EXAMINING MIDDLE SCHOOL STUDENTS’ LEARNING PROGRESSION FOR SCIENTIFIC ARGUMENTATION

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ABSTRACT

EXAMINING MIDDLE SCHOOL STUDENTS' LEARNING PROGRESSION FOR SCIENTIFIC ARGUMENTATION

The purpose of this study is to examine the development of scientific argumentation skills of middle school students at three grade levels. In addition, the change in students' scientific argumentation skills in different science contexts (Physical Science, Earth and Space Science, Life Science, Socioscientific Issues) was also investigated. The participants of the study consisted of 80 students from Grade 5 (27), Grade 6 (26) and Grade 7 (27). In accordance with the objectives of this cross-sectional study, a basic qualitative research design, one of the qualitative research approaches, was adopted. The data of the study consisted of the participants' individual and written responses to four different argumentation tasks and semi-structured follow up interviews. The data obtained were analyzed with constant comparative analysis method and the argumentation elements identified were coded. Two different argumentation frameworks were used in accordance with two different research questions and students' achievements in scientific argumentation skills were determined according to the criteria for levels. When the findings of the first research question were analyzed, it was observed that there was a significant improvement in students' scientific argumentation skills from Grade 5 to Grade 6. However, although they were the only group that reached the highest argumentation level among the other groups, it was observed that Grade 7 students had lower skills compared to Grade 6 students. The main reason for this finding was discussed by presenting the problems 7th grade students had in constructing opposing arguments and various reasons. As another finding, it was revealed that the topic that students had the most difficulty in forming arguments was physical science, followed by the earth and space science, and they formed higher level arguments in socioscientific issues and life science contexts. The findings of the study provide implications that can contribute to science education literature, science education practices and the development of assessment and evaluation tools.

ÖZET

ORTAOKUL ÖĞRENCİLERİNİN BİLİMSEL ARGÜMANTASYON BECERİLERİNİN GELİŞİMİNİN İNCELENMESİ

Bu çalışmanın amacı ortaokul öğrencilerinin bilimsel argümantasyon becerilerinin gelişimini üç sınıf seviyesinde incelemektir. Ayrıca öğrencilerin bilimsel argümantasyon becerilerinin farklı fen bilimleri konu alanlarındaki (Fiziksel Olaylar, Dünya ve Evren, Canlılar ve Yaşam, Sosyobilimsel Konular) değişimi de araştırılmıştır. Çalışmanın katılımcılarını 5, 6 ve 7. sınıf seviyelerinden sırasıyla 27, 26 ve 27 olmak üzere toplamda 80 öğrenci oluşturmuştur. Bu kesitsel çalışmanın hedeflerine uygun olarak nitel araştırma yaklaşımlarından biri olan temel nitel araştırma deseni benimsenmiştir. Araştırmanın verilerini katılımcıların dört farklı argümantasyon çalışmasına verdikleri bireysel ve yazılı yanıtlar ve bu çalışmaları takip eden yarı-yapılandırılmış görüşmeler oluşturmuştur. Elde edilen veriler sürekli karşılaştırmalı analiz tekniği ile incelenmiş ve tespit edilen argümantasyon elementleri kodlanmıştır. İki farklı araştırma sorusuna uygun olarak iki farklı argümantasyon çerçevesi kullanılmış ve öğrencilerin bilimsel argümantasyon becerilerindeki başarıları belirlenen kriterlere göre seviyelendirilmiştir. İlk araştırma sorusunun bulgularına bakıldığında, 5. sınıftan 6. sınıfa doğru öğrencilerin bilimsel argümantasyon becerilerinde belirgin bir gelişme olduğu görülmüştür. Ancak, diğer gruplar arasında en yüksek argümantasyon seviyesine ulaşan tek grup olmalarına rağmen, 7. Sınıf öğrencilerinin 6. sınıf öğrencileri ile karşılaştırıldığında daha düşük becerilere sahip olduğu görülmüştür. Bu bulgunun temel nedeni, 7. sınıf öğrencilerinin karşıt argümanlar oluşturmada yaşadıkları sorunlar ve çeşitli nedenler sunularak tartışılmıştır. Diğer bir bulgu olarak öğrencilerin argüman oluşturmada en çok zorlandıkları konunun fiziksel olaylar olduğu, bunu dünya ve evren konusunun takip ettiği, sosyobilimsel mesele ve canlılar ve yaşam konularında ise daha yüksek seviyeli argümanlar oluşturukları ortaya konulmuştur. Çalışmanın bulguları fen eğitimi literatürüne, fen eğitimindeki uygulamalara ve ölçme ve değerlendirme araçları oluşturmaya katkı sağlayabilecek çıkarımlar sunmuştur.

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1. INTRODUCTION

With the recent worldwide controversial issues such as the decisions concerning the COVID-19 vaccine and environmental policies or local contentious matters, citizens debate over finding reliable information mostly by making judgments based on their personal beliefs. That is one of the reasons why the 21st century is defined by the term “post-truth”. The Oxford Dictionaries has chosen post-truth as the word of the year in 2016 with a definition of taking individual beliefs as the main source for explaining situations rather than using scientific and unbiased facts (Oxford English Dictionary, 2016). Thus, scholars who study the role of science education in the post-truth era propose simulating scientific practices in classrooms as a solution by concentrating on contextual discourse or sense-making activities such as scientific argumentation to fill the gap between scientific reality and public expectations on the term *truth* (Feinstein and Waddington, 2020). At this point, another term comes up to describe an individual’s competence to act socially responsible concerning civic affairs owing to the scientific knowledge and skills one has: scientific literacy (Hurd, 1998). Fundamental components for scientific literacy include not only the knowledge and understanding of science concepts but also skills such as critical thinking for making judgments about scientific discoveries (Miller, 1998; Norris and Phillips, 2003). Therefore, one of the main goals of science education is to raise scientifically literate individuals who can make inquiries in daily life and make qualified decisions about important socio-scientific issues.

Being considered one of the significant aspects of scientific literacy, it is suggested that argumentation should be integrated into science classroom practices to be performed by learners, serving for scientific literacy (Erduran et al., 2005). Scientific argumentation encourages learners to use evidence for supporting their claims through reasoning as well as critique others’ ideas and present counterarguments (Allchin and Zemplen, 2020; Osborne et al., 2004). Fundamentally, science itself is the accumulation of views and arguments from the past until today (Crombie, 1994). Therefore, the place of argumentation in science education essentially lies in displaying to students how scientists study the world. The role of argumentation in science education is also portrayed as a new language in which students can express their understanding of the concepts and use it as a support tool for making scientific reasoning (Driver et al., 2000). Research has demonstrated the significant effect of scientific argumentation on students' critical thinking (Giri and Paily, 2020), scientific process skills (Ping et al., 2020), academic achievement and comprehension (Balci and Yenice, 2015), and scientific competencies (Tsai, 2018).

Not surprisingly, curriculum makers and science educators adopted strategies and methods for the implementation of scientific argumentation in student-based learning environments, taking it as a core scientific practice (Ministry of National Education (MoNE), 2018; National Research Council (NRC), 2012). In the current science curriculum, "argumentation" is particularly suggested to be utilized for classroom instruction, and one of the main goals is stated as to enhance students' skills for reasoning and decision-making about socio-scientific issues through argumentation. Furthermore, it is strongly suggested that a discourse environment should be provided for the learners to articulate their claims, support their claims with reasoning and produce counterarguments to rebut others' claims (MoNE, 2018).

With the aim of supporting teachers and students, it is important to deduce how the whole process of argumentation proceeds and what are the components of the skill as well as how students hierarchically develop such skills. It is asserted that similar to conceptual knowledge, skills also get sophisticated over a period of time on the learning progressions, and exploring those skills only guides strategies and tools used in science education (Corcoran et al., 2009; Kuhn, 2010). There have been several studies exploring how learners' conceptual understandings of a certain topic or practices develop from a basic level to a master level over time (Simon et al., 2018; Christensen, 2023; Dozier et al.,2023). In mathematics education, tracking the students' learning path from a low to a high level is called learning trajectories while it is named learning progressions in the field of science education. Learning progressions can be defined as empirically grounded hypotheses of learners' gradual progress in the understanding of a concept from naïve ideas to more complicated or performing practices from a lower to a higher level (Duschl et al., 2011). The significance of learning progressions in the educational area lies in their potential to inform curriculum design, instruction, and assessment (Alonzo and Gotwals, 2012). With that attitude, the theoretical structuring of the scientific argumentation skill is still a work that has been expanding. Therefore, this study sought to map students' skills for performing argumentation in multiple science contexts as a learning pathway.

1.1. Rationale and Significance of the Study

Most LP studies in science education are carried out in order to map students' progress in physical, earth and space, and life science topics such as matter and energy (Lee and Liu, 2009), celestial motion (Plummer and Maynard, 2014) and natural selection (Furtak, 2012). However, less research investigated science practices such as reasoning (Jung et al., 2020), modelling (Bamberger and Davis, 2013), and argumentation (Berland and McNeill, 2010). Liu and Jackson (2019) mentioned that there is a limited number of studies on the development of a particular scientific practice on a learning progression. In particular, despite the wide range of studies on argumentation in science (He et al., 2019; Setyaningsih and Rahayu, 2023), there has been less attention for developing a learning progression for scientific argumentation (Nussbaum, 2021). Berland and McNeill (2010) observed middle and high school students' argumentation process and products qualitatively and proposed a three-dimensional progression emphasizing instructional contexts and classroom norms. Their study was discontinuous, and they implemented different activities for each age group. Following this study, Osborne et al (2016) proposed three broad levels of a learning progression for scientific argumentation by systematically assessing the high number of 8th and 10th-grade students. Most recently, Zhang and Browne (2022) explored high school students' argumentation skills in terms of consistency with the other hypothetical LPs as well as expanding previous works by adding sublevels to the progression.

From a different point of view, in the current study, younger learners were targeted which was the group that has not yet been examined on a learning progression. Therefore, it is expected to capture students' ongoing processes and keep track of various skills embedded in the argumentative discourse. The findings of the present study are expected to contribute to the research literature as validation with an unexplored sample group.

The study of scientific argumentation as a core practice may provide benefits for many educators when considering the importance of scientific literacy in society. With the aim of serving this objective, scientific argumentation with the perspective of intellectual skill or aimed competency can be traced in a learning progression. Wilson et al. (2023) emphasized that as scientific argumentation is a competency that is a complex combination of ideas on the nature of argumentation, relevant scientific knowledge, and the ability to engage in the practice, learning progressions can help this complexity by tracking cognitive paths as the learners go through more sophisticated levels in their experiences. In the sequenced and detailed version of this practice, the educators may find it easier and more practical to trail argumentative functions that their students demonstrate during an argumentation activity. Finally, the hypothesized results may encourage the practice of scientific argumentation in these grade levels as well as contribute to the design and implementation in science education curriculum, instruction, and assessment. Particularly, there are limited studies that explore students' learning progression of scientific argumentation, and this study is the first one in the Turkish context with the relatively young participants.

1.2. Purpose of the Study

The goal of this study was to explore and map Grade 5, Grade 6, and Grade 7 students' increasingly sophisticated progressions in making argumentation in physical science, earth and space science, and life science topics as well as socio-scientific issues. With that purpose, the findings are expected to validate and extend the hypothetical progression along the trajectories of the argumentation skills.

1.3. Research Questions

The following research questions guided the study:

(i) How does the complexity of middle school students' argumentation skills change across Grades 5 to 7?

(ii) How does the complexity of middle school students' argumentation skills change in different scientific contexts in each grade level?

2. LITERATURE REVIEW

The main purpose of this study was to examine how students' argumentation skills on a learning progression get sophisticated across different grade levels (Grade 5, Grade 6, and Grade 7). Particularly, this study also aimed to explore how this progression changes with respect to the science contexts (physical science, earth and space science, life science, and socioscientific issue).

This chapter summarizes the research into Scientific Argumentation (SA), Learning Progression (LP), and the joint circumstance of these two concepts in the context of science education. This chapter consists of four main sections. The first section describes cognitive developmental theory by Piaget with the aim of revealing the relationship between learning theories and scientific argumentation as well as with learning progressions as a theoretical framework of this study. Then, the next two chapters summarize theoretical frameworks and empirical research for scientific argumentation and theoretical frameworks and empirical research for learning progression. Finally, theoretical background and contemporary studies at the intersection of scientific argumentation and learning progression are presented in detail.

2.1. Learning Theories for Scientific Argumentation and Learning Progression

The theoretical frameworks that guide argumentation studies belong to the fields of developmental psychology, philosophy, language sciences, and science studies (Erduran and Jimenez-Aleixandre, 2012). In the educational literature, research concerning the development of argumentation skills is generally based on general argumentation context in other disciplines (Felton and Kuhn, 2001). The other research studies explain the relationship between learning and argumentation with a perspective of "learn to argue" and "argue to learn" (Dawson and Venville, 2010). Hence, it can be said that there is a limited study that specifically connects a theoretical framework to examine how students' scientific argumentation skills develop over time.

Researchers discuss that there is a disparity between argumentation and learning theories; however, it can be stated that learning takes place when it is focused on how to develop students' argumentation skills such as constructing arguments, providing evidence, etc. (Baker and Schwarz, 2019). While the term argumentation is seen as a kind of reasoning discourse that requires the elements of cognitive psychology, universal logic and philosophy, and even linguistics, scientific argumentation additionally requires scientifically proven claims and pieces of evidence, higher-order cognitive skills, and sometimes scientific content knowledge (Kuhn, 1991; Driver et al., 2000). Thus, fundamentally, gaining the procedural skills of scientific argumentation should be highlighted with the perspective of learning theories.

Looking at the learning theories, it can be observed that some elements of scientific argumentation and the concept of "cognitive disequilibrium" by Piaget (1932) have in common. Hence, cognitive development theory by Piaget (1947) is adopted as the main theoretical framework for this study. When students go through the progress of a quarrel, decision-making, and critiquing during an argument, this causes a disequilibrium where they need to adjust cognitive structures to gain new ideas (Iordanou, 2008). Likely, in scientific argumentation, learners draw on their prior knowledge and practical experiences to construct their own understanding so that they identify among different scientific theories to develop their own arguments in support of one theory and against another. In this study, students are given multiple competing theories to evaluate and make a decision based on their existing mental models. Similarly, it is also asserted that students' reflections on their own individual thinking patterns are fundamental in scientific argumentation (Gould and Parekh, 2018).

Cognitive developmental theory, with four general developmental periods, focuses on children's increasingly comprehensive ways of thinking and reasoning abilities over the years. While children start to think logically and systematically with mental actions at the Concrete Operational Stage (7 to 11 years), they are limited to perform such high level abilities as they still need more concrete models. In contrast, they begin to think about thinking systematically in a more abstract and hypothetical way at the Formal Operational Stage (11 to adulthood) and demonstrate reasoning abilities as well as an order of their thoughts (Crain, 2010). Similarly, learning progressions are students' development pathways in their understanding and skills over time. This study explored students' skill development for performing scientific argumentation from 5th (10-11 years) to 7th grade (12-13 years old) on a learning progression. According to Piaget's Cognitive Development Theory, Grade 5 students are considered to be in the Concrete Operational Stage where they find it challenging to make reasoning and order their thoughts that are fundamental needs for making scientific argumentation. Grade 6 and 7 students, as the members of Formal Operations Stage, are more likely to develop strong arguments through connecting their thoughts in an abstract way.

To summarize, learners progress through distinct stages of cognitive development, and learning happens when they experience instability, like making a decision among competing theories in an argumentation task.

2.2. Scientific Argumentation

Argumentation has been a center of attraction in the science education research field due to its key role in scientific literacy (Jiménez-Aleixandre and Erduran, 2007). Researchers dispute that scientific argumentation supports students not only in their understanding of science concepts and scientific practices but also in their comprehension of the epistemology of science as well as science as a social practice (Driver et al., 2000). In spite of its prominent and frequent referral in the research literature, there is no consensus on the term argumentation since it is defined and described as well as sorted in multiple ways according to its nature of formation and implementation. In their book Fundamentals of Argumentation Theory, van Eemeren et al. (1996) construed argumentation as verbally and socially constructed reasoning activities in a way of intermingling products and processes that aim to deduce a disputed issue through justifying and refuting ideas. To the greatest extent, argumentation is commonly attributed to the debate of thoughts to justify or persuade the other (Osborne and Patterson, 2011). Some scholars agree on a common point that an argument is a product created by individuals with the aim of justifying their explanations, and argumentation is considered to be a complicated process that encompasses all the products and elements during a discourse (Kuhn and Udell, 2003; Sampson and Clark, 2008).

