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Development of Argumentation-Based Guidance Materials in Science Education and Analysis of Student Argumentation Levels

Fen Eğitiminde Argümantasyona Dayalı Rehber Materyal Geliştirilmesi ve Öğrencilerin Argüman Seviyelerinin İncelenmesi

Feyza TÜRK[**] **Nagihan YILDIRIM**[***]

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ABSTRACT: This study used a case study, one of the qualitative research methods, with the aim of developing guidance materials based on the argumentation-based science learning (ABSL) approach for concepts in the 6th grade unit "Sound and Its Properties" and to examine students' argumentation levels and conceptual understanding. The activity sheets completed by the students before and during the implementation process and the semi-structured interviews conducted after the implementation process were used as data collection instruments. A rubric developed by Erduran et al. (2004) was used to address one of the sub-research questions of the study to determine students' level of argumentation. The semi-structured interview data were subjected to descriptive analysis. Responses to conceptual questions were coded as correct, partially correct, incorrect or blank. These categorizations were then summarized in tables, including representative student statements. The results of this study indicate that the students' level of argumentation during the first activities was initially at level 1. As the activities progressed, there was an increase in the number of level 2 arguments, with some activities reaching level 3. However, no level 4 or 5 arguments were produced. The developed materials had a positive effect on students' conceptual learning.

Keywords: Argumentation level, guidance material, sound and its properties.

ÖZ: Bu çalışmada, 6. sınıf "Ses ve Özellikleri" ünitesinde yer alan kavramlara yönelik argümantasyon tabanlı bilim öğrenme (ATBÖ) yaklaşımına dayalı öğretim materyalleri geliştirmek ve öğrencilerin argümantasyon düzeyleri ile kavramsal anlamalarını incelemek amacıyla nitel araştırma yaklaşımlarından durum çalışması kullanılmıştır. Veri toplama aracı olarak öğrencilerin uygulama öncesinde ve uygulama sürecinde doldurdukları etkinlik kâğıtları ve uygulama sonrasında yapılan yarı yapılandırılmış mülakat kullanılmıştır. Öğrencilerin argümantasyon düzeylerini belirlemek için Erduran ve diğerleri (2004) tarafından geliştirilen bir rubrik kullanılmıştır. Yarı yapılandırılmış mülakat verileri betimsel analize tabi tutulmuştur. Kavramla ilgili sorulara verilen yanıtlar doğru, kısmen doğru, yanlış ya da boş olarak kodlanmıştır. Bu kategoriler ve frekans dağılımları örnek öğrenci ifadeleri ile tablolaştırılmıştır. Çalışmanın sonuçları, ilk etkinlikler sırasında öğrencilerin argümantasyon seviyesinin başlangıçta 1. seviyede olduğunu göstermektedir. Etkinlikler ilerledikçe 2. seviye argümanların sayısında artış olmuş, bazı etkinliklerde 3. seviye örneklerine de rastlanmıştır. Ancak 4. veya 5. seviye argüman üretilmemiştir. Geliştirilen materyallerin öğrencilerin kavramsal öğrenmeleri üzerinde olumlu bir etkisi olmuştur.

Anahtar kelimeler: Argüman seviyesi, rehber materyal, ses ve özellikleri.

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[**] Science teacher, Ali Riza Yilmaz Secondary School, Rize, Türkiye, feyza_turk20@erdogan.edu.tr, https://orcid.org/0000-0002-8048 -7917
[***] *Corresponding Author*: Prof. Dr., University of Recep Tayyip Erdogan, Rize, Türkiye, nagihan.yildirim@erdogan.edu.tr, https://orcid.org/0000-0002-2516-4656.

