Journal of Natural Science and Integration
P-ISSN: 2620-4967|E-ISSN: 2620-5092
Vol. 8, No. 2, October 2025, pp 338-350

Available online at:
http://ejournal.uin-suska.ac.id/index.php/JNSI
DOI: 10.24014/jnsi.v8i2.26428

Development of Teaching Materials Based on Scientific Argumentation on the Topic of Earth and Solar System

Farida Nur Setiati[1], Siswanto Siswanto[1*], Eko Juliyanto[1], Eli Trisnowati[1], Firmanul Catur Wibowo[2]

[1] Department of Science Education, Universitas Tidar, Indonesia
[2]Department of Physics Education, Universitas Negeri Jakarta, Indonesia

**Correspondence Author: siswanto@untidar.ac.id*

ABSTRACT
Scientific argumentation plays a crucial role in fostering higher-order thinking and scientific literacy in science education. However, studies have shown that Indonesian students' scientific argumentation skills remain low, while existing science textbooks generally reach only level 2 of argumentation quality. Consequently, these materials are not yet effective in facilitating the development of students' argumentation competence. Furthermore, the topic of the Earth and the Solar System continues to generate misconceptions among students, highlighting the need for learning materials that integrate structured argumentation activities. This study, therefore, aims to develop science teaching materials based on scientific argumentation activities for the topic of the Earth and the Solar System. The research employed the Fuzzy Delphi Method, encompassing five key stages: (1) determining the model of scientific argumentation construction for developing argumentative texts, (2) defining learning indicators for material development, (3) designing teaching materials based on expert-validated indicators, (4) assessing the readability of the materials, and (5) validating the developed materials. The findings indicate that the resulting teaching materials are valid and appropriate for students' cognitive levels. The materials were structured using a scientifically validated argumentation model and learning indicators categorized into cognitive levels of remembering, understanding, analyzing, and creating across five subtopics. Readability analysis using the Fry graph confirmed suitability for the target age group, while expert validation demonstrated high content and construct validity. These results suggest that the developed materials effectively support the integration of scientific argumentation in science learning, particularly on Earth and Solar System concepts.

Keywords: *scientific argumentation, teaching materials, earth and solar system, fuzzy delphi method.*

INTRODUCTION

Scientific argumentation plays a pivotal role in science education, as it enables students to construct knowledge through reasoning, evidence, and critical reflection (Siswanto et al., 2020). Engaging in argumentation provides multiple educational benefits. First, it enhances students' critical thinking abilities, scientific literacy, and conceptual understanding of scientific topics (Deane & Song, 2014). Second, involvement in scientific argumentation activities strengthens students' contextual comprehension of science (Guilfoyle et al., 2021). Third, students who actively participate in argumentation-based learning demonstrate improved mastery of scientific content (Bathgate et al., 2015). Moreover, argumentation helps students develop coherent and accurate conceptions of scientific phenomena, thereby reducing misconceptions (Siswanto et al., 2022).

Given these benefits, integrating scientific argumentation into science learning is essential. One effective approach is the development of teaching materials or science texts that embed structured argumentation activities. Previous studies have demonstrated that argumentation skills can be explicitly taught through such materials (Aryanti, 2024; Hakim, 2020). However, empirical evidence indicates that mastering argumentation remains challenging for many students (Kundariat, 2022). Several factors contribute to this issue, including instructional practices that provide limited opportunities for discussion and reflection, as well as insufficient training in constructing and evaluating arguments (Osborne, 2010; Erduran, 2023).

This problem is also evident in the Indonesian context, where approximately 69% of science teachers in Magelang City have not implemented argumentation-based learning (Sumarni, 2020). Consequently, students' scientific argumentation skills remain underdeveloped. In science learning, argumentation represents a process of critical thinking that involves formulating claims, supporting them with data and evidence, and applying logical reasoning to defend or refute scientific explanations (Osborne, 2007). Through this process, students learn to evaluate evidence critically and construct deeper scientific understanding grounded in relevant data and theoretical frameworks (Berland, 2009).

According to Aryanti (2024), textbooks play an essential role in developing students' scientific argumentation skills. The higher the quality of a textbook, the more effectively it can support meaningful learning processes (Asri, 2017). However, research indicates that most Indonesian science textbooks remain at level 2 of scientific argumentation (Aryanti, 2024), which means that the arguments presented typically consist only of claims supported by data. This level is still insufficient to promote students' higher-order reasoning skills. A scientifically sound argument should include not only claims and data but also warrants that link evidence to reasoning (Simon et al., 2006; Toulmin, 2003; van Eemeren et al., 2014). Therefore, it is necessary to develop teaching materials that incorporate these three fundamental components of argumentation.

