADI model for practicing students' are the tentative argumentation step, the argumentation sessions step, and the writing a scientific report step. **Implication**: Students' argumentation levels are generally 3-4 by implementing ADI. Furthermore, the quality of the arguments developed by students shows the understanding of the concepts possessed by students. Students can reach the cognitive level created (C6) by writing scientific reports. Although students still need scaffolding in developing argumentation. **Integrating specific topics or guiding questions as scaffolding is recommended to develop students' argumentation. Limitation:** This research is limited to a literature review, especially on argumentation skills and conceptual understanding studied based on relevant articles. **Future Research:** Based on this reason, further research related to the development of teaching material oriented to the ADI learning model is needed.

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