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In classrooms where scientific concepts are taught, the primary objective is for the teacher to assume a facilitative role, guiding students as they encounter and engage with different problem situations. Through this process, students are encouraged to develop creative thinking skills to formulate solutions and become active participants in their own learning. To ensure that knowledge is both meaningful and enduring, it is essential to incorporate teaching techniques such as cooperative learning, problem solving, project-based learning and argumentation into educational settings (Altun & Özsevgeç, 2025; Faize, Husain & Nisar, 2017; MONE, 2013; Valero Haro et al., 2020). One pedagogical approach that promotes such experiences is argumentation-based science learning (ABSL). ABSL is grounded in research- and inquiry-based methodologies, with argumentation serving as a critical tool for fostering deep cognitive engagement. The argumentation process enables students to critically evaluate and compare their preexisting mental models with those of their peers. During this comparative analysis, students adopt a scientific mindset, constructing and defending claims through the use of reasoning and evidence. This reflective process not only reinforces accurate mental models but also facilitates the refutation of misconceptions. As a result, conceptual change is achieved through inquiry-based exploration and critical thinking (Aslan, 2010). By integrating ABSL into science education, students are better equipped to develop higher-order thinking skills, enhance their ability to reason scientifically, and engage in meaningful, evidence-based discourse. This approach not only promotes deeper conceptual understanding but also prepares students to think and act like scientists in their problem-solving efforts.

In the argumentation-based science learning (ABSL) approach, incorporating activities that involve research and inquiry, facilitating interactive group work, ensuring the expression of ideas from all groups in the classroom, transforming students' preconceptions, and encouraging the formation of new concepts are of paramount importance (Burke et al., 2005). Furthermore, the use of reflective writing plays a crucial role in reinforcing these processes. During discussions in ABSL, students use their prior knowledge to elaborate on the reasons that support their points of view and strive to substantiate the validity of their thoughts. At the same time, other students involved in the discussion articulated detailed counterarguments, expressed their doubts and advocated alternative hypotheses. This dynamic interaction forces students to support their solutions to real-life problems with specific scientific knowledge and evidence, to link these solutions to established information, and ultimately to persuade their peers by effectively communicating and defending the resulting knowledge. This process mirrors the way scientists develop and present arguments, thereby fostering a scientific mindset in students (Peker, 2017). The concept of an argument refers to the discourse that results from a discussion aimed at supporting a claim. In contrast, argumentation represents the process through which this discourse is generated (Kuhn & Udell, 2003). Fox et al., (1993) define argumentation as the process of generating arguments related to specific thoughts. More comprehensively, argumentation can be described as oral or written.

In the science curriculum (MONE, 2018), the inquiry-based process is described not simply as exploration-experiment but rather as a process of explanation and argument development. The curriculum aims to enable students to make sense of events in their immediate environment and to construct strong claims based on evidence.

Teachers are encouraged to create learning environments where students feel comfortable expressing their ideas without hesitation. In such environments, students should be motivated to articulate their arguments by using multiple supporting reasons and justifications to strengthen their own views while also being encouraged to use counterarguments to challenge opposing views presented by their peers. This emphasis on developing well-supported arguments and engaging in constructive criticism is key to fostering critical thinking and deepening understanding in the context of science education.

As the duration of students' involvement in the argumentation process increases, the quality of the arguments they develop and their thinking skills improve (Erduran et al., 2006). This emphasizes the importance of using the argumentation technique, especially in science courses (Köseoğlu et al., 2008). In this context, it is believed that the inclusion of argumentation-based science learning activities in the guidance materials designed for the "Sound and Its Properties" unit, which has been identified as a topic where students often struggle and have numerous misconceptions, will facilitate teachers' work and significantly contribute to the teaching process. In this study, the researcher developed and applied guidance materials according to the 5E model in the 'Sounds and Properties' unit on the basis of ABSL and examined the students' argumentation levels and conceptual understanding.

Method

This study used a case study design, one of the qualitative research methods, with the aim of developing guidance material based on the argumentation-based science learning (ABSL) approach for concepts in the 6th grade unit "Sound and Its Properties" and to examine students' argumentation levels and conceptual understanding. A case study is an in depth, longitudinal investigation of a single case or event, in which data are systematically collected to understand what happens in a real-world context. It provides insight into the reasons for the occurrence of an event and offers guidance for future studies by identifying areas of focus (Davey, 1991). While determining the sample, the application was carried out in the school where the first researcher was working because it was thought to be easily accessible and more comfortable to work with. In order to make detailed analyzes, the application was made with a class with fewer students. In this context, the sample of the study consisted of 16 sixth-grade students from a middle school in Derepazarı district, Rize Province. The selection of participants was based on voluntary participation, and the students were divided into groups of four. The sample included an equal distribution of 8 female and 8 male students.