Another challenge in science education relates to persistent misconceptions about the topic of the Earth and the Solar System (Rachmawati et al., 2017). The most prevalent misconceptions concern the concepts of meteoroids, meteors, and meteorites, while misconceptions about the Sun are relatively less frequent. Integrating scientific argumentation into teaching materials for this topic is expected to reduce these misconceptions by encouraging students to reason scientifically, analyze evidence, and justify their understanding through logical arguments. Based on these considerations, this study aims to develop science teaching materials grounded in scientific argumentation principles for the topic of the Earth and the Solar System. The developed materials are expected to help improve students' conceptual understanding and minimize misconceptions through structured argumentation-based learning.

METHODOLOGY

Research Design

This study employed the Fuzzy Delphi Method (FDM), which is widely used to establish expert consensus systematically and quantitatively (Chang, 2011). The FDM combines the strengths of the traditional Delphi technique with fuzzy logic principles to minimize subjectivity and ambiguity in expert judgment. In this research, the method was utilized to identify and validate the essential components required for developing science teaching materials based on scientific argumentation. The research was conducted through five main stages. First, the scientific argumentation construction model was determined as the foundation for developing argumentative science texts. This model guided the formulation of claims, data, and warrants in the teaching materials. Second, learning indicators were identified and refined to align with cognitive domains relevant to argumentation-based learning. Third, teaching materials were developed in accordance with the learning indicators that achieved consensus among the expert panel. Fourth, the readability of the developed materials was analyzed to ensure suitability for students' comprehension levels, employing the Fry Graph readability analysis. Finally, the validity of the teaching materials was examined through expert evaluation, focusing on aspects of content accuracy, construct coherence, and pedagogical relevance. Through these systematic stages, the study ensured that the resulting teaching materials were not only scientifically and pedagogically sound but also aligned with expert agreement and student readability standards.

The Fuzzy Delphi method steps were carried out as follows: (1) Identifying expert answers; (2) Determining the linguistic scale using the Liker scale by adding three Fuzzy numbers (m_1, m_2, and m_3), shown in Table 1; (3) Determining the average value of Fuzzy numbers (FN); Calculating the threshold value (d), shown in formula (1); (4) Calculating the deffuzification process (DV) value, shown in formula (2); (5) If the threshold value (d) ≤ 0.2 and deffuzification process (DV) ≥ 0.50 then the agreement status (S) is validly accepted; (6) Perform ranking (R) based on the deffuzification process (DV) value, if needed.

Table 1. Linguistic Scale

Linguistic Scale	Fuzzy Numbers		
	m_1	m_2	m_3
Strongly agree	0.6	0.8	1
Agree	0.4	0.6	0.8
Moderately agree	0.2	0.4	0.6
Disagree	0	0.2	0.4
Strongly disagree	0	0	0.2

(Hendrastuti et al., 2021)

Formula:

$$\boldsymbol{d} = \sqrt{\frac{1}{3}(\overline{m_1} + m_1)^2 + (\overline{m_2} + m_2)^2 + (\overline{m_3} + m_3)^2} \quad (1)$$

$$\boldsymbol{DV} = \frac{1}{3}(\overline{m_1} + \overline{m_2} + \overline{m_3}) \quad (2)$$

Participants

The participants in this study consisted of science education lecturers, science teachers, and language experts. The science education lecturers were selected based on their prior research experience in the field of scientific argumentation, ensuring their expertise in evaluating the conceptual and pedagogical validity of the materials. The participating science teachers were certified educators with practical classroom experience, providing insights into the applicability of the developed teaching materials in real learning contexts. In addition, language experts were involved to assess the linguistic clarity and coherence of the text-based teaching materials.

Data Collection and Analysis.

The initial phase of the research focused on developing a scientific argumentation construction model embedded within science-related texts. This stage involved semi-structured interviews with three experts, all of whom were science education lecturers with prior research experience in scientific argumentation. The interview process aimed to identify essential components and structures that characterize effective scientific argumentation in teaching materials. The interview data were analyzed using thematic analysis following the procedures outlined by Heriyanto (2018). The analysis involved several steps: (1) familiarizing with and understanding the collected interview data, (2) coding relevant statements to identify key concepts, and (3) organizing the codes into coherent themes aligned with the research objectives.

These emerging themes served as the foundation for designing the argumentation construction model that guided the subsequent development of the teaching materials

The second stage involved developing learning indicators that students are expected to master within the cognitive domain for the topic of the Earth and the Solar System. This process was carried out through two rounds of the Delphi technique. In the first round, semi-structured interviews were conducted with four experts in science education to identify key cognitive indicators relevant to argumentation-based learning. The interview data were analyzed using thematic analysis, following the same procedures applied in the first research objective. In the second round, a questionnaire was distributed to ten experts, all of whom were certified science teachers. The purpose of this round was to validate and reach consensus on the learning indicators identified in the previous stage. The collected responses were analyzed using the Fuzzy Delphi Method (FDM) to determine the level of agreement among experts and to refine the final set of indicators based on quantitative consensus values.