Another diverse approach that researchers adopted for argumentation is whether it is an internal process that is constructed in an individual's mind or a social process that is created through collaboration. In this study, individuals' mental processes are aimed to be externalized through written responses in order to observe their internal thinking patterns and strategies that they adopt in the argumentation. This type of activity is often called "solipsistic" or "intrapsychological" as it embraces intra-subjective pathways in monological arguments (Garcia-Mila and Andersen, 2008; Chin and Osborne, 2010). Monologic discourse was defined as responding to problems and advocating assumptions in a written way (Means and Voss, 1996). Kuhn (1993) also proclaims that the interiorized mode of argumentation and the process of inspecting and weighing in a secluded way is similar to how scientists perform science. Generally, this situation corresponds to two different formats of argumentation: written argumentation as an individual's inscribed expression of constructing, evaluating and making decision in an argumentative practice and oral argumentation as multiple performers' socially generated discourse in argumentation (Molinatti et al., 2010; Venville and Dawson, 2010).

As a specific version of argumentation in science education, researchers use the term scientific argumentation as making decisions based on a scientific proposal that presents an alternative viewpoint for scientific interpretation (Duschl and Osborne, 2002; Jimenez-Aleixandre and Erduran, 2007; Iordanou and Constantinou, 2015). The term performance is also used to explain this kind of practice since the learners use their scientific knowledge to achieve a scientific practice (Scott et al., 2019). Moreover, argumentation in the science education context is regarded as a specific form of logical discourse in which students aim to construct their claims either individually or collaboratively and relate pieces of evidence to make reasoning (Duschl, 2007; Erduran et al., 2015). In the following chapter, the intended conceptualization of scientific argumentation as the main phenomenon of the study is explained in detail.

2.2.1. Conceptual Framework for Scientific Argumentation

From different point of view, some researchers investigated argumentation as a competency that includes some constituent skills (Rapanta et al., 2013; Zhang and Browne, 2022) while others examined it as a skill or ability (Venville and Dawson, 2010; Kim and

Roth, 2018). In this study, scientific argumentation will be evaluated as a skill, and it is important to explain how and why it will be addressed as a skill.

Scientific argumentation is described as the ability to assemble a reasonable argument to defend a scientific claim through convenient empirical proofs (Driver et al., 2000). On the other hand, it is considered as a competency which is a complex combination of content knowledge, students' understanding of the nature of argumentation, and ability to construct and critique an argument (Kelly and Takao, 2002; Osborne et al., 2010; Williams, 2022). As the main source and guide of this study, in the hypothetical learning progression model for scientific argumentation, Osborne et al. (2016) used the term competency and investigated the elements from Toulmin's Argument Pattern (Toulmin, 1958). In the science education context, TAP is the most popular and frequently used model for investigating learners' argumentation practice. Nevertheless, Bricker and Bell (2008) questioned this model concerning whether the students' so-called successful performance of TAP elements in their argumentation with the utilization of erroneous science content knowledge is really a successful argumentation. Similarly, von Aufschnaiter et al. (2008) claimed that prior knowledge and content-related familiarity are crucial for students' argumentation performances. However, in this study, as no attention is given to learners' correct or erroneous content knowledge in their argumentation task performances, the skill of making scientific argumentation with its sub-skills is prioritized. The reason behind this is that some research showed that scientific knowledge is an important but not sufficient factor for scientific argumentation (Kolstø et al., 2006). Additionally, Sadler (2004) asserted that content knowledge may cause an escalation in the quantity of justifications, yet it does not affect the quality of reasoning made by students during the argumentation. Consequently, the subskills or components of scientific argumentation conceptualized for this study include constructing and identifying a claim, providing, and identifying evidence, constructing and identifying a warrant, providing a counterargument and counter critique, constructing and providing a comparative argument, and constructing a counterclaim with justification (Osborne et al., 2016).

2.2.2. Theoretical Framework for Scientific Argumentation

The recognition and research in scientific argumentation skills in science education have emerged relatively recently; however, the theoretical underpinnings that serve as the foundation for scientific argumentation can be spotted back to the 1950s (Sampson and Clark, 2008). In the educational field, Toulmin's argument pattern (TAP) is viewed as a seminal template for describing learners' arguments in terms of their elements and the relationships among them (Toulmin, 1958; Driver et al., 2000;). Even though it was not created for science education, it has been utilized as a guide to examine, assess and evaluate learners' scientific argumentation performances. Firstly, a claim is constructed or identified as an opinion based on the data given as a piece of evidence. Then, a warrant is proposed as a relation or link between the data and the claim through reasoning. The backing is then provided as an opportunity to consolidate the claim. In addition to these argumentation components, qualifiers and rebuttals were added later (Toulmin, 2003). While a qualifier shows the degree of certainty and depicts limitations or exceptions of the argument, a rebuttal addresses the objections to potential counterarguments and provides reasoning counter to them. Figure 2.1 depicts this model visually, demonstrating the elements of argumentation and their relations.

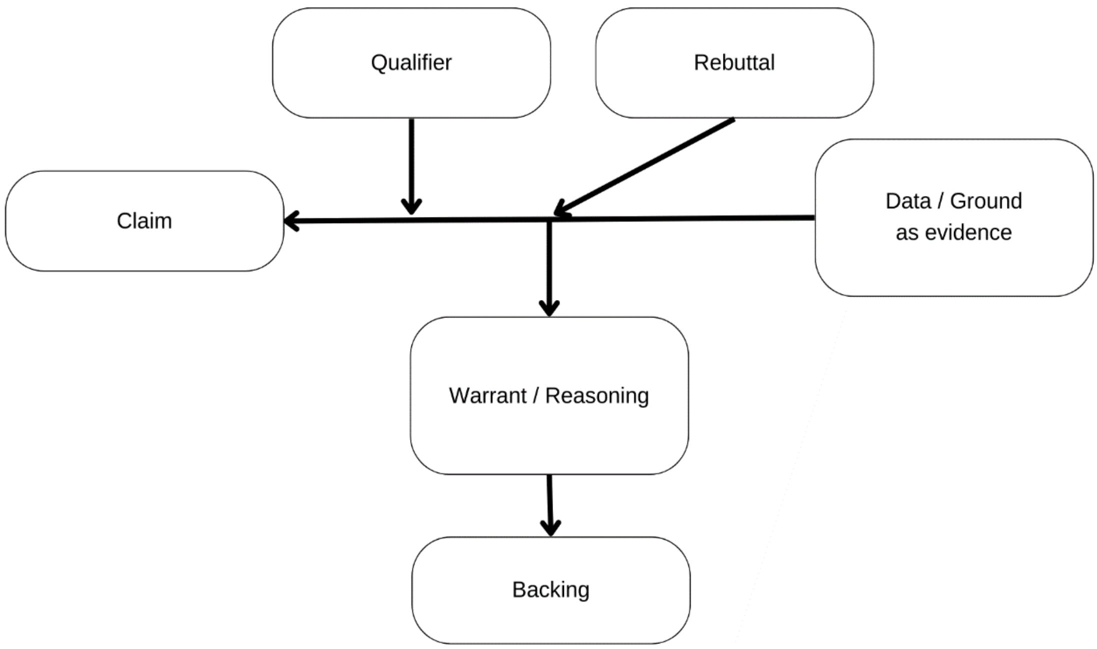

Figure 2.1. Toulmin's argument pattern (2003).

After Toulmin's general framework, as a pioneer researcher in the argumentation field, Kuhn (1993) also summarized argumentation structures as follows: describing and justifying theories, being able to present alternative theories, being able to present counterarguments, and being able to provide rebuttals. Another domain-general framework for students' argumentation structure was provided by Schwarz et al. (2003) under the name of *Argumentative Maps*. They evaluated 5th-grade students' argumentation skills and simplified the practice into categories of assertions or claims, reasonings, and qualifiers. In their models, they focused on the nature of the reasoning as well as the number of reasonings and the structural complexity of the argumentation to evaluate it.

From a different view, Walton's argumentation schemes for presumptive reasoning, which depicts the types of arguments rather than focusing on argument components, are implemented in the science education context (Walton, 1996). From more than 20 categories, Duschl (2007) asserted that 9 of the Walton's schemes are appropriate for both evaluating and guiding argumentation practices in the science classrooms. These are the sign, commitment, position to know, expert opinion, evidence to the hypothesis, correlation to cause, cause to effect, consequences, and analogy (see Table 2.1).

Table 2.1. Modified form of argumentation schemes (Walton, 1996; Duschl, 2007).

Argument sequence	Explanation
Sign	Refers to a source for a claim
Commitment	Suggests an action to be taken in a claim
Position to know	Evaluates a claim to be true or false
Expert opinion	Refers to an expert source additionally
Evidence to hypothesis	Mentions a testable prediction in an argument
Correlation to cause	Connects two events in a causal way
Cause to effect	Explains an observable outcome without controversy
Consequences	Makes reasoning to support/reject depending on the results
Analogy	Argues a case through similar cases

With the perspective of cognitive science and philosophy of science, Böttcher and Meisert (2011) proposed a theoretical framework to describe the argumentation process with a model-based theory specifically in science education. Their approach contrasted with

Toulmin's framework in terms of structural examination of arguments, and they took the scientific argumentation process as a more sophisticated model development in the phases that can be evaluated. They presented their model-based theory under three main structures as follows: procedural competence for arguing, both procedural and conceptual comprehension to understand argumentation and conceptual base for relevant knowledge of models and data.

Having frequently referred to their categorization of argumentation in their work, Zohar and Nemet (2002) analyzed high school students' argumentation practices in the biology context. As a result, they classified the argumentation patterns from students' dialogues obtained during their performance in groups. Firstly, they labeled students' claims or statements as "conclusion" and according to the nature of students' expression. They divided conclusions as "explicit" and "implicit". Following a conclusion, the statement that rationalizes the conclusion is called a "justification". The other two categories are created by students' decisions to agree or disagree with the conclusions of the group members. In case of compliance to a conclusion given by the other, the statement was called a "concession" and "opposition" for the adverse comment. Finally, a direct answer as a contradiction to the opposition is called "counter-opposition".

2.2.3. Empirical Research in Scientific Argumentation

Research into argumentation practices in science education mostly includes intervention studies that investigate the effect of argumentation on students' knowledge, skills, and attitudes with pre/posttests. Having a close relationship with this study, researchers also analyzed how learners engage in scientific argumentation through different assessment studies.

2.2.3.1. Intervention Studies about Scientific Argumentation. The integration of argumentation in science education has been increasing and is seen as a useful tool that contributes to learners' knowledge, skills and attitudes. With the aim of organizing the results of studies in this area, the following table presents research that has had a positive effect on learners.

Table 2.2. A summary of intervention studies concerning scientific argumentation.

Study	Participants	Intervention	Findings
Investigating the development of conceptual understanding levels, scientific habits of mind and argumentation Skills through an educational digital game (Bağ, 2020)	Grade 4 students	Teaching through argumentation-oriented educational digital game for 10 weeks	Conceptual growth in the science unit, gradual improvement in evidence and claim, but very limited development in reasoning and rebuttal.
Grade 5 students' online argumentation about their in-class inquiry investigations (Choi et al., 2014)	Grade 5 students	Science classes with Science Writing Heuristic approach over one academic year	Students supported, provided, challenged, and requested more evidence than just agreeing, disagreeing and proposing a counterclaim. Many students could critique the evidence given.
Examining elementary students' development of oral and written argumentation practices through argument-based inquiry (Chen et al., 2016)	Grade 5 students	Enacting argumentation practices for 16 weeks	Utilization of evidence to defend, back and oppose argument, the quality of evidence and rationality of their arguments increased.

Table 2.2. A summary of intervention studies concerning scientific argumentation (cont.).

Study	Participants	Intervention	Findings
The effect of online argumentation and reflective thinking-based science teaching on sixth graders' cognitive abilities (Acar and Azaklı, 2023)	Grade 6 students	Explicit teaching of TAP, and 17 argumentation activities embedded in 3 units for 12 weeks	Increase in regulation of cognition, logical thinking, and knowledge of cognition. No significant difference on epistemic cognition factors.
Teaching light unit to elementary school students through argumentation (Altun, 2010)	Grade 7 students	Teaching light unit through argumentation for 6 weeks	Increase in academic achievement and levels of understanding of the nature of science. No meaningful difference in attitudes toward science.
The effect of argumentation based science learning approaches on 8th grade students' success at the subjects of cycles of matter and environmental problems and on their argumentation levels (Kutluer, 2020)	Grade 8 students	Implementation of argumentation based science learning method for 5 weeks	Positive effect on students' academic achievement, active participation in class as well as discussions, and argumentation levels.

Table 2.2. A summary of intervention studies concerning scientific argumentation (cont.).

Study	Participants	Intervention	Findings
Fostering students' knowledge and argumentation skills through dilemmas in human genetics (Zohar and Nemet, 2002)	Grade 9 students	Explicit teaching of argumentation skills in a program in the context of human genetics dilemmas	Improvement on students' knowledge test scores and quality of argumentation.
The impact of a classroom intervention on Grade 10 students' argumentation skills, informal reasoning and conceptual understanding of science (Venville and Dawson, 2010)	Grade 10 students	Explicit teaching of argumentation skills and discussion activities in 3 lessons	Development of the genetic knowledge, level of argumentation complexity and quality, and explanation through rational informal reasoning.
Explicit instruction of scientific argumentation in practical work: a feasibility study (Ping et al., 2020)	Grade 10 students	Explicit instruction of scientific argumentation in biology unit, one- week intervention	An increase in writing arguments. However, limited ability to state their claim to refute counterclaim, use data to generate evidence to support their ideas.
Effect of scientific argumentation on the development of critical thinking (Giri and Paily, 2020)	Grade 12 students	Two biology units with a scientific argumentation strategy	Significant improvement on critical thinking ability.

Table 2.2. A summary of intervention studies concerning scientific argumentation (cont.).

Study	Participants	Intervention	Findings
The effect of online argumentation of socio-scientific issues on students' scientific competencies and sustainability attitudes (Tsai, 2018)	Senior high school students and undergraduate students	Participation in online argumentation of 5 local socio-scientific issues through SOAP strategy	Overall, scientific competencies and sustainability attitudes increased. No significant difference in the competencies of "identifying scientific issues" and "using scientific evidence".

As can be interpreted from the studies cited above, even if some research found that the mediation of argumentation activities has a limited or no impact on learners' competences, it is more likely that the use of argumentation-based teaching strategies at different grade levels leads to a significant increase in learners' knowledge, skills, and attitudes.

2.2.3.2. Assessment Studies about Scientific Argumentation. There has been a myriad of studies that investigated learners' argumentation quality based on similar theoretical frameworks. While evaluating the quality of students' individual, group, written and oral scientific arguments, researchers adapted different frameworks. They looked for certain structures and elements in students' responses, specifically examined how they justified their decisions, or focused on how scientific their responses were. Meanwhile, some studies aimed to create assessment tools to be utilized in the evaluation of students' argumentation process and products in the science context. They embraced some theoretical models of argumentation to check whether students showed some elements of argumentation or not. In Table 2.3, recent assessment studies are categorized and explained in detail.

Table 2.3. Examples of scientific argumentation assessment studies.

Study	Participants	Framework	Assessment Tool	Elements and Levels
Examining elementary students' development of oral and written argumentation practices through argument-based inquiry (Chen et al., 2016)	Grade 5 students	Choi, 2008; Sampson et al., 2011; Chen et al., 2013	Argument-based Writing Scoring Rubric	4 levels of performance (Lacking, limited, basic, proficient, exemplary) under: Accuracy of a claim Quality of evidence-sufficiency (number of evidence and rebuttal) Quality of evidence-reasoning Relationship between a claim and a question Relationship between a claim and evidence
Enhancing the quality of argument in school science (Osborne et al., 2004)	Grade 8 students	Toulmin, 1984	Analytical Framework for Assessing the Quality of Argumentation	Level 1: Claim or counterclaim Level 2: Claims with either data, warrants or backings Level 3: Claims or counterclaims with either data, warrants or backings with weak rebuttals Level 4: Claim with strong rebuttal, may have counterclaims Level 5: Extended argument with multiple rebuttals

Table 2.3. Examples of scientific argumentation assessment studies (cont.).

Study	Participants	Framework	Assessment Tool	Elements and Levels
Supporting argumentation through students' questions: case studies in science classrooms (Chin and Osborne, 2010)	Grade 7-8 students	Osborne et al., 2004	Adapted version of Analytical Framework Used to Assess the Quality of Argumentation	1: Simple claim without ground 2: One or more claims with simple grounds (data, warrant or qualifier and backing) 3: One or more claims with strong grounds (data, warrant or qualifier and backing) 4A: One or more claims with grounds (data, warrant or qualifier and backing), rebuttal or support own argument 4B: One or more claims with ground (data, warrant or qualifier and backing) and self-rebuttal
Development of a test of scientific argumentation (Frey et al., 2015)	Middle school students	Toulmin, 1984; Bulgren and Ellis, 2012	Test of Scientific Argumentation	Distinguishing: Claim, fact, opinion and data qualifier Claim and nonclaim Authority, logic and theory Rebuttal and counterargument Quality of reasoning

Table 2.3. Examples of scientific argumentation assessment studies (cont.).