Data Collection Tools

In this study, a guide material containing argumentation-based activities and lesson plans for the 'Sound and its properties' unit was developed and implemented by the lead researcher over the course of 16 lessons. The activity sheets completed by the students before and during the implementation process and the semi-structured interviews conducted after the implementation process were used as data collection instruments. Two types of activity sheets were used in the study. The first set of activity sheets, used before implementation, was designed to assess students' argumentation level and included activities developed by Solak (2016) and Çınar (2013). The first introductory activity was related to the concepts of heat and temperature. Students were given a story about making coffee in a copper and iron coffee pot. In the second activity, a concept cartoon about classrooms was given. After both activities, students were asked questions that would enable them to reach components such as claim and evidence in Tolumin's argumentation model. This pre-implementation activity lasted for two class periods. The second set of activity sheets was part of the guidance materials developed for the study. The guidance materials developed for the study consists of two parts. The first part contains activity sheets using different argumentation techniques. The second part contains detailed lesson plans that provide teachers with step-by-step instructions on how to implement these activities. The lesson plans have been developed according to constructivist learning theory and are aligned with the 5E learning model. A total of 15 activities have been developed for the guidance materials, each designed with specific learning objectives and tailored to argumentation techniques. Detailed information on the learning outcomes and the corresponding argumentation techniques for each activity is given in Table 1. The combination of activity sheets and semi-structured interviews provided a comprehensive set of data to analyze students' argumentation levels and conceptual understanding.

Table 1

Activities Developed for The Learning Outcomes and Argumentation Techniques Used

Activities number	The learning outcomes	The name of activities	Argumentation techniques
1	Predicts the environments in which sound can propagate and tests their predictions.	Particle Structure of Matter	Table of Statements
2		Sound Waves	Prediction-Observation-Explanation
3		Where is Sound?	Concept Cartoon
4		Where does sound travels?	Table of Statements
5	Discover by experimenting that sounds are heard differently with the change of the sound source.	Which Theory is Correct?	Competing Theories
6	Discover by experimenting that the sound is heard differently with the change of the environment in which the sound is emitted.	Different Environments	Competing with Cartoons
7		Bird Sound	Prediction-Observation-Explanation
8	Compares the speed of sound in different environments.	Indian Intelligence	Prediction-Observation-Explanation
9		Tell Me about Speed	Table of Expressions
10	Gives examples of reflection and absorption of sound.	Bat Tactics	Concept Cartoon
11		Where is the Sound?	Prediction-Observation-Explanation

12	Makes predictions to prevent the spread of sound and tests his/her predictions. Explains the importance of sound insulation.	Competing Arguments	Vee Diagram
13	Gives examples of acoustic applications.	Sounds in Cinema	Competing Theories
14		Acoustic	Evaluating Evidence
15	Sound insulation or acoustic applications of the environment to serve as an example of design.	Best Sound	Prediction-Observation-Explanation

The developed guidance material was reviewed by a subject expert and a science teacher. Based on their feedback, necessary adjustments were made, and the final version was completed.

In the semi-structured interviews used in the study, the students were asked a total of 9 concept-based questions related to the learning outcomes of the unit. The semi-structured interview questions were reviewed by an expert in science education to ensure content validity and appropriateness to the level of the students. On the basis of the expert's feedback, the necessary revisions were made, Activity-6, in which students had difficulty during the activity and did not write any answers on the activity sheet was removed from the guide material, changes were made in the concepts used and the questions were finalized. The semi-structured interviews were conducted with one volunteer student from each group (group 1, G1; group 2, G2; group 3, G3; and group 4, G4) for a total of 4 students. Each interview lasted between 15 and 20 minutes, and the students were coded as S1, S2, S3 and S4.

Analyzing the Data

Analysis of activity sheet data a rubric developed by Erduran et al. (2004) was used to address one of the sub-research questions of the study, which was to determine students' level of argumentation. The rubric is detailed in Table 2 and provides a structured approach to assessing the quality and development of students' arguments throughout the study.