The third stage focused on the development of science teaching materials that integrate scientific argumentation activities within the topic of the Earth and the Solar System. This stage synthesized the results of the first and second stages, ensuring that the content structure, argumentation components, and learning indicators were aligned with expert consensus and pedagogical principles. The resulting materials served as prototypes for further readability and validity testing. The fourth step is to analyze the readability level of the developed teaching materials using Fry's graph (Fry, 1968). The steps of analyzing the readability level with Fry's graph are as follows: Selecting one hundred words from the text to be measured for readability, Count the number of sentences in the hundred selected words, Counting the number of syllables of the selected hundred words, Plotting the calculation results onto the Fry chart.

The results of the Fry graph analysis were tested for validity using an inter-rater test. The inter-rater test used is the Cohen Cappa agreement coefficient (Cohen, 1960). At this stage, two language experts were involved. The calculation of the Cohen Kappa coefficient, shown in formula (3). The categories of the Cohen Kappa agreement coefficient value shown in Table 2.

$$\boldsymbol{K} = \frac{\boldsymbol{P_a - P_c}}{\boldsymbol{1 - P_c}} \tag{3}$$

Description:

K = Cohen Kappa coefficient of agreement
Pa = proportion of observed agreement
Pc = proportion of expected agreement
1 = constant

Table 2 Categories of Cohen Kappa Coefficient of Agreement

Value	Category
k < 0.00	Poor agreement
0,00 < 0.20	Slight
0,21 < k < 0.40	Fair
0,41 < k < 0.60	Moderate
0,61 < k < 0.80	Substansial
0,81 < k < 1.00	Almost perfect agreement
k = 1.00	Perfect agreement

(Landis & Koch, 1977)

The fifth stage involved analyzing the validity of the developed teaching materials through expert evaluation. A questionnaire was administered to ten experts, comprising both science education lecturers and certified science teachers. The collected data were analyzed using the Fuzzy Delphi Method (FDM), consistent with the procedure applied in the second stage. The use of the FDM in this step aimed to determine the degree of expert consensus regarding the validity of the developed teaching materials (Saido et al., 2018). The expert validation focused on three main aspects of evaluation: content validity, construct validity, and language validity. Each aspect was further divided into specific assessment indicators designed to measure the quality and appropriateness of the teaching materials in supporting argumentation-based science learning. The detailed indicators used for expert assessment are presented in Table 3.

Table 3 Indicators of Validity Assessment

Aspect Assessment	Indicators Components of Validity Assessment
Scientific Argumentation Aspect	1. Scientific argumentation in the materials presents scientific concepts
	2. Scientific argumentation in teaching materials reaches level 3 which consists of elements of claims, data, and warrant
Linguistic Aspects	3. Scientific argumentation in teaching materials uses proper Indonesian language
	4. Scientific argumentation in teaching materials uses language that is easy to understand
	5. Scientific argumentation in teaching materials uses communicative and interactive language
Presentation Aspect	6. Scientific argumentation in teaching materials has an attractive design
	7. Scientific argumentation in teaching materials has pictures and tables that are clear, interesting, and in accordance with the material
	8. Scientific argumentation in teaching materials uses the right font size, text spacing, and distance between paragraphs

(Textbook Committee, 2016)

RESULT AND DISCUSSION

In the first stage of the study, information was obtained regarding the construction model of scientific argumentation embedded within science texts, based on interviews with three expert respondents. The summarized results of these interviews are presented in Table 4. The findings indicate that claims in a scientific argumentation-based text can take the form of phenomena, statements, or facts. Phenomena can function as claims because their truth can be empirically verified through observable evidence (Leonelli, 2015). Statements also qualify as claims when supported by valid data and can be accepted by the wider scientific community (Gray & Kang, 2014; Zhang & Browne, 2022). Meanwhile, facts can be used as claims because they are verifiable and supported by credible sources or evidence (Heng et al., 2015). The data component may consist of experimental results, supporting theories or laws, processes underlying the claims, classifications of claims, illustrative images, and relevant examples. Experimental results serve as data because they empirically substantiate the claims being made (Toulmin, 2003; van Eemeren et al., 2014). Supporting theories or laws function as data as they conceptually strengthen the validity of the claims (Heng et al., 2015).

Likewise, explanations of processes or types of claims, along with illustrative figures and examples, provide contextual and visual evidence that reinforce the claims (Fatikhiah, 2022; Aryanti, 2024; Kuhn & Lerman, 2021). The warrant serves as a logical bridge that connects the claim to the supporting data. Warrants identified in this study include causal relationships, formulas, applications in daily life, and data explanations. Causal relationships are essential as they establish logical reasoning between evidence and conclusions (Lazarou & Erduran, 2021). Similarly, scientific formulas serve as warrants because they provide theoretical justification linking the claim to empirical data (Laamena et al., 2018). Real-life applications and explanations of data also act as warrants since they contextualize the reasoning process and reinforce the link between claim and evidence (Lazarou & Erduran, 2021). Finally, the backing component strengthens the warrant by offering additional justification or supporting evidence. Backings identified in this study include extended explanations of the warrant and corroborating factual information. Both serve as guarantees that reinforce the validity and reliability of the warrant (Lazarou & Erduran, 2021).