Study	Participants	Framework	Assessment Tool	Elements and Levels
Using automated analysis to assess middle school students' competence with scientific argumentation (Wilson et al., 2023)	Middle school students	Osborne et al., 2016	Holistic Scores for Three Items	3: Claim and at least one evidence and at least one reasoning 2: Claim and at least one reasoning; or claim and at least one evidence 1: One claim or evidence or reasoning; or at least one evidence and one reasoning 0: No claim, evidence or reasoning
Investigating the argument quality of middle school students on a socioscientific issue: effect of local versus global context (Can, 2021)	Grade 8 students	Toulmin, 1958	Argument Quality Evaluation Rubric	Reasoning 3: Multiple warrants and data 2: One warrant and data 1: Only warrant 0: No data or warrant Rebuttal 3: Multiple rebuttals 2: Rebuttal by justifying the claim 1: Rebuttal against the claim 0: No rebuttal

Table 2.3. Examples of scientific argumentation assessment studies (cont.).

Study	Participants	Framework	Assessment Tool	Elements and Levels
The impact of a classroom intervention on Grade 10 students' argumentation skills, informal reasoning and conceptual understanding of science (Venville and Dawson, 2010)	Grade 10 students	Toulmin, 1958	Levels and Descriptions of Argumentation	Level 1: Claim only Level 2: Claim, data that support the claim, and/or warrant Level 3: Claim, data or warrant, backing or qualifier Level 4: Claim, data or warrant, backing and qualifier

2.3. Learning Progression in Science Education

Learning progressions (LPs) are empirically grounded and research-based hypothetical models that made learners' continuously growing cognitive pathways for the understanding of a concept or the ability to perform a practice visible over a period of time (NRC, 2007; Corcoran et al., 2009; Duncan and Rivet, 2013). Even though there is no consensus on the term learning progressions, it is described as a developmental process that includes interconnected strides of a learner's gradual improvement on a scientific concept or practice from a more naïve or incomplete level to a more sophisticated or scientifically correct level (Salinas 2009; Gao et al., 2021). In fact, learning progression is not a novel notion as many researchers studying in the developmental psychology field, examining learners' understanding of scientific concepts over a period of time (Duncan and Hmelo-Silver, 2009). Following the 1990s, research on learning progression increased and reached its peak in about 2009 and its place in the educational context (Liu and Jackson, 2019).

In contrast to general learning theories, learning progressions comprise deviations in our understanding of students' journeys of learning a scientific idea or performing a scientific practice ongoing process (Lehrer and Schauble, 2015). In other words, learning hypotheses on what we know or how we learn about certain topics or practices may be altered with new explorations. Naturally, each learner's progress cannot be the same and it is likely that they show different pathways. Nevertheless, through assessing and tracking common patterns in their ongoing experiences, these pathways can be described (West et al., 2012). Consequently, these hypotheses are grounded in shreds of evidence about unfolding individuals' learning, in opposition to teaching sequences of topics that are established firmly on individual experiences in teaching relevant explanations concerning science concepts (Corcoran et al., 2009; Upahi and Ramnarain, 2021).

Learning progression studies have a significant role in designing and developing a curriculum as well as guiding teachers and instruction with steps to be taken. Research on learning progression also provides criteria for the assessment of students' knowledge or skills in the educational field. Firstly, the characteristics of learning progressions and theoretical frameworks on this concept are summarized, and then empirical research of learning progressions in different topics and practices in science education are presented in the following two sections.

2.3.1. Theoretical Framework for Learning Progression

It was proposed that learning progressions are composed of but not limited to five main elements: learning targets, progress variables, levels of achievement, learning performances, and assessments (NRC, 2007; Corcoran et al., 2009). First of all, learning targets show us the endpoints of the examined concept. Among these endpoints, progress variables take place as the specific elements or dimensions of knowledge or skill are explored. Progress variables determine the levels of achievement that start with the naïve ideas of students which are called the lower anchor, continue with the intermediate level includes learners' considerably correct understanding, and end with the targeted and scientifically more appropriate explanation which is called the upper anchor (Gunckel et al., 2012; Colantonio et al., 2018). In addition to this stepped-up or escalated framework, the landscape approach that is based on the firm and intimate observation and analysis of the learners' progress aims to investigate the associations among the levels (Salinas, 2009).

Research concerning learning progression identified two main attributes of LPs. The first critical aspect of an LP is the grain size, which means the duration and length of time that the progression occurs, and the size of the content covered (Hokayem and Gotwals, 2016; Lehrer and Schauble, 2015). The second feature is the theoretical hypothesis of an LP study, which adopts either a validation or evolutionary approach. Here validation is explained as a strategy that focuses on student development and attempts to validate initial sequences or levels in a learning progression (Neumann et al., 2013). Researchers advised two different approaches of design to validate an LP: instructional interference, which is implemented in classrooms to perceive learners' potential comprehension or abilities after they are informed; and cross-sectional studies that investigate the progression of students from various grade levels at a certain time through assessment tools (Duncan and Hmelo-Silver, 2009). Generally, learning progressions are thought to be examined through a development that occurs over a considerable period of time, in fact in several years (Corcoran et al., 2009). However, it is also viable that short time experiences of learners can also be studied in order to create the intended learning progression (Breslyn et al., 2016). In this study, a cross-sectional study approach was adopted in a way that a learning progression was intended to be developed by examining students from three different grade levels at a point in time. On the other hand, the evolutionary approach considers student development as a process of coproducing and clarifying pathways described through interpretations to be used by the students (Duschl et al., 2011).

2.3.2. Empirical Research in Learning Progression in Science Education

When looking at the studies conducted in the field of learning progression in science education, it appears that there is more focus on the specific science subjects and concepts. However, there are other studies that explore progression levels concerning scientific practices. Moreover, there is multiple research that examined the progression as a fusion of content and practice. Table 2.4 illustrates learning progression studies in these areas.

Table 2.4. Learning progression studies in science education.

LP Study	Content	Practice	Both
Chemical change (Johnson, 2013)	x		
Nature of matter (Stevens, Delgado, and Krajcik, 2010)	x		
Phase transitions (Chiu and Wu, 2013)	x		
Force and motion (Alonzo and Steedle, 2008)	x		
Energy concepts (Lee and Liu, 2010; Neumann et al., 2013; Lacy et al., 2014; Herrmann-Abell and DeBoer, 2017)	x		
Genetics (Duncan et al., 2009; Duncan, Castro-Faix, & Choi, 2014; Todd et al., 2017)	x		
Food chain (Gotwals and Songer, 2010)	x		
Natural selection (Furtak, 2012)	x		
Climate change (Parker et al., 2015)	x		
Scientific modelling (Schwarz et al., 2009; Bamberger and Davis, 2013)		x	
Feedback loop reasoning (Hokayem et al., 2015)		x	
Constructing scientific explanations (Gotwals et al., 2012)		x	
Scientific argumentation (Berland and McNeill, 2010; Osborne et al., 2016)		x	
Meta-modeling knowledge (Fortus et al., 2015; Hovardas, 2016)		x	
Use of evidence in decision making (Bravo-Torija and Jiménez-Aleixandre, 2018)		x	
Reasoning about structure-property (Talanquer, 2018)			x
Reasoning about biodiversity (Songer et al., 2009)			x

2.4. Learning Progression for Scientific Argumentation

In addition to research on the interpretation and assessment of students' argumentation, there is a limited number of studies that integrate the learning progression approach with scientific argumentation. For the first time, Berland and McNeill (2010) accomplished a study to understand 5th, 7th, and 12th-grade students' work in scientific argumentation through their written and spoken responses to create a map for learning progression. Their empirical data was collected through qualitative field observations that students participated in different instructional contexts with diverse tasks with various difficulty levels. The result of the study showed that younger learners could present sophisticated arguments while the older students demonstrated the weakest arguments, depending on the complexity of the instructional context and the support given. Finally, they proposed a three-dimensional learning progression for scientific argumentation: instructional context, argumentation product, and argumentation process. Characteristics of argumentative products were determined as components used, presence of rebuttals, the complexity of claims, appropriateness, and sufficiency of the support. Characteristics of the argumentative process were defined as individuals who state and defend claims, question one another's claims and defense, evaluate one another's claims and defense, and revise their own and others' claims. Responses to claims such as claims being questioned, evaluated, or debated, and the level of student participation whether it is teacher-prompted or spontaneous were taken into consideration.

Table 2.5. Learning progression adapted from Berland and McNeill (2010).

		Argumentative Product				Argumentative Process	
		Components	Rebuttals	Claims	Defense	Responses to claims	Student engagement
Grade 5	Study 1	Some components	No rebuttal	Claims do not answer questions	No defense	No argument discourse	No argument discourse
Grade 5	Study 2	All components	Rebuttals verbally	Claims answer the questions	Defense is suitable and sufficient	Claims are discussed	Students were guided by the teachers
Grade 7		All components	Rebuttals verbally	Claims are causal	Defense is suitable and sufficient	Claims are discussed	Done by students
Grade 12		All components	Rebuttals verbally	Claims answer the questions	Defense is suitable	Claims are discussed and evaluated	Done by students and teachers

As can be seen in Table 5, as the representation of students' argumentation progresses, the darker the color of the components, the more sophisticated students' responses are. In this learning progression, there are multiple variables and factors influencing participants' performances, and thus it does not serve as a methodically consistent and systematic way to track these aimed components. Additionally, for some tasks, students were given training for some weeks while in other tasks a different approach was endorsed to track students' argumentation performances.

After Berland and McNeill's learning progression model for scientific argumentation, the only study to investigate learners' argumentation progresses in the science context was carried out by Osborne et al. (2016) with a totally different perspective. First of all, they defined argumentation as a competency that is a mixture of content knowledge as well as procedural knowledge, and epistemic knowledge and skill (Osborne et al., 2016). In their 4-year-long mixed-method study, they used items ranging from low to high levels for testing the complexity of the scientific argumentation of a large number of 8th-grade students and 10th-grade students. Exceptionally, they focused on the construction and critique of claims, warrants and evidence, by taking models of Toulmin (1958), Walton (1990) and Ford (2008) into consideration.

Table 2.6. Learning progression adapted from Osborne et al. (2016).

Levels		Characteristics
0	0	No evidence of scientific argumentation.
	0a	Students can construct a claim.
	0b	Students can identify a claim given by another person.
	0c	Students can give evidence to support a claim.
	0d	Students can identify a piece of evidence given.
1	1a	Students can construct a warrant that links claim and evidence.
	1b	Students can identify a warrant given by another person.
	1c	Students can construct a complete argument with claim, evidence and warrant.
	1d	Students can give a counterargument, rebut a claim given by another person.
2	2a	Students can provide a counter critique about why an argument is flawed.
	2b	Students can evaluate competing arguments, choose and construct arguments.
	2c	Students can construct two-sided arguments, provide weak and strong sides.
	2d	Students can offer arguments with justification of why it is better than others.

As can be seen in Table 2.6, in the proposed learning progression model for scientific argumentation there are three dimensions; the lowest level is introducing claim and evidence, and the next level is explaining the relationship between argument elements as well as providing counterargument, the top-most level is to make critique and comparison. At the end of the study, it was suggested that in the future sublevels can be elaborated or an additional investigation can be applied to the highest level of the progression. Additionally, more detailed qualitative research like the present study that collects data from individual interviews and open-ended questions was posed as a future direction to delineate how such small sublevels are constructed toward the more extensive and high level of argumentation. Osborne et al. also suggested that the effect of context of argumentation on students' progression can be investigated. Likewise, in this study, four argumentation tasks are developed in four different contexts.

Lately, Zhang and Browne (2022) aimed to assess and explore a high number of Chinese high school students' scientific argumentation as a series of competencies. Different from the former studies, their concern was to find out participants' awareness and ability to both talk about and talk in argumentation in a systematic way.

Table 2.7. Learning progression adapted from Zhang and Browne (2022).

Levels	Identification	Evaluation	Production
Level 0	Students cannot identify a claim or a rebuttal.	Students cannot evaluate a claim, evidence, and the connection between them.	Students cannot generate simple arguments.
Level 1	Students can identify a claim or a rebuttal in an argument.	Students can notice evidence that is supporting a claim in a connected way and evaluate weak rebuttals.	Students can generate a simple rebuttal and reasoning about SSI contents.
Level 2	Students can identify a reason or evidence in an argument.	Students can evaluate evidence and claim as well as the connection between them and engage in generating rebuttals.	Students can evaluate relevant evidence, generate strong reasoning and rebuttal in scientific contents.
Level 3			Students can generate appropriate reasoning and rebuttal in both SSI and scientific contexts.

As can be seen in Table 2.7, in their study, Zhang and Browne concentrated on the three facets: identification, evaluation, and production of claim, evidence, reason, and rebuttal in students' scientific arguments. They hypothesized a three-level progression for scientific argumentation competence (SAC) and found that their learning progression is consistent with Osborne et al.'s (2016) learning progression levels for argumentation to a great extent. However, as a slight difference from Osborne et al. study (2016), Zhang and Browne (2022) found empirical data about how identifying evidence and reason did not change in levels of difficulty. As an addition to the previous learning progression study, they made an extension by adding the component of the "evaluation of a scientific argument" and considered it as a component in level 1 in Osborne et al. 's learning progression since it does not indicate either critique or comparison. At the end of their study, they suggested that becoming acquainted with the basic ideas of argumentation might eradicate abrupt variables. Before the data collection in this study, the components of argumentation were explained to the participants to ensure their familiarity with the terms and to decrease the demands for working memory during the implementation of the tasks at least.

In summary, preceding studies examined a diverse group of participants' learning progression in scientific argumentation competencies with common patterns, but from different perspectives. These hypothesized levels are the basis of our study; however, new sublevels are aimed to be explored with participants from different but continuous grade levels.

3. METHODOLOGY

The main purpose of this study was to explore students' learning progression for scientific argumentation across different grade levels (Grade 5, Grade 6, and Grade 7). Therefore, the following research questions guided the study:

(i) How does the complexity of middle school students' argumentation skills change across Grades 5 to 7?
(ii) How does the complexity of middle school students' argumentation skills change in different scientific contexts in each grade level?

This section outlines the research design implemented in the study of scientific argumentation skills of middle school students at a private middle school in Istanbul, Türkiye. This chapter first describes why a basic qualitative research methodology was adopted as the research design. Additionally, the data collection process and the procedures are described in detail. Data analysis processes are also explained deliberately including the coding steps. Lastly, strategies carried out for the validity and reliability of the study are clarified.

3.1. Research Design

This study was guided by the two research questions. Both questions aimed to find patterns in students' responses for the scientific argumentation tasks. The first research question focused on the patterns of progression in students' overall argumentation skills across different grade levels. The second research question directed to find how these patterns change in different science contexts in each grade level. With the purpose of getting and exploring the meanings and insights from participants' written and oral responses thoroughly, a qualitative research approach was employed (Creswell, 2012). Adopting qualitative research methods, researchers in the education field can explore how learning occurs, understand educational concepts deeply, define and produce theories through learners' individual intentions and experiences (Sullivan and Sergeant, 2011).

Since the aim of the current study was to understand how the ongoing process of the participants in a scientific practice develops, a basic qualitative research study was chosen. In the applied fields of practice such as education, it is considered to be the most prevalent type of qualitative research method (Merriam and Tisdell, 2016). Meriam (2009) considers a basic qualitative study as a guide to determine more beneficial tools and methods for teachers as well as stakeholders in the educational field. Instead of declaring a specific type among the qualitative research methods such as phenomenology, ethnography etc., researchers simply call their method as basic, generic, or interpretive (Merriam and Tisdell, 2016). The research questions that guide this qualitative study serve best under the title of basic qualitative study specifically, since the value of meaning behind the participants' responses and aim to disclose the process they experience in the first hand (Baxter and Jack, 2008).

Besides, learning progression studies are generally carried out with longitudinal or cross-sectional designs. Nevertheless, as longitudinal studies require long time periods such as two or more years to track learners' progressions, such a study would be challenging to accomplish within a limited time. Therefore, due to the nature of the study where the data collected from students across different grade levels at a point of time, a cross-sectional design was utilized (Creswell, 2012).

Constant comparative method is the main method of this research study for analyzing data to get deeper interpretations through making repeated and continuous comparisons across the codes, categories, and concepts (Charmaz, 2014). Theoretical sampling with the combination of inductive and deductive reasoning was performed as the categories appear. It is a strategy for guiding the researcher for decision making during in-depth analytic work. Coding, memo writing was also performed by the researcher. Memos can be defined as the internal conversations of the researcher concerning the data analysis process, and these notes are written in an informal style (Charmaz, 2014).

3.2. Participants of the Study

This study was conducted at a private school where the researcher currently works. In total 80 students from three different grade levels completed the written argumentation tasks. Table 3.1 summarizes the basic information regarding the participants.

Table 3.1. Demographics of participants.