Table 2

Analysis of Argumentation Levels

Argumentation Level	Description
Level 1	Contains a simple claim or a claim in response to an opposing argument.
Level 2	Includes claims supported by data, reasoning, and feedback but lacks rebuttals.
Level 3	Features a series of opposing claims or claims supported by data, reasoning, and weak rebuttals.
Level 4	Contains clearly defined rebuttals and may include one or more claims and opposing claims, though the latter is not needed.
Level 5	Comprises extended arguments with multiple rebuttals, demonstrating a high level of complexity and depth.

The responses on the students' activity sheets, both before and after the application, were coded according to the levels to which they corresponded. Researcher triangulation was used in this process. In this process, the researcher and the supervising lecturer coded separately to which level in Table 2 the students' answers in the activity sheets were appropriate; then, it was determined that there was harmony between the two coding, and the determined argument levels were presented in frequency tables. In terms of analysis, examples of student expressions from each level and explanations of why these expressions were classified at that level are presented below.

‘Since the substances are different, they have different temperatures of essence.’ ‘No. It consists of three states.’ The statements were evaluated at Level 1 because they contained a simple claim or a simple argument against it.

‘Since particles hit each other, waves are formed in water, that is, particles make translational movements.’, ’Since there are no particles in space, sounds cannot be heard. For example, when Star Wars ships shoot beams, no sound is produced, but managers make sound effects.’ The statements were evaluated at Level 2 because they did not contain data, justifications or rebuttals.

‘In the first case, since the lid of the metal container is closed, the sound hits around and cannot come out. In the second case, since the lid is open, the sound comes out easily.’ The statement was evaluated at Level 3 because it contains data, justifications and rebuttal elements.

In the process of evaluating and tabulating the arguments from the activity sheets, different classification methods were used for different argumentation techniques:

1. For argumentation techniques such as the statement table, Vee diagram and valuation of evidence, where multiple arguments are typically generated within a single activity sheet, the frequency of each argumentation level is tabulated. This method provides a quantitative measure of the prevalence of different levels of argumentation in the responses, providing a comprehensive overview of argumentation quality.

2. For techniques such as concept cartoons and competing theories, which generally produce a single argument per sheet, the level of argument is directly classified and presented in the tabulation. This simple classification method effectively captures the complexity of the argument in the context of these specific techniques.

3. For the prediction-observation-explanation technique, where arguments were generated separately in the prediction and explanation sections, these sections were analyzed independently. Consequently, the arguments produced in the prediction phase and those produced in the explanation phase are presented separately in the tables to clarify the different contributions of each phase to the overall argumentation process.

Analysis of Semi-structured Interview Data

The semi-structured interview data were subjected to descriptive analysis. Responses to concept-related questions were categorized and coded as correct, partially correct, incorrect or blank. These categorizations were then summarized in tables, including representative student statements, to illustrate the distribution and nature of the responses.

Ethical Procedures

In this study, all the rules specified to be followed within the scope of "Higher Education Institutions Scientific Research and Publication Ethics Directive" were complied with. None of the actions specified under the title of "Actions Contrary to Scientific Research and Publication Ethics", which is the second part of the directive, were not carried out. Ethics committee approval dated 04.01.2022 and numbered 2022/12 was obtained from Recep Tayyip Erdoğan University Social and Human Sciences Ethics Committee for this study. The study was produced from the master's thesis named " Based guide materials in science education and investigation of students' argument levels 6th grade students' argument levels".

Results

The findings from the study are presented in two sections: findings from activities and findings from interviews.

Findings from the Pre-Implementation Activities

The findings from the pre-implementation activities, which were designed to determine the students' initial levels of argumentation, are presented in the form of a frequency table containing sample statements from the students about their levels of argumentation.

Table 3

Students' Argumentation Levels and Sample Statements in the Pre-implementation Activity

Group Number	Argumentation Level	Argument Examples
G1	1	They argued that the substances are different and that one will heat faster while the other will heat slower.
G2	1	Since the substances are different, their specific heat capacities are also different
G3	1	Elif is applying what she learned to real-life situations.
G4	1	Since iron is a thermal conductor, it will cook at a different rate.