Overall, the results demonstrate that a well-structured argumentation construction model comprising claims, data, warrants, and backings can guide the development of science teaching materials that promote reasoning, critical thinking, and conceptual understanding. This aligns with the theoretical framework of Toulmin's Argumentation Pattern (Toulmin, 2003), emphasizing that effective argumentation facilitates deeper engagement with scientific concepts and minimizes misconceptions.

Table 4. Scientific Argumentation Construction Model

Scientific Argumentation Elements	Technique to Display Scientific Argumentation Elements
Claim	1. Phenomena 2. Statement 3. Fact
Data	1. Experiment result 2. Supporting theories 3. The process of claim 4. Types of claim 5. Illustrative images 6. Relevant examples
Warrant	1. Causal relationship 2. Formula 3. Application in daily life 4. Data explanation
Backing	1. Further explanation of the warrant 2. Supporting facts

Based on the second step, the sub materials and learning indicators obtained in the first round of delphi are shown in Table 5. Furthermore, in the second round of delphi, the sub materials were analyzed for agreement and ranked. The results are shown in Table 6.

Table 5. First Round Delphi for Sub materials and Learning Indicators

Sub materials	Learning Indicators	Code Indicators
Solar System	Mention the kinds of celestial bodies	1A
	Describe the differences between celestial bodies	2A
	Collect information to support opinions on which celestial bodies are suitable for human life	3A
Earth and its Satellites	Describe the difference between natural and artificial satellites	1B
	Describe the effects of the movement of the Earth and celestial bodies on natural phenomena on Earth	2B
Sun	Explain the role of the Sun in life	1C
Ecosystems and Natural Processes on Earth	Analyze ecosystems and natural processes on Earth	1D
Theories in the Solar System	Recognize theories of the universe (e.g. magnetic force and Kepler's laws)	1E

Table 6. Second Round Delphi for Sub Materials

Sub materials	Code Sub materials	d value	DV value	Rank	Status
Solar System	SM 1	0.11	0.75	1	Valid
Earth and its Satellites	SM 2	0.11	0.75	1	Valid
Sun	SM 3	0.11	0.75	1	Valid
Ecosystems and Natural Processes on Earth	SM 4	0.14	0.73	2	Valid

Sub materials	Code Sub materials	d value	DV value	Rank	Status
Theories in the Solar System	SM 5	0.15	0.70	3	Valid

The next step, in the second round of Delphi, the learning indicators in the cognitive domain in each sub materials were analyzed for agreement and ranked. The results are shown in Table 7.

Table 7. Second Round Delphi for Learning Indicators

Sub materials	Code Indicators	d value	DV value	Rank	Status
Solar System	1A	0.17	0.72	2	Valid
	2A	0.15	0.72	2	Valid
	3A	0.11	0.75	1	Valid
Earth and its Satellites	1B	0.17	0.72	2	Valid
	2B	0.05	0.78	1	Valid
Sun	1C	0.08	0.77	-	Valid
Ecosystems and Natural Processes on Earth	1D	0.11	0.77	-	Valid
Theories in the Solar System	1E	0.11	0.65	-	Valid

Based on the results presented in Table 6, the subtopics that students are required to study include the Solar System (SM1), the Earth and Its Satellites (SM2), the Sun (SM3), Ecosystems and Natural Processes on Earth (SM4), and Theories in the Solar System (SM5). Expert consensus confirmed that SM1, SM2, SM3, and SM5 are essential components of science learning. These subtopics are considered important because they introduce students to a new interdisciplinary context that connects mathematical reasoning, physical principles, and chemical processes related to astronomical phenomena (Plummer et al., 2015). Furthermore, the experts also agreed on the inclusion of SM4 (Ecosystems and Natural Processes on Earth) as a crucial subtopic. This component is significant because it enables students to understand the interrelationship between biotic and abiotic components within Earth's ecosystems and how these interactions sustain environmental balance (Zangori et al., 2020). The integration of this subtopic within the Earth and Solar System theme supports the concept of integrated science learning, allowing students to perceive the interconnectedness of natural systems across disciplines.

As shown in Table 7, eight learning indicators were validated and agreed upon by experts as essential cognitive targets for the topic of the Earth and the Solar System. These indicators span four cognitive levels remembering (C1), understanding (C2), analyzing (C4), and creating (C6) based on the revised Bloom's taxonomy (Anderson & Krathwohl, 2001). The inclusion of these indicators is pedagogically important because they: Help students recall and recognize key concepts within the material; Enable students to comprehend and interpret scientific information presented in both oral and written forms; Train students to identify relationships among pieces of information and connect them to broader scientific goals; and Encourage students to synthesize ideas and construct coherent scientific explanations. Collectively, these results demonstrate that the developed learning indicators align with both cognitive development theory and argumentation-based pedagogy, ensuring that students engage actively with content while developing deeper conceptual understanding of Earth and Solar System phenomena.