Abbreviation for student names	Grade Level	Number of participants *n* (N=80)	Gender				Age range
			Female		Male		
			f	%	*f*	%	
G5S1-G5S27	5th	27	13	48	14	52	10-11
G6S1-G6S26	6th	26	14	53	12	47	11-12
G7S1-G7S27	7th	27	14	52	13	48	12-13

As can be seen in Table 3.1, the number of participants for each grade level is almost even. Similarly, the gender distribution within a grade level as well as among all the grade levels is balanced almost equally. These distributions are demonstrated as frequency and percentage values. Group names are created according to the grade levels (G5, G6, G7) and students are numbered (S1-S27) in these groups to be expressed in short throughout the study. Students from each group were invited to participate in the study, and those who volunteered and whose parents gave consent for their participation to the study involved in the study. Parents were signed a consent form which provided all the required information about the study (Appendix A). Therefore, as the sampling method, convenience sampling was utilized for the selection of the participants. This sample type depends on available participants who are close by or within reach to the researchers (Lune and Berg, 2017).

3.2.1. Context of the Study

In the year 2018, the Ministry of National Education published a new science curriculum for the middle schools (MoNE, 2018), and the school where the study was carried out adopted this centralized core curriculum for the science courses. This curriculum provides means for a student-based constructivist learning environment and encourages the implementation of scientific practices such as inquiry-based learning and argumentation practices. The school, where the research was conducted, adopts inquiry-based science education, aiming to help students learn the concepts with questions, discussions and experiments on a regular basis. The number of students in a class varies from 15 to 20 students per class. Accordingly, every science classroom is divided into two sections: at least 1 laboratory hour to make investigations and 3-4 regular class hours to discuss concepts.

In addition to the MoNE curriculum, the school applies the International Baccalaureate (IB) teaching program in all age groups, allowing middle school students to study in the Middle Years Program (MYP) particularly. With the Sciences framework, students are aimed to make real-world ethical-reasoning skills as well as creative and critical thinking through theoretical research from different sources, observation, and experimentation in both individual and collaborative work (IBO, 2014).

The participants usually come from high income families, yet there are also students from middle income families who receive scholarships. Even though the majority of students have Turkish nationality, there are students who are mixed-raced and come from different countries, and whose mother tongue is not Turkish. Finally, it should be emphasized that all the classes are carefully arranged by the teachers to equally include mixed-ability students.

The academic performance of the students in the context of science varies to a large extent. Even though the exams are not challenging, in fact quite easy, for the students, the overall average score in science for the 5th grade is about 85, for the 6th grade it is 82 and for the 7th grade it is 80. In each class there are at least 3 students who are considered low achieving and a maximum of 5 students who are considered high achieving. The rest of the class can be described as average students.

As can be seen from the students' academic scores, 7th graders are the least successful group in science. In addition, their performance in science lessons showed that, unlike 5th and 6th graders, 7th graders neither actively participate in lessons nor show the motivation to learn about science. It is also important to emphasize that Grade 7 students received distance education in all of Grade 5 and most of Grade 6, the introduction to middle school.

Limited number of participants' argumentation-related experiences may come from extracurricular activities such as school debate contests in social and environmental sciences studies. In science lessons, in particular, students are encouraged and required to give statements and present claims based on evidence. Even though scientific argumentation is not explicitly and actively thought and implemented in science lessons, the elements are used frequently.

3.3. Data Collection

With the aim of examining middle school students' scientific argumentation skills on a progression in detail, data were collected through the individual argumentation tasks and the follow-up semi-structured interviews. The following sections provide information about how these tasks were designed and implemented. Methods for ensuring the validity and reliability of the study are also explained in detail.

3.3.1. Argumentation Tasks

In order to observe students' ongoing process and skills during scientific argumentation practices, they are asked to individually provide written responses to the open-ended questions for different tasks. The main features of four argumentation tasks are summarized in Table 3.2.

Table 3.2. Scientific argumentation tasks.

Task name	Science Context	Topic	Task Summary	Reference
Can you create the strongest argument?	Physical Science	Force and Motion	Students choose one claim from three alternatives, two evidence statements from six alternatives, one reasoning from three alternatives. Then, they are asked to give a complete argument, a counterargument, a rebuttal and a counterrebuttal through four open ended questions.	McNeill, 2011

Table 3.2. Scientific argumentation tasks (cont.).

Task name	Science Context	Topic	Task Summary	Reference
The formation of the Moon	Earth and Space Science	The Universe	Two theoretical models for the Moon formation and three pieces of evidence are given. Students are asked to decide a better model with evidence and reasoning, to give counterarguments to the other model with evidence and good features of the other model.	Bailey et al., 2016
An argument about anchovy fish	Life Science	Ecosystem	A case concerning the extinction of Anchovy fish is given with eight pieces of evidence. Students are asked to decide whether it is endangered or not by providing evidence and reasonings. They are also asked to provide a counterclaim, weakness and strength of the counterargument and rebuttals.	Palermo, 2017
Wind power plants	Socioscientific Issue	Renewable Resources	Information concerning positive and negative effects of wind power plants are given in a text, and students are asked to decide whether it should be built or not with proofs, explanations, rebuttals and counterrebuttals.	Karamanlı, 2019

As it is seen in Table 3.2, tasks are adopted from three science contexts (physical science, earth and space science, life science) and a socioscientific issue. These argumentation tasks gathered from various studies, and the related resources were translated and modified with respect to the goals of the study (Bailey et al., 2016; Karamanlı, 2019; McNeill, 2011; Palermo, 2017). The nature of these tasks is explained comprehensively in the following paragraphs.

The four tasks are adjusted according to the argumentation model of Competing Theories: Ideas and Evidence given by Osborne, Erduran and Simon (2004), who are inspired by Solomon, Duveen and Scott's work (1992). In this approach, students are given a concept, two or more competing theories or explanations concerning that concept and pieces of evidence that are appropriate for either, both or neither of the proposed theories (Osborne et al., 2004). Among these, students are expected to decide on their claims, choose or look for evidence that support their claims and make a complete argument. Meanwhile, the students were provided with appropriate data that can be used for proposing arguments for the different ideas as to prevent extraneous factors affecting the main construct (Jin et al., 2021). Similarly, all the tasks are based on a dialectical method that one of the two conflicting ideas was defended by the students. A dialectical method can be defined as a philosophical approach in argumentation that leads learners to make reasoning, analyzing and combining two or more competing ideas with the purpose of reaching a more extensive result (Walton, 1998).

Moreover, these tasks were completed by the students individually in the written form with the aim of exploring each student's mental process as they engage in argumentation. It is also asserted that individual written responses as the students' self-reflections are favorable when compared to large group discussions (Kuhn et al., 2016). This approach is also named as "monologic discourse" (Means and Voss, 1996). Thus, all the tasks are designed and applied as a means of individual assessment for dialogic argumentation skills in the science context.

Finally, the reason behind applying tasks from three content domains of science was to let students express themselves in diverse topics and observe whether there is a significant difference among the responses since learners' argumentation patterns may change in diverse contexts. Additionally, an SSI based argumentation task included controversial issues that motivates students to engage in meaningful discourse (Lin and Mintzes, 2010). In addition to Osborne et al. (2016), Zohar and Nemet (2002) also emphasized a need to examine students' argumentation skills in different contexts.

3.3.2. Semi-structured Interviews

As the researcher aimed to delineate the participants' ongoing processes of their argumentation skills, their responses recorded through individual interviews were used as the main data source along with students' written responses. Interviewing is utilized when there is a need to learn more about individuals' interpretation of their ideas on a specific topic (Merriam and Tisdell, 2016). In this research, semi-structured interviewing was used as a qualitative data collection method. Brenner (2006) stated that such interviews help understanding individuals' cognitive processes and lived experience. While conducting one-on-one semi-structured interviews, the actual questions from the argumentation tasks were asked to the participants, allowing a flexible conversation for elaborating their explanations. After the completion of the argumentation tasks, the responses of the students were checked in terms of the appropriateness of the answers. Then, the students who did not express themselves clearly were noted down and selected to interview to expand and confirm their responses. A total of 14 individual interview sessions (based on the number of tasks) were conducted (see Table 3.3). These interviews lasted for a maximum of 10 minutes, and during the session the voice recordings were stored on the researcher's cell phone. In addition, voice recordings were transcribed by the researcher into an online document.

Table 3.3. Information about the interviews.

Grade Level	Task 1	Task 2	Task 3	Task 4	Total
Grade 5		6	1	2	9
Grade 6		1	1	1	3
Grade 7	1			1	2
Total	1	7	2	4	14

3.3.3. Data Collection Procedure

Before the data collection, an ethical permission was received from Natural Sciences and Engineering Fields Institutional Review Board for Research with Human Subjects (FMİNAREK), which was presented in Appendix A. Then the approval letter was obtained from the Istanbul Provincial Directorate of National Education (MEB) (see Appendix A).

After all, consent forms were distributed to the students to be approved by their parents. Consent form for parents can be seen in Appendix A.

One week before the data collection period, the researcher, and also the science teacher of participants, briefly informed students about the argumentation process and performed an example of a scientific argumentation task through one-large group discussion. Such an instruction was designed and performed according to Zohar and Nemet's recommendations about the elements of argumentation training (2002). First of all, explicit information concerning the formal structure and components of scientific argumentation was provided to the students, which lasted about 30 minutes. As the second crucial element recommended, the opportunity for learners to be engaged in scientific argumentation is ensured through creating a discourse environment. In this session, students were divided into two groups and developed scientific argumentation elements defending one of two competing theories about the dinosaurs being related to birds or reptiles. Following this procedure, students were expected to individually provide written responses to the four argumentation tasks, spending approximately 30 minutes on each task, distributed in four different days. After the collection of the responses offered in the written argumentation tasks, 14 individual interviews, which were previously explained in detail, were performed. The figure presented below demonstrates the flow of the intervention period and data collection procedure.

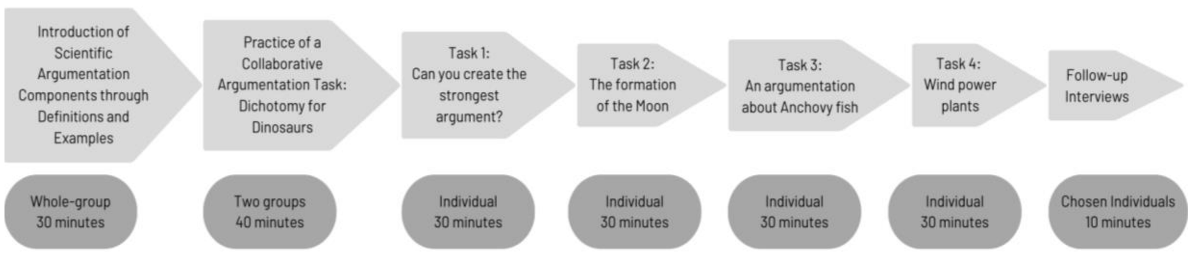

Figure 3.1. Data collection procedure.

3.4. Data Analysis

The data analysis started with the examination of written responses of 80 students from Grade 5 through Grade 7 to four different individually completed argumentation tasks, and the transcriptions of 14 follow up interviews. The researcher transcribed the interviews verbatim in order to establish precision of the answers. In this study, a constant comparison analysis method was performed (Glase and Straus, 1967). Firstly, an initial coding scheme was created through categories adopted from Toulmin's work on argumentation and dimensions given by the existing hypothetical learning progression suggested in the previous studies (Berland and McNeill, 2010; Osborne et al., 2016; Zhang and Browne, 2022). From three general dimensions "Identification" is adopted from Zhang and Browne's (2022) study while "Construction & Critique" is already mentioned by Osborne et. al (2016). It is important to underline that the following definitions in Table 3.4 are embraced and implemented in the data analysis period.

Table 3.4. Definitions of the argumentation components.

Component	Definition	Reference
Claim	Opinions or decision statements concerning a phenomenon being discussed.	Toulmin, 1958
Evidence	Piece of data or ground that either supports or opposes the claim.	Toulmin, 1958
Warrant	Explanations that link the claim and evidence through logical or empirical reasoning.	Toulmin, 1958
Rebuttal	Answers proposed as objections to the potential counterarguments.	Toulmin, 2003
Counterargument	Opposing ideas or alternative viewpoints that are against an argument.	Kuhn, 1993
Counterclaim	A simple opposing claim.	Osborne et al., 2004
Counterrebuttal	Defeating statement given against a defeater.	Godden, 2014

As the new data collected from a new sample group, the coding scheme is expected to be modified through addition or elimination process (Lune and Berg, 2017). Therefore, this situation also requires an inductive approach where the codes are emerged through examination of the data (Glaser and Strauss, 1967). Through inductive reasoning, the collected data can be grounded to the existing categories. In the coding, the researcher compared data with data, asking analytic questions to interpret the responses and construct labels for each piece of data (Charmaz, 2014). In the current study, theoretical sampling is performed with the constant comparative method where the data is coded and compared with the other coded data, and when a new code was emerged, the codes either expanded or integrated within the existing category (Glaser and Strauss, 1967). Therefore, as the coding proceeds, an initial coding scheme was revised and clarified repeatedly. As a result, new codes have emerged from the participants' responses with the aim of fitting the data into the coding scheme.

The types of the codes as the components of a scientific argumentation were determined and noted on a coding sheet to be described in detail and to be used as a guide during the coding process. These codes are defined as following:

Table 3.5. Coding scheme.

Code	Abbreviation	Meaning of the code
Identification of a claim	I_c	Students select a claim among competing theories.
Identification of evidence	I_c	Students select one or more evidence that support their claim from a list of evidence.
Construction of a claim	C_c	Students construct a claim.
Construction of evidence	C_e	Students construct evidence supporting their claim.
Construction of warrant	C_w	Students construct a warrant that connects their claims and evidence.
Construction of counterclaim	C_cc	Students construct a statement against a claim.
Construction of counterargument	C_ca	Students construct a counterargument against an argument.
Construction of rebuttal	C_r	Students construct a rebuttal against a counterargument.
Construction of counterrebuttal	C_cr	Students provide a rebuttal against another person's rebuttal.

Table 3.5. Coding scheme (cont.).

Code	Abbreviation	Meaning of the code
Critique the strengths of counterargument	S_ca	Students provide an explanation about what makes the counterargument stronger.
Critique the weaknesses of counterargument	W_ca	Students provide an explanation about why the counterargument is weaker.
Critique the strengths of own argument	S_a	Students provide an explanation about why their argument is stronger.
Critique the weaknesses of own argument	W_a	Students provide an explanation about the weak aspects of their argument.

The components of "*construction of a claim*", "*identification a claim*", "*construction* of *evidence*", "*identification of evidence*", "*construction of warrant*", *"construction of rebuttal"* and "*construction of counterargument*" were already in the coding scheme. However, students constructed simple claims against their own claims, and these indicated a new component of "*counterclaim*". Similarly, "*counterrebuttal*" emerged as the learners created counter responses against their rebuttals. Finally, instead of combining strength or weakness of arguments, the dimension of "*critique*" was divided into four as "*strengths of own argument*", "*weaknesses of own argument*", "*strengths of counterargument*" and "*weaknesses of counterargument*" (see Table 3.5).

3.4.1. Levels of Learning Progression for Scientific Argumentation

The students' responses were first converted into a digital document form. The answers were coded with respect to the coding scheme (see Table 12). Following the completion of the coding process, two different approaches with different frameworks were embraced to establish students' levels for making scientific argumentation. The reason for this decision lies in the nature of both argumentation tasks and the research questions. The first task included only identification and construction dimensions, the second task did not include one construction and two critique components, the third task did not include one identification component, and the fourth task did not include any identification component as well as three critique components. Attempted components in each task and its relation to the two research questions are demonstrated in Table 3.6.

Table 3.6. Relation between argumentation tasks and research questions.

Components	Task 1	Task 2	Task 3	Task 4	RQ 1	RQ 2
I_c	x	x	-	-	x	-
I_e	x	x	x	-	x	-
C_c	x	x	x	x	x	x
C_e	x	x	x	x	x	x
C_w	x	x	x	x	x	x
C_cc	x	x	x	x	x	x
C_ca	x	x	x	x	x	x
C_r	x	x	x	x	x	x
C_cr	x	-	x	x	x	-
S_ca	-	x	x	-	x	-
W_ca	-	x	x	-	x	-
S_a	-	-	x	x	x	-
W_a	-	-	x	-	x	-

With the aim of answering the first research question, the focus was given on the grade level and thus all the 13 components were aimed to be found in students' answers in all the tasks. In other words, the proficiency levels of Grade 5-7 students' scientific argumentation skills were determined through participants' responses in all four tasks. Moreover, in order to explore the second research question, responses to each four tasks were targeted, and thus it was essential to find common components that can be found in every task. For each investigation unit, frameworks and pathways retained are given in the following sections in detail.

3.4.1.1. Identification of Argumentation Levels for Research Question 1. After the finalization of the coding process, some subskills became distinct in terms of students' ability to achieve them. The stand-out components were given attention and accepted as the required criteria for reaching a certain argumentation level. The established levels and their indicators were created to fit the data into the described progression categories (see Table 3.5). The final progression levels, their indicators and descriptions can be seen in Table 3.7.

Table 3.7. Descriptions of each level of scientific argumentation.