When the table is analyzed, it is seen that all students in the groups produced arguments at level 1 and that the students' answers included a simple claim or a claim in response to an opposing argument.

Findings from the Main Implementation Activities

The argumentation levels of the students obtained from the activities conducted during the main implementation are presented in a frequency table, which includes sample statements from the students.

Table 4

Students' Argumentation Levels and Sample Statements from Activities During the main Implementation

Activity No		Argumentation Level 1 (f)	2 (f)	3 (f)	4 (f)	5 (f)	Sample Statements
1	G1	4	4				Correct. Because every particle makes vibrational motion. No. It consists of three states.
	G2	2	-				
	G3	6	2				
	G4	4	4				
2	G1	1	1				Sound waves are similar to the waves created when a stone is thrown into water, and as they spread, their intensity decreases.
	G2	1	2				
	G3	1	-				
	G4	1	1				
3	G1		1				When a particle is found in space, sound waves reach the Earth. When meteors collide in space, sound is heard.
	G2		1				
	G3		1				
	G4		1				
4	G1	6	4				Because there is air on Earth. Sound spreads around by vibrating.
	G2	6	4				
	G3	3	3				
	G4	9	1				
5	G1	1					When the same object is struck with different materials, the sound changes. All materials vibrate at the same rate.
	G2	1					
	G3	1					
	G4	2					
6	G1						Because they are close to each other based on their particles, sound propagates better. Because sound does not encounter any obstacles in the air and propagates better.
	G2						
	G3		1				
	G4	1					
7	G1		2				The particles in water are more organized than in gas, so they could hear better when they came out of the sea.
	G2	1	1				
	G3	1					

	G4	1	1		
8	G1		2		For example, when we shout or talk to someone in the water, the sound changes moderately. In the air, it changes less because there is matter in the air, and the sound propagates at the same pitch. In solids, since there is no air, the sound changes significantly."
	G2	1	1		
	G3	1			
	G4	1	1		
9	G1		1		It spread faster in solid because the particles are more dense, slower in liquid because there are fewer gaps, and slower in gas because there are many gaps.
	G2		1		
	G3		1		
	G4		1		
10	G1	3	2		For example, when we put our ear to the desk, we hear a sound. It spreads in every gas.
	G2	7			
	G3	2	1		
	G4	2	2		
11	G1		1		Since sound travels faster in a solid and slower in a gas, and there is gas in the hole, if the bat goes to the place where sound travels slower, it can find the butterfly by passing through the holes.
	G2		1		
	G3		1		
	G4		1		
12	G1		1	1	When the lid was closed, the sound stayed inside and came out very little, but when the lid was open, the sound came out very well.
	G2	1	1		
	G3		2		
	G4		2		
13	G1	1			Arguments say that sound travels when it hits a wall, while counterarguments say the opposite, for example, arguments say that sound travels slower in a vacuum, while counterarguments say that it travels more easily. Because other explanations are different.
	G2	1			
	G3		1		
	G4	4			
14	G1			1	We prefer the 2nd theory so that it does not damage our ears. We do not prefer theory 1. The reason is that thermal insulation materials are used to prevent the sound from spreading too much.
	G2		1		
	G3			1	
	G4		1		
15	G1	1	1		Since the sound outside was more intense, the sound of the mechanical objects inside was not fully heard. Sound can be reduced by sound insulation.
	G2	1			
	G3		1		
	G4	1	1		

Table 4 shows that the students generally produced arguments at the 1st and 2nd levels. However, toward the end of the activities, examples of arguments at the 3rd level were encountered. In activity 12, G1, in activity 14, G1 and G3 formed arguments at the third level. The answers of students in these groups contain a series of opposing claims or claims supported by data, reasoning and weak rebuttals.

Findings from the Semi-structured Interviews

In the interviews, the students were asked conceptual questions related to the "Sound and Its Properties" unit and their opinions about the implementation process. The students' answers to the conceptual questions were coded as correct, partially correct, incorrect, or blank and are presented in Table 5.