Based on the results of the fourth stage, the readability level of the science teaching materials developed through scientific argumentation activities was found to be appropriate for Grade 7 students at the junior high school level. The readability assessment was conducted using five representative text samples selected from different sections of the developed materials. The results of this analysis, as presented in Table 8, indicate that the materials are linguistically and cognitively suitable for the target age group. This finding demonstrates that the sentence structure, vocabulary, and overall textual complexity are aligned with students' comprehension levels, thereby ensuring that the materials can be effectively utilized in classroom learning without causing cognitive overload

Table 8. Analysis of the Readability Level of the Developed Teaching Materials

Code Discourse	Number of Sentences	Number of Syllables	Meeting Point on Fry's Graph	Readability Level	Readability Level
(i)	(ii)	(iii)	(iv)	(v)	(vi)
D1	7.6	141.6	Class 7	Grade 6,**7**,8	Appropriate
D2	7.9	144.6	Class 7	Grade 6,**7**,8	Appropriate
D3	10	158.4	Class 8	Grade **7**,8,9	Appropriate
D4	10	157.2	Class 8	Grade 7,8,9	Appropriate
D5	9	148.8	Class 7	Grade 6,**7**,8	Appropriate
	Cohen Kappa Coefficient of Agreement			**1**	

The readability analysis using Fry's Readability Graph showed that discourse samples D1, D2, and D5 correspond to Grade 7, while D3 and D4 correspond to Grade 8 reading levels. According to Fry's (1968) readability theory, the final grade level of a text is determined by adjusting one level above and below the obtained range to account for text variability (Hidayati et al., 2018). Based on this principle, the teaching materials developed through scientific argumentation activities on the topic of the Earth and the Solar System are classified as suitable for Grade 7 students at the junior high school level.

Several factors support this conclusion. First, the selected discourse samples met the established criteria, as they were drawn from representative passages that exclude visual elements such as pictures, tables, blank pages, numerical formulas, or section titles (Hidayati et al., 2018). This ensured that the readability assessment was based solely on the textual content. Second, the number of sentences in each sample was within the recommended range neither excessively long nor too brief thus meeting the criteria for appropriate sentence complexity. Previous studies have shown that optimal sentence length significantly influences the readability level of scientific texts (Maruti et al., 2023). Third, the number of syllables within the selected discourses corresponded to the expected range for Grade 7 texts, as an increase in syllable count typically indicates higher reading difficulty (Azizah & Budijastuti, 2020).

Additionally, an inter-rater reliability test was conducted using the Cohen's Kappa coefficient to determine the consistency of expert judgments. The analysis yielded a Kappa value of 1.00, indicating perfect agreement among the raters (Cohen, 1960). This finding further validates that the developed teaching materials are linguistically and cognitively appropriate for Grade 7 students. Consequently, the materials can be confidently implemented at the junior high school level to support students' engagement in scientific argumentation-based learning.

Table 9. Validation Results of Each Sub Materials with Delphi One Round

Sub materials	Indicator of Validity Assessment	d value	DV value	Status
Solar System	1	0.03	0.79	Valid
	2	0.00	0.80	Valid
	3	0.12	0.64	Valid
	4	0.14	0.67	Valid
	5	0.11	0.75	Valid
	6	0.14	0.67	Valid
	7	0.15	0.67	Valid
	8	0.13	0.74	Valid
Earth and its Satellites	1	0.00	0.80	Valid
	2	0.00	0.80	Valid
	3	0.15	0.66	Valid

Sub materials	Indicator of Validity Assessment	d value	DV value	Status
	4	0.14	0.67	Valid
	5	0.09	0.76	Valid
	6	0.14	0.67	Valid
	7	0.15	0.67	Valid
	8	0.14	0.73	Valid
Sun	1	0.03	0.79	Valid
	2	0.00	0.80	Valid
	3	0.15	0.66	Valid
	4	0.15	0.68	Valid
	5	0.06	0.78	Valid
	6	0.15	0.68	Valid
	7	0.15	0.68	Valid
	8	0.11	0.75	Valid
Ecosystems and Natural Processes on Earth	1	0.03	0.79	Valid
	2	0.00	0.80	Valid
	3	0.12	0.64	Valid
	4	0.14	0.67	Valid
	5	0.09	0.76	Valid
	6	0.14	0.67	Valid
	7	0.13	0.67	Valid
	8	0.09	0.76	Valid
Theories in the Solar System	1	0.07	0.78	Valid
	2	0.00	0.80	Valid
	3	0.15	0.66	Valid
	4	0.15	0.68	Valid
	5	0.09	0.76	Valid
	6	0.14	0.67	Valid
	7	0.14	0.67	Valid
	8	0.09	0.76	Valid

Based on the fifth step, the teaching materials developed through scientific argumentation on the topic of the Earth and Solar System were determined to be valid, as shown in Table 9. The validation results, obtained through expert consensus using the Fuzzy Delphi method, indicate that the materials meet the essential criteria for conceptual, linguistic, and visual quality. Several factors contribute to the validity of these teaching materials. First, the materials successfully present accurate and coherent scientific concepts that explain both micro and macro phenomena, aligning with the characteristics of science learning materials described by Liu et al. (2019). Second, the materials demonstrate a high quality of scientific argumentation, incorporating the essential components of a sound argument claims, data, warrants, and backing as proposed by Toulmin (2003) and reinforced by Simon et al. (2006). This structure enables students to construct and justify scientific reasoning effectively.