Levels	Descriptions
Level 0	Students cannot identify, construct or critique.
Level 1	Students must identify at least one claim and one piece of evidence. They must construct at least one claim and one piece of evidence.
Level 2	Students must identify at least one claim and one piece of evidence. They must construct at least one claim, one piece of evidence, either one warrant or a counterclaim, or both.
Level 3	Students must identify at least one claim and one piece of evidence. They must construct at least one claim, one piece of evidence, one warrant, one counterclaim, and one counterargument.
Level 4	Students must identify at least one claim and one piece of evidence. They must construct at least one claim, one piece of evidence, one counterclaim, one warrant, one counterargument and one rebuttal. They may or may not critique the strengths or weaknesses of their own arguments or counterarguments.
Level 5	Students must identify at least one claim and one piece of evidence. They must construct at least one claim, one piece of evidence, one counterclaim, one warrant, one counterargument, one rebuttal, and one counterrebuttal. They must critique at least one strength or weakness of their own arguments or counterarguments.
Level 6	Students must identify at least one claim and one piece of evidence. They must construct at least one claim, one piece of evidence, one counterclaim, one warrant, one counterargument, one rebuttal and one counterrebuttal. They must critique the strength and weakness of their own arguments and counterarguments.

This study revealed an empirically grounded learning progression for students' scientific argumentation skills. First of all, accomplishment of all components by the participants were considered to be the highest level (Level 6) for making scientific argumentation. Conversely, failing to demonstrate any of these components was considered the lowest level (Level 0), yet the lower anchor is accepted as the next level (Level 1).

Following the determination of the upper and lower anchors of the learning progression, students' achievement on identifying and constructing claims and pieces of evidence that support them were examined. Consequently, it was found that these four components were displayed by almost all participants, constituting Level 1.

When compared to the subskills achieved in Level 1, it was observed that there were a smaller number of students who could construct warrant and counterclaim. Therefore, these argumentation components were chosen as the criteria to move to the next level, Level 2. It was also noticed that students who exhibited both warrant and counterclaim in their constructed responses found it challenging to construct counterarguments. Hence, constructing a counterargument was the skill that prevailed in order to move on to the next level, Level 3.

Constructing a rebuttal was the next outstanding argumentation component that was demanding for participants to compose, after constructing a claim, counterclaim, and counterargument. Thus, constructing a rebuttal to the counterargument was seen as an element that led participants to the upper level, Level 4. For students in this stage, it was also challenging to critique their own arguments and counterarguments in terms of weakness and strength. For this reason, even if the students demonstrate these skills, critiquing the strength and weakness of their own arguments and counterarguments was not a criterion for students at Level 4.

As one of the components of Construction dimension of the hypothesized learning progression, construction of a counterrebuttal against a rebuttal statement was the most outstanding sub-skill since only a limited number of students could achieve this. Therefore, constructing a counterrebuttal was considered to be a standard to be reached for Level 5. Additionally, students in this level must critique at least one weakness or strength of their own arguments or the opponent's arguments, as it is not difficult for them to accomplish.

Consequently, as it is justified above thoroughly, the learning progression includes six general levels which are summarized in Table 3.8.

Table 3.8. Representation of scientific argumentation progression including codes.

	Progress Variables												
	Identification		Construction							Critique			
Levels	I_c	I_e	C_c	C_e	C_w	C_cc	C_ca	C_r	C_cr	W_ca	S_ca	W_a	S_a
Level 0													
Level 1	x	x	x	x									
Level 2	x	x	x	x	x*	x*							
Level 3	x	x	x	x	x	x	x						
Level 4	x	x	x	x	x	x	x	x		x/o	x/o	x/o	x/o
Level 5	x	x	x	x	x	x	x	x	x	x*	x*	x*	x*
Level 6	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 3.8 shortly provides information concerning the classification and coding of the students' responses in terms of their scientific argumentation skills. Moreover, "x" represents students' ability to perform the marked subskill while "x/o" means that the subskill may be achieved by the student or not. Finally, "x*" serves as the successful demonstration of a certain number from the marked subskills. For example, for Level 5 students must generate at least one weakness or strength of their own arguments or the opponent's arguments. Concerning these symbols and explanations, for each level, comprehensive exemplary statements are provided. Level 0 does not indicate any trace of identification, construction, or critique elements; thus, no description is provided below for Level 0.

Level 1: This level takes place as the lower anchor of the learning progression. For Level 1, students must identify a claim and a piece of evidence. They can also construct a claim and a piece of evidence; however, they do not produce any other components of a scientific argumentation process. In other words, from two competing theories, students can recognize and select one of them according to their decisions. After identification, they can identify appropriate evidence from a set of evidence. In addition, they can construct simple statements of claims and pieces of evidence that go along with their claims. As an example of a participant whose skills for scientific argumentation level was evaluated to be Level 1, G5S11 could identify and construct claim and evidence, however she could not reason a relation between her claims and evidence through a warrant. A fragment from her responses is given below.

"I think model A is better (claim) *because it is easier to understand and explain. Also, model visualization in Evidence 3 and its utilization in schools are taken as evidence* (evidence)*."* (no warrant is provided)

Level 2: In addition to identifying and constructing a claim and evidence, students, who achieved the Level 2, now could construct a warrant that relates their claims and evidence or state a simple counterclaim against their main idea, or they can do both. As an example of a Level 2 student, G5S16 stated a claim and gave evidence for supporting his claim by making reasoning. He could also present a simple counterclaim for the first task. An excerpt from this student's written response from the third task is given below.

"My car is the fastest car in the world, and it is solid/strong (claim)*. Because my car is made of both the lightest material in the world carbon fiber and the friction force is reduced and therefore the fastest and the tires are thin* (evidence & warrant)*. ... They would say it is not only about being light* (counterclaim)*."*

Another example for Level 2 students is G5S2 who completed the identification dimension successfully, constructed a claim, evidence, and warrant. However, she could not present a simple counterclaim in any of her tasks. A brief passage from her response is given below.

"*I don't think anchovies in the Black Sea are in danger of extinction* (claim)*. Evidence number 3, 5, and 6 support it* (evidence)*. Also hunting and selling of anchovies would be banned* (evidence)*. Anchovy fish in the Black Sea region is not in danger of extinction because if anchovy were about to become extinct, it would be in the news* (warrant) *...."*

Level 3: At this level, as an addition to the prior level's requirements, students must be able to construct both counterclaim and warrant as well as to present counterarguments. What distinguishes counterclaims from counterarguments is that the latter must be more complicated opposing ideas with reasoning. As a member of Level 3, a sixth grader's (G6S17) response to the third task's questions are given below.

"My vehicle must be light in material, strong and lightly loaded. ... They would say it must be too heavy and hard (counterclaim)*. ... The car should be lighter because if it is light it will glide much faster due to its load* (evidence & warrant)*. ... They would say "If it has more weight, it becomes closer to the ground, so it goes faster* (counterargument)*. …"

The statements above demonstrate that the participant can make a claim concerning a dichotomy and support his ideas through appropriate evidence. He also provides reasoning about how his evidence defends her claims. Then, he is able to propose a counterargument that comprehensively explains opponents' reasoning of the counterclaim.

Level 4: At Level 4, it is required that the student must construct a claim, evidence, counterclaim, warrant, counterargument, and rebuttal without counterrebuttal missing only one component of construction dimension. For rebuttal, students must refute either counterclaim or counterarguments through evidence and making reasoning. Yet, they may or may not critique the strengths or weaknesses of their own arguments or counterarguments. Being involved at the Level 4, a sixth grader's (G6S11) reaction to the third task is given below.

> *"I think the anchovy fish in the Black Sea is not extinct* (claim). *Evidence 3,4,5,6 are supporting but 1,2,7,8 are not appropriate* (evidence). *Anchovy is a fast-growing fish and weather conditions favorably affect its development. For these reasons, the fish population is increasing. In case of hunting, young fish cannot be hunted due to the increase in the catchable length to 9 cm and sustainability is ensured* (warrant). *The opposer may say that Anchovy fish in the Black Sea are extinct* (counterclaim). *... Anchovy is a fast-growing fish. They cannot be extinct because they reproduce and grow quickly, even if some of them are damaged by different factors* (rebuttal). *... Due to factors such as old age, being eaten by different creatures, epidemics, water pollution, nutrient deficiency and breeding, many anchovies are damaged and die. This endangers their generation* (counterargument). *Anchovies can grow and reproduce fast. Although they can be damaged, this is not true for all anchovies. Fishing has a major negative impact on the anchovy population* (strength of counterargument). *The catchable length has been increased to 9 cm by the Ministry of Food, Agriculture and Livestock. Not every hunter can catch every anchovy he wants, and young anchovies provide continuity* (strength of own argument)*."*

Overall, as a member of Level 4, the student could identify claim, evidence and warrant; construct claim, evidence, warrant, counterclaim, counterargument, rebuttal but not a counterrebuttal; critique strengths of own and counterargument.

Level 5: At this level, other than the required components at Level 4, a counter rebuttal must be produced by the participants. A counterrebuttal is the answer to a rebuttal that aims to refute a counterargument. This subskill can be considered the most challenging element of the proposed learning progression. Moreover, they must critique at least one strength or weakness of their own arguments or counterarguments. As a participant who successfully reached this level of the learning progression, a fifth grader (G5S14) replied to the questions in the first task and an excerpt is given below.

"... in order for the car to go fast, its weight must be low. The heavier the weight, the stronger the contact with the ground and the vehicle slows down. The more force is applied, the more wind resistance is reduced, and the more force is applied against wind resistance (claim, evidence, warrant). *… the opponent may say that it can go fast no matter how much the weight is. Even if the force increases or decreases, the same speed occurs because the force is applied* (counterclaim, counterargument). *… Weight slows down the vehicle, for example, we are faster when walking normally but slower when carrying a chair. As there is a speed difference between vehicles with different engine powers (Lamborghini and Tofaş), force creates a speed difference* (rebuttal). *… At the slightest bump, the car loses its balance and slows down due to its lightweight* (counterrebuttal).*"*

As it is interpreted above, the student could produce all the necessary components in the identification and construction dimensions of a scientific argumentation. Additionally, he could critique one of four criteria. As the first task does not guide or direct participants to the critique dimension, the student's skill of critique was observed in the second task. In this task the student proposed a weakness of the counterargument, and it is cited below.

"There is not enough evidence that the Earth cannot pull the Moon from a great distance. Earth cannot attract other planets and fragments (weakness of counterargument)."

As a final and top level of the hypothesized learning progression for scientific argumentation, Level 6 was determined as the upper anchor. As it was mentioned before, in this level, all of the argument variables were aimed to be found in the students' responses. Therefore, in addition to the former level of progression, students must critique the strength and weakness of their own arguments and the counterarguments. Only one student, a seventh grader, was able to reach that level and exhibit these skills.

In this section learning progression for scientific argumentation levels are summarized and explained in detail through students' actual answers with the aim of serving a basis for answering research questions. For the first research question of "*How does the complexity of middle school students' argumentation change across Grade 5 to Grade 7?*", the frequency of the participant levels that were determined across all four tasks is counted and compared across three grade levels.

To answer the second research question of "*How does the complexity of middle school students' argumentation change in different scientific contexts in each grade level?*", the adaptation of Venville and Dawson's levels for scientific argumentation skills (2010) is used to compare levels for each task particularly.

3.4.1.2. Identification of Argumentation Levels for Research Question 2. In the first place, the original version of levels for scientific argumentation skill provided by Venville and Dawson (2010). The common subskills attempted to be examined for all four tasks in the current study were paired according to the descriptions and examples given in the article by Venville and Dawson as well as the coding definitions of the present study. Before presenting the guide that was used to explore the second research question, it is important to highlight some of the main issues that were paid attention during the matching process. In Venville and Dawson's study, the researchers explained that they were not able to distinguish between the subskills that participants reported for the construction of evidence and for the construction of a warrant. While both codes do not need to be present simultaneously, they may coexist. Therefore, even if there is evidence without a warrant, it will be considered at that certain level, and this applies to all levels. Additionally, Venville and Dawson attempted to examine the elements of *backing* and *qualifiers* in students' scientific arguments, using a different approach compared to the present study. The qualifiers in their study were defined as the conditions under which claims are deemed valid. Upon examining these instances, it became evident that this skill was highly compatible with the construction of counterclaims or counterarguments. The rationale for this choice is rooted in the presence of contrasting claims within the examples of qualifier statements in their study. Moreover, Venville and Dawson described and exemplified backing in a way to justify warrants. An analysis was carried out for the current study to identify the argumentation subskill that was most closely related to the concept of 'backing', and it was found that constructing rebuttals was the most appropriate choice. This decision was based on the observation that participants' refutations effectively support students' arguments. In Table 3.9, the levels for evaluating the students' argumentation skills are provided in detail.

Table 3.9. Scientific argumentation levels in comparison to Venville and Dawson (2010).

Levels	Descriptions by Venville & Dawson (2010)	The present study
Level 1	Claim	Constructing claim (C_c)
Level 2	Claim, Evidence and/or Warrant	Constructing claim (C_c) Constructing evidence (C_e) and/or Constructing warrant (C_w)

Table 3.9. Scientific argumentation levels in comparison to Venville and Dawson (2010) (cont.).

Levels	Descriptions by Venville & Dawson (2010)	The present study
Level 3	Claim, Evidence and/or Warrant, Backing/Qualifier	Constructing claim (C_c) Constructing evidence (C_e) and/or Constructing warrant (C_w) Constructing counterclaim (C_cc) /counterargument (C_ca)
Level 4	Claim, Evidence and/or Warrant, Qualifier, Backing	Constructing claim (C_c) Constructing evidence (C_e) and/or Constructing warrant (C_w) Constructing counterclaim (C_cc) /counterargument (C_ca) Constructing rebuttal (C_r)

As indicated in Table 3.9, Venville and Dawson considered Level 1 as being able to construct a claim. This criterion was matched with the component of Constructing Claim (C_c) in the coding scheme (see Table 3.5) of the study at hand. According to Venville and Dawson's argumentation levels, in addition to being able to state a claim, a piece of data that supports the claim and/or the warrant that connects the two were required to be accomplished for Level 2. The Constructing Evidence (C_e) and Constructing Warrant (C_w) were the paired argumentation components for Level 2 aligned with the coding scheme identified for the current study.

It was stipulated that Venville and Dawson set the criteria that either backing or a qualifier must be presented to be at Level 3. As it was declared before, a *qualifier* was matched with a counterclaim or a counterargument that is considered to be a prerequisite for constructing a rebuttal, which is closely associated with *backing*. A rebuttal; however, cannot exist independently. Thus, the construction of a counterclaim (C_cc) or counterargument (C_ca) as a *qualifier* is deemed satisfactory for attaining this level. In addition to these skills, constructing rebuttal (C_r) was required to be attained to move to the upper level, Level 4.

Following the coding guide elaborated before, students' levels were established. After determining the frequency of students' levels for four tasks with different contexts, the variation in students' scientific argumentation skills in different science contexts is revealed.

3.5. Validity and Reliability of the Study

In qualitative studies, there are a variety of perspectives on validation, such as its definition, the terms to be used, and the procedures to be followed (Wolcott, 1994; Whittemore et al., 2001; Lincoln et al., 2011). In this study, Creswell and Poth's perspective and terms are embraced (2018). Thus, the utilization of the validation process is considered as an assessment for the accuracy of the findings, and it includes a sequence of strategies such as spending time in the field that the research held, detailed explanations of method and elements and the position of the researcher. Reliability is also discussed in various ways in qualitative research, yet the focus is always on the stability as well as replicability of the research process and findings (Silverman, 2013). There are also procedures and strategies to ensure reliability of this study that are expressed in the following sections.

3.5.1. Validation Strategies Adopted in the Study

Since it is impossible for a qualitative researcher to snatch the "reality", with the aim of ensuring the credibility of this study, multiple strategies for validation were endorsed. Triangulation, which is considered to be a distinguished method in a qualitative study, is applied (Cohen et al., 2018). Moreover, the position of the researcher was explained to clarify researcher bias to the readers and the contribution of prolonged engagement during the whole data collection process was described. With thick and rich descriptions about the context of the study, participant attributes as well as the process of generation of the codes was transferred in detail.

3.5.1.1. Triangulation. Triangulation is a validation strategy that attempts to study a phenomenon through multiple sources of data, methods, researchers or theories (Creswell, 2013). In this study, participants' responses as the main data source were gathered in both written and spoken way, through argumentation tasks completed on paper and follow-up interviews, respectively. With various data forms, the students' responses intended to be captured in a more holistic manner. Secondly, students' answers were also analyzed with more than one researcher, and the thesis supervisor's perspective concerning the meaning of the codes was taken into account. This strategy can enable more accurate interpretation of the responses provided by the participants, and receiving input from an experienced researcher can help clarify the interpretation of the data. Finally, even though Osborne and his colleagues' (2016) learning progression model was acknowledged as the main theory, Zhang and Browne's (2022) recent study, an updated version of the hypothetical model for scientific argumentation, was also taken into account during the formation of the coding components. Embodying various theories can strengthen the theoretical foundation of the study as well as perceiving the core of the skills that are under investigation. To sum up, throughout the data collection and analysis period, several techniques were applied not only to minimize potential biases but also to improve overall validity of the study.