Table 5

Findings from Students' Responses to Conceptual Questions Related to the 'Sound and Its Properties' Unit

Question No/Content	Correct	Partially Correct	False	Empty	Sample student statements
1-2	S1, S2, S3, S4	-	-	-	Solid, liquid, gas. Environments where matter is present (Correct)
3	S1, S2, S3, S4	-	-	-	We hear different sounds. (Correct)
4	S3	S1, S2, S4	-	-	The speed and height of the sound changes. (Correct) The intensity of the sound changes. (Partially Correct)
5	S3	S1, S2, S4	-	-	Particles are compact in solids, sparse in liquids and sparser in gases. (Partially Correct)
6	S2	S1, S3, S4	-	-	There may be an echo (Partially correct) Sound can pass through matter, be reflected back, or be retained by matter. (Correct)
7-8	S1, S4	S3	-	S2	When I do not want the sound to go out... (Partly Correct)
9	S3, S4	S2	-	S1	It is called making changes in the environment so that the sound does not go away. (Correct) It makes it easier to hear the sound in an environment. (Partly Correct)

Table 5 shows that the students answered questions 1, 2, and 3 correctly, whereas they provided correct and partially correct answers to the other questions.

Discussion and Conclusions

The aim of this study was to develop a guide material based on the argumentation-based science learning approach for the concepts of the 6th grade unit on 'Sounds and Their Properties' and to investigate students' argumentation levels and conceptual understanding. Students' written arguments in guide material based on the argumentation-based science learning approach were gathered and examined using Erduran et al. (2004)'s analytical framework, which is based on the components of Toulmin's Argumentation Model. Five levels of analysis were performed. While second-level arguments included a claim along with data, justifications, and backings, first-level arguments only had a claim and basic counterclaims. In addition to these basic components, third-level arguments included feeble rebuttals, but fourth-level arguments included more direct rebuttals. There were more rebuttals in the fifth level, indicating a more advanced level of argumentation. The findings showed that prior to implementation, students' argumentation levels were at level 1 according to the activities developed by Solak (2016) and Çınar (2013) (see Table 3). The analysis of the argumentation levels from the activities carried out during the application process revealed that in the initial activities, the students produced mainly Level 1 arguments. However, as the activities progressed, an increase in Level 2 arguments was observed, with a very limited number of Level 3 arguments and no evidence of Level 4 or 5 arguments (see Table 4). According to a thorough analysis of activities centered around argumentation, students mostly focused on the three main tenets of Toulmin's Argumentation Model: claim, data, and justifications. Backings, qualifiers, and rebuttals serve as supplementary components, even though these three aspects form the basis of an argument (Toulmin, 2003). Students created arguments using just claims and data in some tasks, while in others they added assertions with evidence or justifications. As a result, more than fifty percent of the arguments stayed at the second level, suggesting that there was little increase in argument complexity. This situation may be seen as a sign that the sample's students were typically capable of making claims, presenting data to support them, and engaging in argumentation. They found it difficult to articulate opposing opinions and provide evidence for their assertions, nevertheless. It was noted during the implementation phase that students struggled to follow the teacher's directions to produce rebuttals and counterclaims. This implies that because the argumentation method was unfamiliar to them, students had trouble adjusting. The short implementation period, the challenge of adjusting to a new approach, or the students' lack of readiness to use justification and rebuttal successfully are some potential causes of this. These findings are consistent with the results of similar studies conducted by Çak (2020), Daşgın (2022), Uluçınar-Sağır et al., (2021) and Yalçınkaya (2018).

The observed increase in the level of argumentation in subsequent activities may be attributed to the design of the activities and the application process, which encouraged the students to use all the elements of the Toulmin argumentation model. For example, in the activity entitled 'Sounds in Cinema', which aimed to address the outcome 'Provide examples of acoustic applications', a competing theories activity was implemented. In this activity, students had to choose between two theories about sound from different sources, identify relevant evidence from the data provided, generate new evidence, justify their choices and present counterarguments. An examination of the activity sheets (see Table 4) revealed that students produced Level 2 and Level 3 arguments equally in this activity. This finding suggests that when students are intentionally guided to produce claims, data, justifications, counterarguments and other components of argumentation, their level of argumentation is likely to improve (Çak, 2020). In argumentation, the quality of arguments, especially rebuttal element, some studies in the literature have found significant differences in argument quality (Çınar, 2013; Zohar & Nemet, 2002). However, when we look at the overall implementation, students had difficulty in writing rebuttals. Therefore, it can be said that arguments were not encountered at higher levels.