Third, the materials exhibit linguistic accuracy, including correct sentence structure, precise word choice, and appropriate spelling, consistent with the standards of effective Indonesian language use in educational contexts (Nurdjan et al., 2016). Fourth, the number of sentences and syllables within the texts is appropriate for Grade 7 students, supporting comprehension and cognitive accessibility, as suggested by Maruti et al. (2023). Fifth, the materials employ communicative and interactive language through embedded small-group discussion prompts, which foster student engagement and collaborative learning an approach recommended by Noviyanti et al. (2017). Sixth, the teaching materials possess an aesthetically appealing design, characterized by consistent layout, well-organized content, and supportive illustrations. These features align with the principles of textbook design established by the Textbook Committee (2016). Seventh, the inclusion of clear and contextually relevant images and tables enhances the comprehensibility of the material and supports visual learning, consistent with the recommendations of Postigo and López-Manjón (2019). Eighth, the font size and text spacing are carefully adjusted to ensure readability and visual comfort, in line with ergonomic and educational design guidelines proposed by Hojjati and Muniandy (2014). Overall, these findings confirm that the developed teaching materials fulfill the pedagogical, linguistic, and visual requirements of valid instructional resources for Grade 7 students, effectively supporting science learning through argumentation-based approaches.

CONCLUSION

This study generated several key findings. First, the construction of teaching materials based on scientific argumentation for the topic of Earth and the Solar System can be effectively represented through the integration of the four core argumentation elements claim, data, warrant, and backing. The claim element can be expressed through phenomena, statements, and facts; the data element through experimental results, supporting theories, the process and types of claims, illustrative images, and relevant examples. The warrant element is represented by causal relationships, formulas, real-life applications, and data explanations, while the backing element is manifested through further elaborations of warrants and supporting evidence. Second, the learning indicators that junior high school students should master in the cognitive domain for the topic of Earth and the Solar System are organized according to sub-materials as follows: Solar System: (1) identify various celestial bodies, (2) describe differences among celestial bodies, and (3) collect information to justify opinions on celestial bodies suitable for human habitation. Earth and Its Satellites: (1) explain the differences between natural and artificial satellites, and (2) describe the effects of the Earth's and celestial bodies' movements on natural phenomena on Earth. The Sun: explain the role of the Sun in sustaining life. Ecosystems and Natural Processes on Earth: analyze ecosystems and natural processes occurring on Earth. Theories in the Solar System: identify and recognize key theories explaining the structure and evolution of the universe.

Third, the developed teaching materials based on scientific argumentation possess an appropriate readability level for Grade 7 students, as indicated by Fry's graph analysis, ensuring accessibility and comprehension for the intended age group. Fourth, the developed teaching materials were evaluated and validated by 17 experts, demonstrating high levels of validity in terms of scientific content accuracy, linguistic appropriateness, argumentation quality, and visual design. Overall, the findings indicate that the scientific argumentation-based teaching materials developed in this study are pedagogically sound, scientifically accurate, linguistically accessible, and visually engaging. These materials can therefore serve as a valid and effective learning resource to enhance students' conceptual understanding and reasoning skills in integrated science learning at the junior high school level.

REFERENCES

Anderson, L. W., & Krathwohl, D. R. (2001). *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. Longman.

Aryanti, D., Siswanto, S., Juliyanto, E., Trisnowati, E., & Amirul, M. A. (2024). Analysis of Science Textbooks from The Aspect of Scientific Argumentation: Comparing Several Books on The Topic of Heat. *Journal of Natural Science and Integration*, *7*(1), 69-81.

Asri, A. S. (2017). Telaah Buku Teks Pegangan Guru dan Siswa Pada Mata Pelajaran Bahasa Indonesia Kelas VII Berbasis Kurikulum 2013. In *RETORIKA: Jurnal Ilmu Bahasa* (Vol. 3, Issue 1). http://ejournal.warmadewa.ac.id/index.php/jret

Azizah, V. N., & Budijastuti, W. (2020). The Relationship of Illustrative Content in Flipbook Type of E-Book As An Illustrative Learning Media In Immune System with Reading Test Results Using Fry Graphics. *Berkala Ilmiah Pendidikan Biologi (BioEdu)*, *9*(1), 109-114.