3.5.1.2. Position of the Researcher. With the aim of reducing researcher bias, a reflexive approach as a validation method was embraced in the study (Rowe, 2014; Holmes, 2020). The possible impacts of the researcher's perspectives and theoretical beliefs, researcher's lens as an insider in the study and the context of the study may influence the research (Savin-Baden and Major, 2013). In the first place, the researcher was aware of these variables, and this self-awareness helped to diminish any possible influence throughout the research process. As mentioned previously, the researcher also held the role of a teacher, and this circumstance could influence the process of intervention or data collection. Since the researcher was teaching science to half of the participants, they may have some preconceived notions that may lead to an impact on their behaviors either less or more inclined to participate honestly or be motivated. With informed consent, they were told that this study would not have any negative effect on them. With minimizing power, they were told that their contribution to the study was very valuable, and it was emphasized that each answer was valuable and would not be considered wrong or unsuccessful. Moreover, from the explicit teaching of argumentation to the collection and analysis of data through individual tasks and interviews, it may be challenging for the researcher-teacher to be completely objective. Thus, the researcher may unwillingly affect students' responses. With the aim of mitigating the effect of this problem, the researcher labeled each student name randomly during the data analysis period.

From a different perspective, the researcher's background knowledge and past experiences concerning scientific argumentation may affect the study. The researcher took courses that gave information about scientific argumentation during her undergraduate years. She also made comprehensive studies under two separate courses in her master's degree, in which she gained a deep knowledge of argumentation studies. In her teaching experience, she integrated and applied the argumentation technique in her lessons. All the knowledge and experiences can affect the stages of research, such as deciding on data collection materials, coding of the responses, interpretation of the findings and the quality of the research. The researcher's background in scientific argumentation helped her to become better qualified in terms of knowledge and skills and contributed positively to the study. Even so, guidance was sought from the thesis supervisor in making various decisions during the whole study, an important factor that diminish the researcher's potential bias due to her background. In addition, the constant comparison method which can help decrease the impact of preconceived notions on data interpretation was firmly favored.

3.5.1.3. Prolonged Engagement. First of all, the researcher has been working as a science teacher in the school where the research study was conducted and already engaged in the site for a long time. The researcher was also familiar with the participants as well as their regular schedule of learning cycles and embedded and implemented all the activities and tasks for data collection as weekly sessions. Moreover, Merriam (2009) specifically claims that this strategy aims for spending a sufficient period of time until the data become saturated. The time spent in the research context allowed the researcher to develop a deeper understanding of the data, data analysis and its interpretation.

3.5.1.4. Thick and Rich Descriptions. Thick description is a concept for explaining the elements constituting and influencing a phenomenon being explored in detail (Ponterotto, 2006). Readers should be exposed to not only direct reports of findings and documented details but also deeper meanings and interpretations of the focused phenomena clearly (Stahl and King, 2020). With the aim of achieving this in this study, the features of the students as well as the research context and data collection procedure were provided in detail in the previous sections. Furthermore, the coding and analysis of data were extensively summarized. In the meantime, participants' responses were offered as empirical evidence for data analysis and findings.

3.5.1.5. Systematic Validation of Learning Progression. With the purpose of increasing the validity of a learning progression, Anderson (2008) proposed three major qualities that researchers should pay attention to. The first one is ensuring the *conceptual coherence* of the LP. That means the current learning progression should demonstrate a coherent development of how initially simple skills become sophisticated over time. The second one is *compatibility with the existing research.* In other words, the current findings should expand the learning progressions established before, with a top-down approach. The third one is the *empirical validity* of the LP. It is basically adapting a bottom-up process that the current learning progression is grounded in the data from actual students.

3.5.2. Increasing Reliability of the Study

Traditionally, the term of reliability claims that if a study is repeated, the results would be the same. However, this becomes ambiguous in a qualitative study where human behaviors are not stationary, and the data is interpreted in different ways. Therefore, the condition for reliability of a research study should be if the data is consistent with the results. With this perspective, reliability of the current study is concentrated on ensuring readers about the consistency that the data and results are dependable (Merriam and Tisdell, 2016).

In order to ensure compatibility of the participants' answers and their interpretation, the coding scheme for the data analysis process of the transcripts was accomplished by the two researchers. Another reason behind this decision was to assure objectivity and restrict favorability of certain codes. In total, there were 306 written responses, including transcripts of interviews. The researcher coded all 306 responses, while the second researcher (a graduate student) examined and recoded only a proportion of these responses. Firstly, 10% of all responses, representing approximately 30 written responses, were randomly selected through an online application. Following this procedure, by dividing the number of agreements by the total number of codes, the intercoder reliability between the researchers was calculated (Miles and Huberman, 1994). The percentage of agreement of researchers is expected to be 85% to 90% (Miles et al., 2014). If the measured percentage is around these values, the determined coding system by the researchers is reliable. After transforming the ratio obtained before into the percentage form, the intercoder reliability was found as 86%. Hence, the intercoder reliability of this study can be acknowledged as fair and acceptable.

4. FINDINGS

The main purpose of this study was to explore students' progression for performing scientific argumentation skills from more naïve to more sophisticated way throughout Grade 5, Grade 6 and Grade 7. As it was explained in the former chapters, the learning progression was created as a result of data analysis of 80 participants' written and spoken answers. Through constant comparative method, 13 components under 3 dimensions emerged as follows:

(i) Identification
- Identifying Claim
- Identifying Evidence

(ii) Construction
- Constructing Claim
- Constructing Evidence
- Constructing Warrant
- Constructing Counterclaim
- Constructing Counterargument
- Constructing Rebuttal
- Constructing Counterrebuttal

(iii) Critique
- Critiquing Weakness of Counterargument
- Critiquing Strength of Counterargument
- Critiquing Weakness of own Argument
- Critiquing Strength of own Argument

The hierarchical model depicting the learning progression for scientific argumentation, as illustrated in Figure 4.1, showcases the emerging dimensions and components. These elements are arranged both horizontally and vertically in a manner that reflects their increasing sophistication levels. However, this does not mean that learners show a linear development when they perform their scientific argumentation skills.

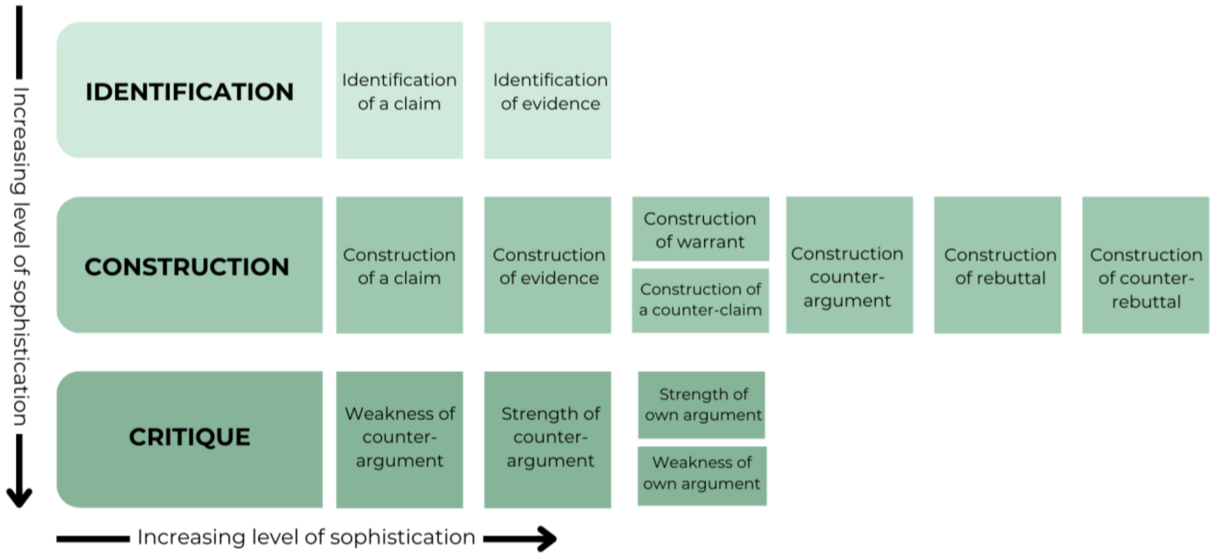

Figure 4.1. Dimensions and components in scientific argumentation learning progression.

With the aim of addressing two research questions given (RQ1 and RQ2) separately, this section is divided into two parts. Firstly, whether the learning progression in students' scientific argumentation skills depended on grade levels will be elaborated in detail in section 4.1. After then, the change of progression of students' scientific argumentation skills depending on the context will be explained in depth in section 4.2. Finally, findings concerning participants' nonlinear progressions will be given through examples in section 4.3.

(i) How does the complexity of middle school students' argumentation skills change across Grades 5 to 7?
(ii) How does the complexity of middle school students' argumentation skills change in different scientific contexts in each grade level?

4.1. Students' Scientific Argumentation Skills on a Learning Progression

To further give an answer to the first research question, students' written responses to all the tasks were examined and coded on an online document. After then participants' learning progression levels were identified in a rigorous manner that was already described in the former chapter. With the purpose of exploring the progress across grade levels, the number of students' levels for making argumentation for each grade level was counted separately. As a result, a frequency table was created. The distribution of the levels for each grade level was depicted as frequency and percentage in Table 4.1.

Table 4.1. Frequencies of learning progression levels for scientific argumentation skills.

Levels	G5	G6	G7
	f (%)	*f (%)*	*f (%)*
Level 1	1 (4)	0 (0)	0 (0)
Level 2	8 (30)	6 (23)	11 (41)
Level 3	6 (22)	1 (4)	3 (11)
Level 4	10 (37)	16 (61)	9 (33)
Level 5	2 (7)	3 (12)	3 (11)
Level 6	0 (0)	0 (0)	1 (4)
Total	27 (100)	26 (100)	27 (100)

Overall, at the highest proficiency level, Level 6, only 1 participant achieved this level. 8 students were categorized at Level 5, indicating a high level of proficiency just below the top level. The majority of the participants, specifically 35 students, were assessed as Level 4. A total of 10 students were placed at Level 3 and 25 students were categorized at Level 2. At the lowest level, Level 1, only one student was assessed.

As the lower anchor of the learning progression, Level 1 was performed by only 1 fifth grader that neither of the Grade 6 nor Grade 7 students were displayed the lowest level for scientific argumentation skills. Even though the student was able to identify and construct claims and pieces of evidence, her responses to all the four tasks were coded, and there was no instance of constructing a warrant. The responses of the student labeled as G5S11 and the coding of the scientific argumentation sub-skills are quoted and given in 4.2 below.

Table 4.2. Examples from student responses for Level 1.

Coded sub-skills	Excerpts from data
Identifying evidence	*“Evidence numbered 5 and 6 are appropriate …”*
Constructing claim	*“I think model A is better as it is easier to understand and explain.”*

Table 4.2. Examples from student responses for Level 1 (cont.).

Coded sub-skills	Excerpts from data
Constructing claim	*"If I were to design a car, I would make sure that it is robust, and I would use better quality products."*
Constructing claim	*"I don't think there is anything about extinction."*
Constructing evidence	*"... Also, model visualization in Evidence 3 and its utilization in schools are taken as evidence. ..."*

In addition to the sub-skills required to be on Level 1, students who are at Level 2 were expected to construct either a warrant or a counterclaim or both. Having the highest percentage in this level (41%), eleven Grade 7 students, as the oldest participants, could perform these sub-skills. The other subskills in the constructing dimension, such as counterargument and rebuttal, were lacking in their responses. Furthermore, 8 students representing 30 percent of the fifth-grade student population that includes the youngest pupils among the participants, extended their participation to this level. Finally, at this level, participation was the least common among Grade 6 students, with only 6 students (comprising 23% of the total) taking part in this study. The following table presents the responses given in the written tasks and transcribed interviews by the students who are categorized in Level 2, along with the subskills identified within these responses.

Table 4.3. Examples from student responses for Level 2.

Students	Excerpts from data	Sub-skills
G5S3	*"I think anchovy fish in the Black Sea are not endangered* (claim)... *They say anchovy fish would be extinct and endangered* (counterclaim).*" "I think model B is better* (claim). *... When tiny meteors collide, they become big* (evidence).*"*	C_c, C_e, C_cc
G5S8	*"I would not allow wind power plants* (claim) *because of the risks* (warrant), *such as bird deaths and breaking out fires* (evidence)*..." "Anchovy fish will run out* (claim) ... *They would say that anchovies can be inexhaustible* (counterclaim). *"*	C_c, C_e, C_w, C_cc

Table 4.3. Examples from student responses for Level 2 (cont.).

Students	Excerpts from data	Sub-skills
G6S22	***"I think model A is better*** (claim) *because there is an image that supports this evidence. ... The Moon is indeed different from the axis of rotation of the other planets* (evidence)*." "I think ... there is a possibility of extinction* (claim)**. ...** *Anchovy consumption has been very high* (evidence)*... Since there is so much anchovy consumption, there may not be an increase in the generation* (warrant)*."*	C_c, C_e, C_w
G7S26	*"I think model A is better because it is logical* (claim)*... the Earth's gravitational pull is very likely to attract the Moon* (evidence and warrant)*. ..."*	C_c, C_e, C_w

At Level 3, students are anticipated to demonstrate their argumentation skills as they construct a warrant, counterclaim, and counterargument. Consequently, 22% (6) of the Grade 5 students fulfilled the expectations of Level 3. Then, 11% (3) Grade 7 students, who are the seniors among participant groups, showed the argumentation criteria of Level 3. Only a single student in the Grade 6 group indicated the characteristic argumentation skills of Level 3.

Table 4.4. Examples from student responses for Level 3.

Student	Excerpts from data	Sub-skills
G5S6	*"Yes, I would allow it (wind power plants)* (claim)*. ... because wind energy is clean and renewable* (warrant & evidence)*. ... He/she could say no, not allowing it* (counterclaim)*."* *"I don't think anchovies are going extinct* (claim)*. The Black Sea accounts for approximately 76% of marine production, especially anchovy* (evidence)*. ... she/he can present me with my arguments and say, no, oil pollution continues to threaten Black Sea coastal ecosystems, overfishing or marine pollution has contributed to the* (counterargument) *extinction of anchovies* (counterclaim)*."*	C_c, C_e, C_w, C_cc, C_ca

Table 4.4. Examples from student responses for Level 3 (cont.).

Student	Excerpts from data	Sub-skills
G6S17	*"Yes, I would allow it* (*wind power plants*) (claim)*, because it does not harm nature* (warrant)*. ... Wind energy is renewable energy and does not harm the environment and does not deplete our resources* (evidence)*. ..."* *"I think model B is better* (claim) *because it makes more sense to me. ... Evidence 2 also supports it* (evidence)*. ... It means the pieces came together and began to revolve around the Earth* (warrant)*. ... A random piece of rock that has joined the Earth's gravitational pull* (counterclaim)*...* *"The car must be light, strong and lightly loaded* (claim) *... The car should be lighter because if it is light* (warrant) *it will glide much faster due to its load* (evidence)*. They may say it must be too heavy* (counterclaim) *and say no, if it has more weight, it hits the ground hard. So it goes faster* (counterargument)*."*	C_c, C_e, C_w, C_cc, C_ca
G7S10	*"No, I would not allow it (wind turbines)* (claim) *because, no matter how positive it may be. ... . I would not prefer to build it in living areas because it is both risky for life safety, and because it creates noise pollution and negatively affects radio, television, and other communication waves* (evidence and warrant)*. ... There are some positive aspects of wind power plants so he/she would explain them (*counterargument)*."* *"Against my claim, he/she would suggest that not only the speed but also the size and weight of the car play a role* (counterclaim)*."*	C_c, C_e, C_w, C_ca, C_cc

Having the highest number of participants across all the progression levels for scientific argumentation skills, a total of 35 participants achieved to be at Level 4. In other words, their responses included all the subskills under the construction dimension in the progression except one, that is constructing counterrebuttal. In addition, some of the students in this level could even critique their own and opposite arguments. Having the highest frequency, 61% (15) of Grade 6 students' argumentation skills were classified in this level. In the youngest participant group, 37% (10) Grade 5 students' argumentation skills were categorized as Level 4. Although the Grade 7 students were the eldest participant group, 33% (9) of the Grade 7 students could reach Level 4. Some examples from student responses as well as the codes expected to be noted for this level are given in Table 4.5 below.

Table 4.5. Examples from student responses for Level 4.