Through argumentation-based science learning (ABSL) activities, students are given the opportunity to engage in critical thinking and inquiry, thus becoming active participants in their learning process. Through this approach, students not only explore and discuss information but also defend their positions against the various arguments presented by their peers. This process promotes a collaborative learning environment in which students must persuade and be persuaded, thus enhancing their ability to engage in discourse and reflection (Aktaş & Doğan, 2018). The ABSL approach is designed to support learning from peers, as the information discussed is rooted in their own knowledge base. Evaluating, understanding and sharing this knowledge is an important outcome of the ABSL process (Burke et al., 2005). Similarly, Çalışkan and Kabucu (2021) investigated the effects of an argumentation-based approach to science learning on 7th-grade students' understanding of science, their approaches to learning science, and their levels of argumentation in the context of astronomy. The study concluded that there was a significant increase in students' argumentation levels throughout the implementation of the approach. In the present study, targeted interventions through ABSL activities were introduced in addition to standard teaching methods. Despite these efforts, the results indicated that the argumentation levels remained predominantly at levels 1 and 2, with only occasional instances of level 3 arguments. These findings are consistent with findings in the literature (Çak, 2020; Daşgın, 2022; Uluçınar et al., 2021; Yalçınkaya, 2018). This observation highlights the need for a more comprehensive approach to the development of learning environments. Rather than relying solely on short-term interventions, it is crucial to implement strategies that encompass the entire learning process to more effectively enhance students' argumentation skills (Aktaş & Doğan, 2018; Uluçınar Sağır et al., 2021).

A comprehensive analysis of the activities revealed that students used the claim component more frequently than other elements of argumentation did. Specifically, the use of the data, justification, and counterclaim components was less frequent than the use of the claim (see Table 4) (Çinici et al., 2014; Demirel, 2015; Uluçınar-Sağır & Kılıç, 2012). In their study, Uluçınar-Sağır et al. (2021) reported that students faced difficulties in following the guidelines for the argumentation process. They attributed these difficulties to students' difficulties in adapting to the novel argumentation process, the limited duration of the implementation, and insufficient readiness to effectively use the justification and counterclaim components. Similar problems were observed in the current study, which may explain the limited use of elements other than claims by students.

A significant outcome of the research was the development of group discussions into full class discussions, facilitated by the presentation of each group's ideas at the end of the activities. This shift is noteworthy, as it encourages greater interaction between students and increases their engagement with the lesson. Initially, the pupils were reluctant to articulate their thoughts in the activity sheets and group discussions. Over time, however, they began to formulate more detailed and nuanced sentences. For example, in the initial activity entitled 'The Particulate Nature of Matter', the students were given a table of statements and asked to evaluate and justify the accuracy of each statement. Early student responses included "True. Because every particle vibrates" and "No. It consists of three states". In contrast, in one of the final activities, "The Echoing Sound", the students articulated more complex arguments such as "In the first scenario, the metal lid is closed, so the sound bounces around and cannot escape. In the second scenario, with the lid open, the sound can escape more freely", and "When the lid is closed, the sound is trapped, and less sound escapes, whereas when the lid is open, the sound is not trapped, and more sound is produced". The progression observed in the students' expressions can be interpreted as an indication that through the activities and discussions developed, the students became increasingly familiar with the argumentation process, leading to a more sophisticated use of argumentative elements. It seems that as students progressed through the activities, they became more aware of their actions and the reasons behind them. Group discussions in the argumentation process enable students to question the ideas of other students as well as themselves and to construct their own knowledge. Since the activities are implemented as small group discussions or class discussions, students have the opportunity to think about the topic and the dialogues they established with their classmates contributed to increasing their argumentation levels. The implementation enabled students to think like scientists and encouraged them in their pursuit of knowledge. Numerous studies in the literature support the idea that the argumentation process serves as a guide for students in constructing knowledge and contributes to the development of scientifically literate individuals (Çinici et al., 2014; Deveci, 2009; Driver et al., 2000; Kabataş-Memiş & Çakan-Akkaş, 2016; Köseoğlu et al., 2008; Norris & Phillips, 2003; Uluçınar & Kılıç, 2012).