Bathgate, M., Crowell, A., Schunn, C., Cannady, M., & Dorph, R. (2015). The Learning Benefits of Being Willing and Able to Engage in Scientific Argumentation. *International Journal of Science Education*, *37*(10), 1590–1612. https://doi.org/10.1080/09500693.2015.1045958

Berland, L. K., & Reiser, B. J. (2009). Making sense of argumentation and explanation. *Science Education*, 93(1), 26-55.

Chang, P. L., Hsu, C. W., & Chang, P. C. (2011). Fuzzy Delphi Method for Evaluating and Improving the Quality of Curriculum. *International Journal of Fuzzy Systems*, 13(2), 117-129.

Cohen, J. (1960). A Coefficient of Agreement For Nominal Scales. *Psycological Measurement*, 37–46.

Deane, P., & Song, Y. (2014). A Case Study in Principled Assessment Design: Designing Assessments To Measure and Support The Development of Argumentative Reading and Writing Skills. *Psicología Educativa*, *20*(2), 99–108. https://doi.org/https://doi.org/10.1016/j.pse.2014.10.001

Erduran, S., & Park, W. (2023). Argumentation in physics education research: Recent trends and key themes. *The international handbook of physics education research: Learning physics*, 16-32.

Fatikhiah, F. Al. (2022). Analisis Buku Teks IPA SMP dari Aspek Scientific Explanation pada Materi Tekanan Zat. *(Skripsi, Universitas Tidar).*

Fry, E. (1968). A Readability Formula that Saves Time. *Journal of Reading*, 513–516.

Gray, R., & Kang, N. H. (2014). The Structure of Scientific Arguments by Secondary Science Teachers: Comparison of experimental and historical science topics. *International Journal of Science Education*, *36*(1), 46–65. https://doi.org/10.1080/09500693.2012.715779

Guilfoyle, L., Hillier, J., & Fancourt, N. (2021). Students' Argumentation In The Contexts Of Science, Religious Education, and Interdisciplinary Science-Religious Education Scenarios. *Research in Science and Technological Education*. https://doi.org/10.1080/02635143.2021.1947223

Hakim, A., Sahmadesti, I., & Hadisaputra, S. (2020). Promoting Students' Argumentation Skill Through Development Science Teaching Materials Based on Guided Inquiry Models. In *Journal of Physics: Conference Series* (Vol. 1521, No. 4, p. 042117). IOP Publishing.

Heng, L. L., Surif, J., & Seng, C. H. (2015). Malaysian Students' Scientific Argumentation: Do Groups Perform Better Than Individuals? *International Journal of Science Education*, *37*(3), 505–528. https://doi.org/10.1080/09500693.2014.995147

Heriyanto. (2018). Thematic Analysis sebagai Metode Menganalisa Data untuk Penelitian Kualitatif. *ANUVA*, *2*(3), 317–324.

Hidayati, P. P., Ahmad, A., & Inggriyani, F. (2018). Penggunaan Formula Grafik Fry untuk Menganalisis Keterbacaan Wacana Mahasiswa PGSD. *Mimbar Sekolah Dasar*, *5*(2), 116. https://doi.org/10.17509/mimbar-sd.v5i2.11496

Hojjati, N., & Muniandy, B. (2014). The Effects of Font Type and Spacing of Text for Online Readability and Performance. In *Contemporary Educational Technology* (Vol. 5, Issue 2).

Kuhn, D., & Lerman, D. (2021). Yes But: Developing A Critical Stance Toward Evidence. *International Journal of Science Education*, *43*(7), 1036–1053. https://doi.org/10.1080/09500693.2021.1897897

Kundariat, M., Maghfiroh, L., Indriwat, S. E., Rohman, F., & Priambodo, B. (2022). Revealing the Effect of Local-Based Teaching Materials toward Scientific Reasoning, Argumentation, and Problem-Solving in Biology Classroom. *Journal of Biological Education Indonesia (Jurnal Pendidikan Biologi Indonesia)*, *8*(3), 287-295.

Laamena, C. M., Nusantara, T., Irawan, E. B., & Muksar, M. (2018). Analysis of the Students' Argumentation based on the level of Ability: Study on the Process of Mathematical Proof. *Journal of Physics: Confere nce Series*, *1028*(1). https://doi.org/10.1088/1742-6596/1028/1/012156

Lazarou, D., & Erduran, S. (2021). "Evaluate What I Was Taught, Not What You Expected Me to Know": Evaluating Students' Arguments Based on Science Teachers' Adaptations to Toulmin's Argument Pattern. *Journal of Science Teacher Education*, *32*(3), 306–324. https://doi.org/10.1080/1046560X.2020.1820663

Leonelli, S. (2015). What Counts as Scientific Data? A Relational Framework. *Philosophy of Science*, *82*(5), 810–821. https://doi.org/10.1086/684083