Student	Excerpts from data	Sub-skills
G5S5	*"I think model B is better* (claim) *since the percentages (elements from the surface of the Moon and the Earth) are similar because it is detached from the Earth, and also here, as seen in evidence 3, the Moon follows the Earth, because it is something that belongs to the Earth. Like mother and child, it follows its own mother, not a stranger* (evidence & warrant). *... If the Moon is made of dust and other objects* (counterclaim), *why would it follow the Earth? It could also follow Mars. If the two pieces can merge and follow the Earth, then it wouldn't be the Earth's anyway. It wouldn't be so smooth, a meteorite would break when it hits a meteorite, and since the Moon is a part of the Earth, when meteorites hit it, they just crater its surface* (rebuttal). *... (logical part of model A) it could be the gravitational pull of the earth* (strength of counterargument).*"* *"I would allow it because it is very useful and a source of energy* (warrant)*... It is an economical energy source and provides easy electrical energy* (evidence). *... People may think that as the power plants rotate, their propellers kill flying animals. They can be struck by lightning and torn apart* (counterargument).*"*	C_c, C_e, C_w, C_cc, C_ca, C_r, S_ca

Table 4.5. Examples from student responses for Level 4 (cont.).

Student	Excerpts from data	Sub-skills
G6S11	*"I think model B is better* (claim) *because I think it is more realistic. I know that other celestial bodies can be formed when celestial bodies collide, and the materials on the surface of the Moon and the Earth are very similar* (evidence). *Since the substances are similar, it is possible that they used to be the same piece and then separated* (warrant). ... *Why does the Moon orbit the Earth when there are planets with greater gravitational pull than the Earth?* (rebuttal) ... *They may claim that gravity has an effect on the Moon's orbit around the Earth* (counterargument)*, but this happened after the collision. The Moon is only focused on orbiting the Earth. ... They have a point that celestial bodies with little gravitational attraction can be attracted to those with more* (strength of counterargument)*."* *"I think an object with a light and large force goes faster than others* (claim) *and they may say that a heavier object will be faster* (counterclaim)*. ..."*	C_c, C_e, C_w, C_cc, C_ca, C_r, S_ca
G6S23	*"I don't think they are (anchovy fish) endangered* (claim). ... *Evidence 5 and 6 are supporting my claim. Anchovy fish covers 75% of fishing* (evidence). ... *but they may say it's becoming extinct* (counterclaim), *hunting has increased as well as increased fishing with technology, marine pollution* (counterargument). *However, it says that production also increased* (rebuttal)*."* *"I think model B is better because it seemed more convincing to me, and I made the right inference that they merge and form a planet* (claim). ... *As it says there, the rocks left from the planet also fall* (evidence)*, which supports my claim* (warrant)*."*	C_c, C_e, C_w, C_cc, C_ca, C_r

Table 4.5. Examples from student responses for Level 4 (cont.).

Student	Excerpts from data	Sub-skills
G7S7	*"With the aim of designing the fastest car, robustness is essential. Sturdiness makes sure that the car completes the road safely with a high speed* (claim). ... *They may say that a light car can go faster* (counterclaim); *however, due to less mass, the car can stop on the halfway* (rebuttal).*"* *"I wouldn't allow it (wind power plants)* (claim). *It causes noise pollution and causes the death of living things* (evidence)*, so I would not take the risk and allow it* (warrant). ... *I would list my evidence for saving and say that no matter how much energy it produces as they claim* (counterargument)*, it is harmful to nature and living things."* *"I think the anchovy fish is not endangered* (claim). ... *The opposite of my claim is that anchovy fish are endangered* (counterclaim) *because they are consumed too much* (counterargument). *Only marine pollution can strengthen the opposing side. As mentioned in Evidence 7, fish die in areas of oil, etc.* (strength of counterargument).*"*	C_c, C_e, C_w, C_cc, C_ca, C_r

In addition to the skills at Level 4, students at Level 5 were expected to show all the criteria for the construction dimension, particularly constructing counterrebuttal. Furthermore, these students were required to present at least one of the four elements in the critique dimension. As a result, only 8 students in total met these criteria, and they were able to reach this level of argumentation. Having the same frequency, 3 students' argumentation skills from both Grade 6 and Grade 7 were classified into this level, while 2 Grade 5 students' argumentation skills were identified to be Level 5.

Table 4.6. Examples from student responses for Level 5.

Student	Excerpts from data	Sub-skills
G5S13	*"I think the fastest car should have a fast engine and should also be lighter* (claim)*, because the speed of an overweight person is not the same as the speed of a thin person. A car with a new and powerful engine is not the same as a car with an old and slow engine* (evidence and warrant). *He/she can present the idea that a car goes faster when it is heavier (*counterclaim). ... *However, the speed of an overweight person is not the same as the speed of a thin person, so heavier things don't go faster (*rebuttal). *I would reply, "I don't think so, bigger cars go faster because they have bigger wheels, and thus they go a long distance"* (counterrebuttal)*."* *"I think the anchovy fish in the Black Sea are not running out* (claim) *(as evidence 1, 2, 7, 8 indicates), the fish in the Black Sea are running out* (counterclaim and counterargument). *...Their arguments of water pollution and higher rates of average anchovy catches ...* (strength of counterargument)*."*	C_c, C_e, C_w, C_cc, C_ca, C_r, C_cr, S_ca
G6S7	*"I think model B is better because planets can collide, and debris is naturally produced. This debris can be combined with the gravity of the planet* (claim). *The proportions of elements in the Earth and the Moon are almost identical. Also, when planets collide, heat is generated, and this heat can fuse the rocks formed by the collision* (evidence). *I have used collisions as my proof, and I have also presented some evidence about the elements* (warrant). *If the Moon was just wandering around and came into Earth's orbit* (counterclaim) *because of gravity* (counterargument)*, every object that passed by it would enter it. Every object that came near the Earth would be a satellite. Instead of melting in the atmosphere, it could be a satellite* (rebuttal). *There are some big meteorites, and they can enter planetary orbits, and this supports the opposite idea* (strength of counterargument)*."*	C_c, C_e, C_w, C_cc, C_ca, C_r, C_cr, S_ca

Table 4.6. Examples from student responses for Level 5 (cont.).

Student	Excerpts from data	Sub-skills
G6S7	*"If I reduce the force exerted by the wind on it as much as possible as it travels, the distance it will take will increase* (claim). *I think that (opposite view) would be less load carrying, they would show the loads in the cars as evidence* (counterclaim). *However, it will not be able to withstand the wind unless it is aerodynamic, even if it carries a small load and not even a little stone, its resistance to the wind depends on the distance it travels in a certain time* (rebuttal). *As an answer, she could have said that there are cars that are aerodynamic and cannot go from the load in them* (counterrebuttal)*."*	C_c, C_e, C_w, C_cc, C_ca, C_r, C_cr, S_ca
G7S6	*"I think anchovies are becoming extinct* (claim). *Anchovy is the most hunted fish in the Black Sea. The catch has increased, and it was caught more than the normal value between 2014-2015* (evidence). *At the same time, there are reasons for the death of fish other than fishing* (evidence and warrant). *Increased reproduction* (counterclaim) *and the fact that they no longer hunt small fish (*counterargument). *However, the smaller fish may not be fished, but the larger fish will become extinct because they will reproduce and because we hunt the larger ones* (rebuttal)*, thus it leads to increased reproduction because the more fish there are, the more fish there are in the sea, even if we catch them* (counterrebuttal)*."* *"Yes, I would allow it* (claim)*, it has more positive economic and logical benefits* (evidence). *... it is also a more economical and environmentally friendly strength of own argument* (strength of own argument). *They may say that it is easier and cleaner to use other energy* (counterargument)*."*	C_c, C_e, C_w, C_cc, C_ca, C_r, C_cr, S_a

At Level 6, which is considered as the highest level of the learning progression for scientific argumentation presented in this study, students were expected to perform the subskills in all dimensions (Identification, Construction, Critique). It has been determined that only one student was capable of achieving these advanced skills. This is a seventh-grade student with the label G7S11. Table 4.7 below provides the responses of this student in three different tasks, and the codes identified within these responses.

Table 4.7. Examples from the student's responses at Level 6.

Student	Excerpts from data	Sub-skills
G7S11	*"I think model B is better as the Moon is made of rocks, stones and dust* (claim) *and when the large body hit the Earth, fragments from the Earth* (evidence) *influenced the formation of the Moon* (warrant). *If the Earth attracted it as they say* (counterclaim)*, it would have attracted other structures, as the Moon is the only satellite of the Earth* (rebuttal). *The fact that the Moon is gravitated by the Earth and orbit it, makes my argument stronger* (strength of counterargument).*" "No, I would not allow it* (claim). *It causes noise pollution, has negative impact on communication waves, has a risk of fragmentation and causes animals to die* (evidence). *This supports my decision positively, as it is very harmful to nature* (warrant). *I would say that it can harm nature and living things and there are different ways. He may say it is cheaper, more economic* (counterargument).*" "I think anchovy fish are becoming extinct* (claim) *as they are hunted more and because of the sea pollution, now there is pollution and hunting, so fish are becoming extinct compared to the past* (warrant and evidence). *They would claim that anchovy fish are not endangered* (counterclaim) *due to the warming of the weather and growth of the fish* (counterargument). *Yes, they breed a lot* (weakness of their own argument) *but they also die from pollution* (rebuttal). *There are more factors that can cause their death* (strength of own argument). *They reproduce and die. If the ratio is equal, they don't become extinct* (counterrebuttal). *They breed in warm weather, many fish die because of pollution regardless of temperature* (weakness of counterargument).*"*	C_c, C_e, C_w, C_cc, C_ca, C_r, C_cr, S_a, W_a, S_ca, W_ca

To sum up, when the students' learning progression for scientific argumentation skills was examined, it was revealed that there was only one Grade 5 student in Level 1, which was accepted as the lower anchor, and one Grade 7 student in Level 6, which was considered as the upper anchor. While the highest proportion of Grade 7 students (41%) was at Level 2, the highest proportion of Grade 5 and Grade 6 students (37% and 61% respectively) were at Level 4. Figure 4.2 provides a detailed and visual representation of the argumentation skill levels of the students and the distribution of them based on their grade level.

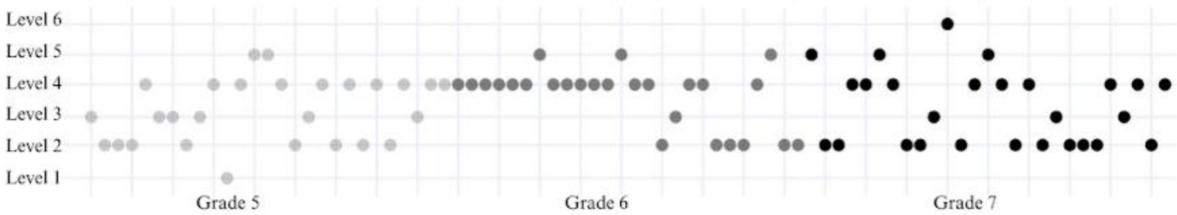

Figure 4.2. Distribution of students' scientific argumentation skill levels by grade.

Figure 4.2 visually demonstrates the distribution of scientific argumentation skill levels across fifth grade students, sixth grade students and seventh grade students in this study. The findings showed that older students could reach the topmost level, Level 6, and performed higher skill for making scientific argumentation. The seventh graders were clustered around Level 2 and Level 4 of the distribution. Similarly, it was seen that Grade 6 students' argumentation skills were condensed at Level 4. Finally, the fifth graders possessed a range of skill levels however, they had lower scientific argumentation skills than the Grade 6 and Grade 7 students.

4.2. Students' Scientific Argumentation Skills in Different Contexts

In order to explain the second research question, a different framework was adapted to identify the levels of students' scientific argumentation performances for each task. The analytic scheme proposed by Venville and Dawson (2010) concerning the levels for scientific argumentation evaluation were adapted, and the procedure was described in the previous chapter. Students' responses were already coded according to the coding scheme of the present study. Based on the criteria for argumentation, the levels of students' argumentation skills for the 4 tasks were identified. Regardless of the grade level of the students, the number of students at each level within the scope of each task was counted. The results are displayed as frequencies and percentage values in Table 4.8.

Table 4.8. Level of scientific argumentation skills by task.

Levels	Task 1 (Physical Science)	Task 2 (Earth and Space Science)	Task 3 (Life Science)	Task 4 (Socioscientific Issue)
	f (%)	*f (%)*	*f (%)*	*f (%)*
Level 4	3 (4)	20 (26)	21 (29)	8 (10)
Level 3	8 (10)	4 (5)	18 (24)	29 (38)
Level 2	9 (12)	25 (33)	9 (12)	37 (48)
Level 1	54 (68)	27 (36)	26 (35)	3 (4)
Level 0	5 (6)	0 (0)	0 (0)	0 (0)
Total	79 (100)	76 (100)	74 (100)	77 (100)

As can be seen in Table 4.8, the task for the physical science domain required the development of arguments on the subject of force and motion. Students frequently indicated the criteria of Level 1, and 68% of the students (54) are observed to be performing argumentation skills at Level 1, that is, they can only form claims. With these claims, students basically stated their ideas for making a car faster. Following this, with lower but similar statistics, 9 students (12%) and 8 students (10%) were able to take part in Level 2 and Level 3 respectively. The criteria for Level 2 were the provision of scientific evidence such as experiment results to support the claim, with or without showing the reasoning behind how the provided evidence caused a car to go faster. In addition to this, in order to reach Level 3, students were expected to give simple or complicated allegations that may contradict their claims which means a counterclaim and a counterargument respectively. Furthermore, there were students (5 students) who could not even produce a meaningful and complete claim considering how a car can go faster. The highest level, Level 4, required students to construct rebuttals to given possible counterstatements, and only 3 students were able to demonstrate the expected sub-skills for Level 4 scientific argumentation.

Task 2 was about an Earth and Space Science topic that involved students selecting one of the two theories regarding the Moon's formation, presenting supporting evidence, justifications, and so on for their chosen theory, and offering explanations to counter the opposing theory. In this task, with the highest and similar frequencies, 27 students who can produce simple claims were on Level 1, and 25 students who can construct evidence were at Level 2. Moreover, with the lowest frequency, only 4 students were determined to be at Level 3, while 20 students could reach the highest level, Level 4. In other words, in this domain most of the students who can construct counterclaim and counterargument could also construct rebuttals.

In task 3, there was an activity related to the concept of biodiversity in the ecosystem topic in the life science domain. Students were asked to make claims about whether a species is endangered or not in connection with environmental problems and to discuss these claims in a scientific way. The vast majority of students (35%) only expressed their own claims and were at the lowest level, Level 1. A similar proportion, but in terms of the complexity of the skill, 21 and 18 students took part in Level 4 and Level 3 respectively, whereas 9 students took part in Level 2 by supporting their claims with appropriate evidence.

The final assignment, titled Wind Power Plants, required students to construct their scientific arguments concerning a socio-scientific issue (SSI). This task involved exploring both the favorable and unfavorable aspects of a controversial societal topic. When the distribution of the scientific argumentation levels of the students who completed this task is analyzed, it is noticed that the highest number of students took place in Level 2 and this trend is followed by Level 3 with 29 students. Moreover, 8 students could reach the highest skill level, while only 3 students were on Level 1.

Overall, with the aim of visualizing the distribution of scientific argumentation levels across the tasks, the distribution of scientific argumentation levels according to tasks is illustrated in Figure 4.3 below.

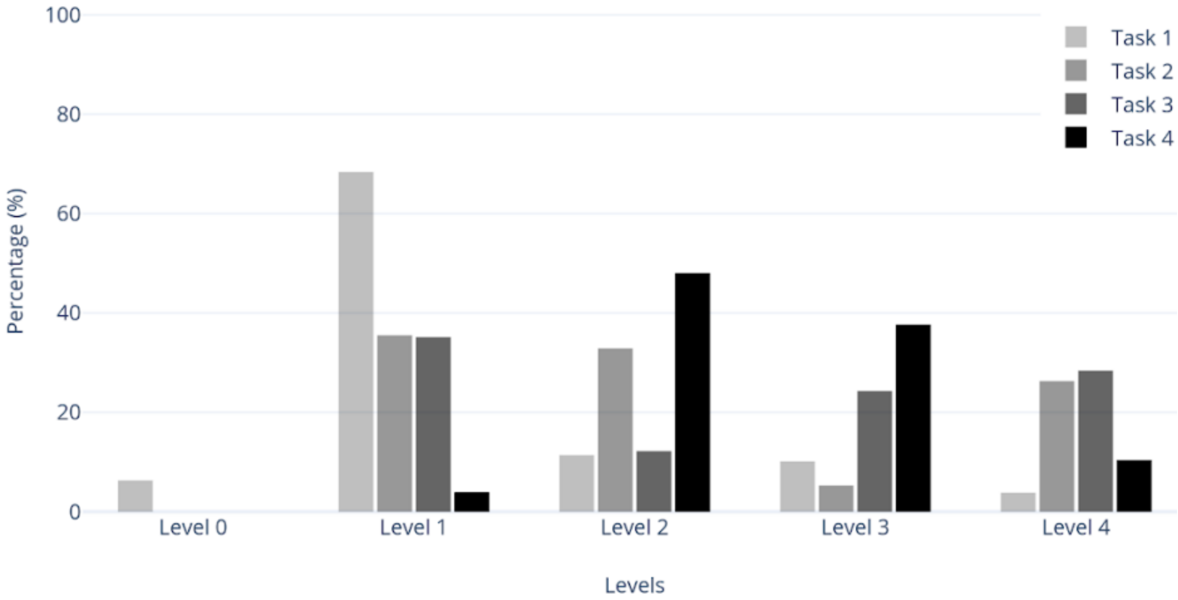

Figure 4.3. Distribution of scientific argumentation skill levels by task type.