In the semi-structured interviews, the students were asked conceptual questions related to the unit 'Sound and its properties'. An analysis of the data collected (see Table 5) revealed that the students did not respond incorrectly to any of the questions related to the unit. Some answers were partially correct, and there were two cases where two students did not answer the questions. This finding suggests that the activities developed had a positive effect on students' understanding of the concepts of the unit. The literature supports the notion that argumentation has a positive effect on students' academic performance and conceptual learning (Aslan, 2018; Aydoğdu, 2017; Er & Kırındı, 2020; Gülen & Yaman, 2018; Işıker, 2017; Kutluer, 2020; Tüccaroğlu, 2018; Yalçınkaya, 2018). As Chin and Osborne (2010) point out, argumentation plays an important role in students' learning of science as well as in both the thinking process and the development of scientific reasoning and conceptual understanding. In the implemented activities, the students took individual responsibility for their learning and engaged with concepts through activities, experiments, and other methods. They had the opportunity to work like scientists, thus experiencing scientific thinking processes. It can be concluded that these experiences, as well as the process itself, had a positive effect on students' conceptual learning.

In summary, the results of this study indicate that the students' level of argumentation during the first activities was initially at level 1. As the activities progressed, there was an increase in the number of level 2 arguments, with some examples reaching level 3. However, no level 4 or 5 arguments were produced. Students used the claim component more frequently than other argumentative elements, such as data, justification and counterclaims, which were used less frequently than claims. The developed materials had a positive effect on students' conceptual learning.

Limitations and Implications

The study involved the implementation of argumentation-based science learning (ABSL) activities as a targeted intervention in the existing learning process. Despite these efforts, most of the students' arguments were predominantly at levels 1 and 2, with only occasional examples reaching level 3. This finding highlights the need for comprehensive educational interventions that address the entire learning process rather than relying on short-term or isolated activities to effectively develop argumentation skills. This study is limited to argumentation-based prediction-observation-explanation, table of statements, competing theories, concept cartoon, vee diagram, etc. activities conducted in 16 class hours. To make a more detailed examination of students' argument levels, similar practices can be carried out in a longer period of one semester or two semesters and the results obtained can be compared with the results of this study. Considering these findings, it is imperative to integrate contemporary teaching methods and techniques that actively engage students, as recommended in the curriculum. The widespread adoption of such methods in science education is essential to improve students' argumentation skills and promote deeper conceptual understanding.

This study is limited to the implementation of a guidance material developed for the ‘Sound and its properties’ unit. Similar efforts could be made for other units within the science curriculum, making these materials available for teachers to use. This would allow teachers to easily access preprepared resources tailored to their students' needs and available tools, ultimately saving both time and effort.

The study revealed that students' argumentation levels were predominantly at levels 1 and 2, which is consistent with findings from the literature. There was no analysis of why the argument levels were so low. Future research should focus on exploring the reasons for students' difficulties in developing arguments at higher levels. A detailed investigation of these challenges could inform the creation of new materials and interventions aimed at developing argumentation skills.

In addition, although this study used different argumentation techniques (prediction-observation-explanation, table of statements, competing theories, concept cartoon, vee diagram etc.) to assess students' argumentation levels, it did not analyze which specific technique was most effective. Future research could compare the effectiveness of different argumentation techniques in improving the quality of arguments. Such comparative studies would provide valuable insights into which methods are most effective in improving students' argumentation skills.

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Statement of Responsibility

This study was taken from the firs author's master thesis conducted under the supervision of the second author. The authors have no relevant financial or non-financial interests to disclose. In this sense,

Author 1: Investigation, Conceptualization and Methodology, Writing- Original Thesis, Reading the First Draft of Manuscript and Final Manuscript.

Author 2: Supervision, Investigation, Conceptualization and Methodology, Writing- Original draft preparation, Reviewing and Editing, Submission

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by the authors. The first draft of the manuscript was written by Nagihan Yildirim and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Conflicts of Interest

No potential conflict of interest was declared by the authors.

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