Liu, Q. T., Liu, B. W., & Lin, Y. R. (2019). The Influence of Prior Knowledge and Collaborative Online Learning Environment on Students' Argumentation in Descriptive and Theoretical Scientific Concept. *International Journal of Science Education*, *41*(2), 165–187. https://doi.org/10.1080/09500693.2018.1545100

Maruti, E. S., Cahyono, B. E. H., Kurniawati, R. P., & Hanif, M. (2023). Do Javanese Textbooks Convey Relevant Material? Evidence of Readability and Value of Learning Outcomes. *Preventing School Failure: Alternative Education for Children and Youth*, 1–6. https://doi.org/10.1080/1045988X.2023.2181299

Noviyanti, D., Sutini, A., & Kurniawati, K. (2017). Pendekatan Komunikatif Interaktif untuk Meningkatkan Kosakata Anak Usia Dini. *Cakrawala Dini*, *8*(1).

Nurdjan, S., Firman, & Mirnawati. (2016). *Bahasa Indonesia untuk Perguruan Tinggi*. Makassar: Penerbit Aksara Timur.

Osborne, J. (2010). *Arguing to Learn in Science: The Role of Collaborative, Critical Discourse.* Science, 328(5977), 463–466.

Plummer, J. D., Palma, C., Flarend, A., Rubin, K., Ong, Y. S., Botzer, B., McDonald, S., & Furman, T. (2015). Development of a Learning Progression for the Formation of the Solar System. *International Journal of Science Education*, *37*(9), 1381–1401. https://doi.org/10.1080/09500693.2015.1036386

Postigo, Y., & López-Manjón, A. (2019). Images in biology: are instructional criteria used in textbook image design? *International Journal of Science Education*, *41*(2), 210–229. https://doi.org/10.1080/09500693.2018.1548043

Rachmawati, S., Susanto, H., & Fianti, F. (2017). Penggunaan Metode CRI (Certainty Of Response Index) Berbantuan Soal PISA (Programme Of International Student Assesment) untuk Mengidentifikasi Miskonsepsi IPA Materi Tata Surya. *UPEJ Unnes Physics Education Journal*, *6*(3), 26-31.

Saido, G. A. M., Siraj, S., DeWitt, D., & Al-Amedy, O. S. (2018). Development of An Instructional Model for Higher Order Thinking in Science Among Secondary School Students: A Fuzzy Delphi Approach. *International Journal of Science Education*, *40*(8), 847–866. https://doi.org/10.1080/09500693.2018.1452307

Simon, S., Erduran, S., & Osborne, J. (2006). Learning To Teach Argumentation: Research and Development in The Science Classroom. *International Journal of Science Education*, *28*(2–3), 235–260. https://doi.org/10.1080/09500690500336957

Siswanto, S., Anci, S. Y., Yusiran, Y., Hartono, H., Subali, B., & Trisnowati, E. (2020). Scientific or Not? Mapping Category of Students' Written Argument. *Proceedings of the 7th Mathematics, Science, and Computer Science Education International Seminar, MSCEIS 2019*. https://doi.org/10.4108/eai.12-10-2019.2296492

Siswanto, S., Hartono, H., Subali, B., & Masturi, M. (2022). Infusing Explicit Argumentation in Science Reading Activities: Helping Prospective Science Teachers Reduce Misconception and Foster Argumentation Skills. *Pegem Egitim ve Ogretim Dergisi*, *12*(3), 177–189. https://doi.org/10.47750/pegegog.12.03.19

Sumarni, S., Aryanti, D., & Siswanto. (2020). Pandangan Guru IPA tentang Nature of Science(NOS) dan Argumentasi Ilmiah Serta Kendala dalam Pengajarannya. *Indonesian Journal of Natural Science Education (IJNSE)*, *3*(2), 362438.

Textbook Committee. (2016). *Guidling Principles for Quality Textbooks*. Hongkong: Education Bureau.

Toulmin, S. (2003). *The Uses of Argument, Updated Edition*. Cambridge: University Press.

van Eemeren, F. H., Garssen, B., Krabbe, E. C. W., Snoeck Henkemans, A. F., Verheij, B., & Wagemans, J. H. M. (2014). Toulmin's Model of Argumentation. In F. H. van Eemeren, B. Garssen, E. C. W. Krabbe, A. F. Snoeck Henkemans, B. Verheij, & J. H. M. Wagemans (Eds.), *Handbook of Argumentation Theory* (pp. 203–256). Springer Netherlands. https://doi.org/10.1007/978-90-481-9473-5_4

Zangori, L., Ke, L., Sadler, T. D., & Peel, A. (2020). Exploring primary students causal reasoning about ecosystems. *International Journal of Science Education*, *42*(11), 1799–1817. https://doi.org/10.1080/09500693.2020.1783718

Zhang, J., & Browne, W. J. (2022). Exploring Chinese High School Students' Performance and Perceptions of Scientific Argumentation by Understanding It as A Three-Component Progression of Competencies. *Journal of Research in Science Teaching*. https://doi.org/10.1002/tea.21819