As can be observed in Figure 4.3, the task with the highest number of Level 1 students is Task 1, which has a physical science topic. Besides, none of the tasks except Task 1 has students at Level 0. In Task 4, which is an SSI topic, while the number of students with Level 1 is the lowest, the number of students with Level 2 and Level 3 in this activity has the highest frequency compared to other tasks. Moreover, the task types with the highest number of students reaching the highest level of Level 4 are Task 3 on the life science domain with 21 students and Task 2 on an earth and space science topic with 20 students.

In the first three tasks, students predominantly achieved Level 1 performance, whereas for task 4, they mainly demonstrated Level 2 performance. As an example, the responses of the student (G6S25) whose argumentation skill levels showed the same pattern as the highest frequency for all tasks are given in Table 4.9.

Table 4.9. Scientific argumentation levels and excerpts of student G6S25.

Task	Excerpts	Level
Task 1	*"The fastest vehicle should be light and pulled fast* (claim). *I would disprove their claims by ... with experiments. ..."*	Level 1

Table 4.9. Scientific argumentation levels and excerpts of student G6S25 (cont.).

Task	Excerpts	Level
Task 2	*"I think model B is better because the Moon is formed when a large celestial body collides with the Earth* (claim). *Evidence, people support it. If the Moon revolved around Sun, it wouldn't suddenly be pulled to Earth's gravity* (counterargument)*."*	Level 1
Task 3	*"I think it will not go extinct* (claim) *as evidence 3,4,5,6 are supporting. If they were in danger of extinction they would not be hunted. The counter idea would be that anchovies are endangered* (counterclaim). *Anchovies would not be hunted if they were extinct."*	Level 1
Task 4	*"I wouldn't allow wind power plants* (claim). *The text given above supports my idea. I think people who live in the area will suffer, but those living in the outer area will be fine* (evidence)*."*	Level 2

When the student's performance in each task is analyzed, it is seen that the task in which the student can express himself the weakest is physical science. In Task 2, a topic of earth and space science, and in Task 3, a life science topic, his level is observed to be low because he cannot construct evidence in both tasks. Finally, in Task 4, which is based on a socioscientific issue, he could present claims and evidence in a simple way using more casual statements. As another example for students' performance in scientific argumentation across the four tasks, a student labeled as G7S4 is selected due to the wide variation of the skill levels in each task. The students' responses, coded components noted in the quotes and determined levels for scientific argumentation skills are given in Table 4.10.

Table 4.10. Scientific argumentation levels and excerpts of student coded G7S4.

Task	Excerpts	Level
Task 1	*"Since the engine of the car will be heavy, I can make the car go faster by using light, less material while designing the car* (claim). *If the materials of the car were of good quality and were made stronger, he would offer a counter idea that it would go faster*. (counterclaim). *"*	Level 1

Table 4.10. Scientific argumentation levels and excerpts of student coded G7S4 (cont.).

Task	Excerpts	Level
Task 2	*"I think Model A is better because, in my opinion, Model A suits me better* (claim) *and I chose Evidence 1* (identifying evidence). *Because if it collided with the Earth* (counterclaim), *the water and living things on our Earth would pass through, and the Moon would have trees, oxygen and a habitable environment. The Moon would be more developed. If there had been a collision with the Earth, there would have been a visible trace left on the Earth* (rebuttal)*."*	Level 1
Task 3	*"I think the anchovy fish species is not endangered in the Black Sea yet* (claim)*. It is forbidden to catch immature anchovies and in recent years, it has been observed that young anchovy groups have increased due to temperatures* (evidence)*. In this way, there is no problem of anchovy depletion* (warrant)*. The result of increased hunting and unconscious hunting may be the end of the anchovy species* (counterargument)*. The increase in anchovies is directly proportional to the increase in fishing. While one increases, the other also increases so that it does not run out* (rebuttal)*."*	Level 4
Task 4	*"Yes, I would allow wind power plants* (claim)*. Wind energy is a clean and renewable energy source with no air pollution and no emissions of greenhouse gases. It is an economical energy source as there are no fuel costs and operating costs are lower* (evidence)*. Wind power plants are a sustainable energy and Green Energy because they produce energy without the use of fossil fuels and are beneficial to the environment* (warrant)*. … They would ask this: what would happen to the animals and noise pollution if there were no more settlements?* (counterargument)*"*	Level 3

As can be seen above, it is visible that the student can make a claim reflecting his/her own opinion in the activity on the topic of physics, but he/she cannot provide evidence to support it. Although he/she can write a counterclaim about what another opposing view might be, he/she cannot provide evidence and warrant, so his/her skill level is determined as Level 1. In Task 2, which is an earth and space science topic, the student could not provide any scientific evidence even though he/she could present various elements about the theory he/she chose, and therefore his/her skill level was assessed as Level 1. When these first two levels are compared, it is clear that the student exhibited more components in the second task. In addition, in Task 3, which involves a life science topic, the student's responses coded as claim, evidence, warrant, counterargument and rebuttal were expressed quite explicitly, which enabled the student to reach the highest skill level, Level 4. Finally, in Task 4, which requires scientific argumentation about an SSI topic, it is found that the student was able to successfully construct all elements except rebuttal and as a result, his/her level was determined as Level 3.

4.3. Nonlinear Pathways in and through the Levels

When the skill levels of the students and their achievement of the subskills required by these levels were analyzed, non-linear patterns were encountered. To be more precise, it was observed that a student might jump some steps while progressing in the Identification, Construction and Critique dimensions. An example of this situation is when a student can do the higher level sub-skill at Level 5 but cannot yet express some specific precursors at Level 4. In Table 4.11 below, excerpts from the answers of two students who exemplify this situation and the items coded from the responses are provided.

Table 4.11. Excerpts from students who showed nonlinear progression.

Student	Excerpts
G5S23	*"My car is the fastest as it has medium weight, it's pulled by many ropes* (claim). *One person may say that mine is faster as it's lighter* (counterclaim). *I would say that it can't be, as when it's light, it goes the other way and slows down* (rebuttal).*" "Anchovies are running out as they are consumed* (claim). *Oil pollutes the sea, and the living things die* (evidence and warrant).*" "I think model A is better, it says it orbits the Sun freely. A planet can pull some of the objects near it and orbit around it* (claim). *If the stones collided with each other* (counterclaim)*, there would be chaos on Earth and planets. One of them must hit the other planets but it is not happening* (rebuttal).*"*

Table 4.11. Excerpts from students who showed nonlinear progression (cont.).

Student	Excerpts
G6S16	*"Strong motor and light weight make my car go faster* (claim). *... He/she would say that heavily loaded cars go faster* (counterclaim). *I would reply that a heavily loaded car starts its motion much more slowly than a light car* (rebuttal)*." "Yes, I would allow wind power plants* (claim). *... more efficient electricity is produced by wind turbines* (evidence). *"*

As presented in Table 4.11, when the answers of the student labelled G5S23 are examined, it is noticed that he/she successfully performed the higher level sub-skill of constructing rebuttal, but he/she did not address the counterargument element, which requires relatively lower level skills. Similarly, in the responses of the student coded G6S16, while the rebuttal component, which is considered to be at a higher level, was identified, a statement about the constructing warrant and constructing counterargument subskills could not be detected.

Another nonlinear path case is that as the age of the students increase, i.e. from Grade 5 to Grade 7, low levels can be encountered despite the increase in grade level. For example, Grade 7 students may be at low levels even though they are the oldest. Looking at the data, it was observed that the number of Grade 7 students at Level 1 and Level 2 (11 students) was higher than the number of Grade 5 and Grade 6 students individually (9 and 6 respectively). Another example, there are 10 Grade 5 students and 16 Grade 6 students at Level 4, whereas there are only 9 students at such a highly skilled level.

5. DISCUSSION

The purpose of the study is to map the progression of middle school students' scientific argumentation skills and to explore the level of sophistication of argumentation skills in different science domains. The following research questions were adopted to guide the study:

(i) How does the complexity of middle school students’ argumentation change across Grade 5 to Grade 7?

(ii) How does the complexity of middle school students’ argumentation change in different scientific contexts in each grade level?

Qualitative data was obtained in the form of written tasks and semi-structured interviews from Grade 5 (27 students), Grade 6 (26 students), and Grade 7 (27 students). Hence, in alignment with the objectives of this cross-sectional study, a basic qualitative research study approach was employed as methodology (Merriam, 2009). The data was analyzed using a constant comparative approach that involved a systematic process of comparing pieces of data, looking for similar patterns as coding progress. (Charmaz, 2014). At the end of the analysis, a relationship was observed between the 3 main dimensions and the 13 subskills under these dimensions in terms of complexity as shown in Figure 5.1.

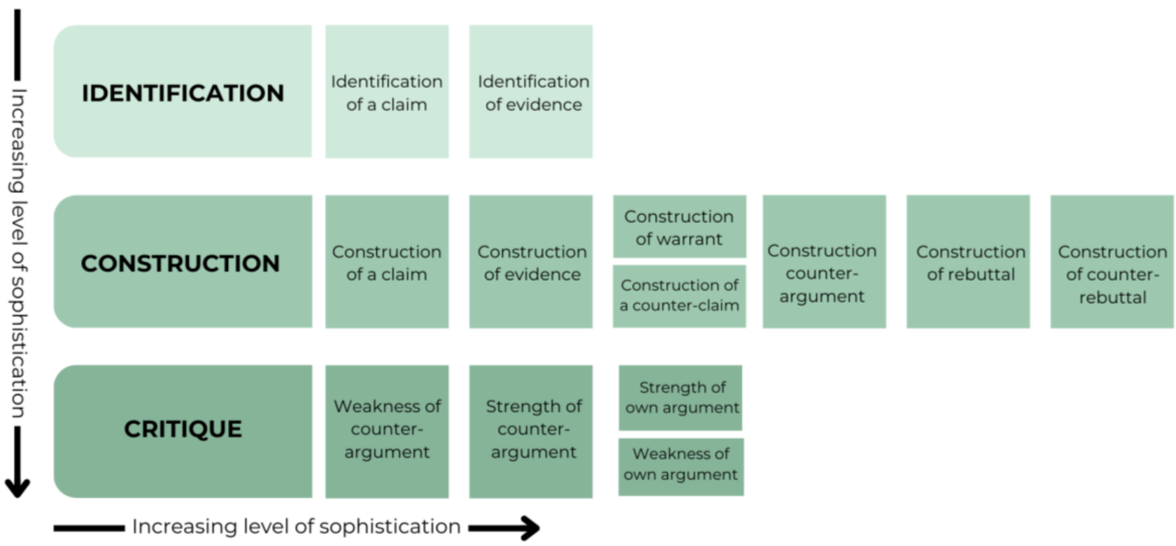

Figure 5.1. Dimensions and components in scientific argumentation learning progression.

Initially, in Figure 5.1, the hierarchy of subskills in terms of complexity, which emerged as a result of the analysis of the data obtained from the participants in this study, is shown in the learning progression. In this section, it is aimed to make a comparison with the progress in similar studies in the literature and to give an insight to explain the reasons.

In this study, the easiest subskill for the students was to identify claims and evidence. Then it was quite easy for the participants of the present study to construct a claim. However, it was observed that they had some difficulty in expressing the scientific evidence supporting their claims. Similar to this hierarchical progression, several studies expressed that *claim* is the most frequent element to be generated by the participants (Chin and Osborne, 2010) and constructing a piece of *evidence* that supports the claim follow this trend (Evagorou and Osborne, 2013; Karamanlı, 2019; Çalışkan, 2020). However, there are also some studies that the frequency of evidence elements suggested by students were higher than their claims (Choi et al., 2014; Wang et al., 2021). This difference and the high number of evidence may stem from the data set given in the data collection tool.

Moreover, this study found that it is more difficult for the participants to explain how their evidence supported their claims, namely constructing *warrants*. Several studies also declared that the least frequent component among the three mentioned argumentation elements (claim, evidence, warrant) is warrant (Choi et al., 2014; Wang et al., 2021;). Evagorou and Osborne (2013) also found in their research that the warrants formed by the students were very low in terms of numbers.

For students in the current study, making the connection and maintaining reasoning between the claim and evidence was the equivalent of presenting a simple counterclaim. In contrast, according to the research carried out by Choi and her colleagues (2014), constructing a counterclaim is a distinctly more demanding skill than constructing a warrant. This difference may be due to the nature of the given task, that is, the level of difficulty, or items that do not prepare the ground for the formation of that component.

Furthermore, in this study it was observed that fewer students stated *counterarguments* which are more complex versions of counterclaims that include strong reasoning links. Following the expression of counterarguments, one of the most difficult components for students to construct was *rebuttal*. Participants had difficulty in constructing logical and scientific statements to refute the counterargument. Similar studies concerning scientific argumentation mentioned proving rebuttal as the topmost component to be achieved by the participants (Chin and Osborne, 2010; Choi et al., 2014). In these studies, it was claimed that a limited number of students could develop rebuttals that are a challenge against a counterargument (Karamanlı, 2019) and almost no rebuttal was found to be explored (Evagorou and Osborne, 2013). However, in their research, Felton and Kuhn (2001) found that it is more difficult for students to form a counterargument than it is to critique a counterargument, namely a rebuttal.

Additionally, in the present study, it was also observed that students were able to criticize the strengths and weaknesses of the opposing argument. However, they did not show the same skill level in criticizing the strengths and weaknesses of their own arguments. In their study, Chin and Osborne (2010) also stated that the most challenging element for students to perform was “self-rebuttal” that was explained as finding weakness in one’s own argument. Finally, in our study the least identified and counted component in the students' responses was constructing a counterrebuttal in the Construction dimension. General levels and their indicators were given in detail in Chapter 3 (see Table 3.7).

The two most closely related studies with the current study are Osborne et al.'s (2016) learning progression for scientific argumentation with Grade 8 and Grade 10 students, the first systematic example, and Zhang and Browne's (2022) work on learning progression for science education with high school students, which contributed to the former study. When the results of these two studies are analyzed in more detail with a view to comparing them with the results of the present study, it is clear that there are certain differences. First of all, the learning progression proposed by Osborne et al. (2016) has two main dimensions, Construction and Critique. In their study, they claimed that identification of a claim is more challenging than construction of a claim and the same goes for the identification of an evidence and providing evidence. In contrast, the current study has three dimensions, Identification, Construction and Critique, on a hierarchy that the subskills under the Identification dimension are less demanding for students than the subskills under the Construction dimension. Thus, in the current study, it is suggested that identifying a claim is easier for students than constructing a claim, as well as identifying a piece of evidence is easier than generating evidence. The other components in the current study also change drastically as compared to the Osborne and his colleagues' research study, yet there is a significant commonality that in both learning progression levels, the tasks that involve critique components were much more challenging for students to handle.

Zhang and Browne (2022) had also three dimensions, Identification, Evaluation and Production, in their research on a learning progression for scientific argumentation. However, these dimensions were not sophistically ordered among themselves and formed the progression levels accordingly. Instead, there were components of identification, evaluation and production in both Level 1 and Level 2 in a mixed way, without a prerequisite. Only for Level 3, the topmost level there were only Production components which are limited to some numbers. In the following, Table 5.1 presents a comparison of these two learning progression levels and the levels based on the results obtained from this study.

Table 5.1. Comparison with other learning progression studies for scientific argumentation.

Study	Sublevels/Levels in the Learning Progression for Scientific Argumentation											
Osborne et. al. (2016)	0a construct claim	0b identify claim	0c provide evidence	0d identify evidence	1a construct reason	1b identify reason	1c construct an argument	1d provide rebuttal	2a provide a counter-critique	2b strong side of own argument	2c provide weak and strong sides	2d construct a new argument
Zhang and Browne (2022)	1	1	1-2	2	1-3	2	1-3	1-2	2-3	-	-	-
This study	1	1	1	1	2	-	2	4	3-4-5	4-5	6	-

5.1. Discussion of the First Research Question

This cross-sectional study prevailed the progression of scientific argumentation skills moving from Grade 5 to Grade 7. In this section, the general achievement tendencies of the students at each grade level will be compared and discussed with the skills of the students at the same level in the related research literature. Thus, it will be discussed how students' argumentation skills develop in terms of sophistication as they get more mature.

In the current study, the distribution of the scientific argumentation levels of the Grade 5 students was found to be quite wide. It was observed that all the students were able to construct a claim and appropriate evidence, and the majority of them were able to establish a logical connection between these two components using a warrant. More than half of the students at this grade level were able to construct counterclaims and counterarguments. The majority of students had great difficulty in constructing rebuttals that could refute the counterarguments. Only two of the students who were able to perform this skill were able to form a counterrebuttal, which is considered as the highest skill. Grade 5 students were found to be at an intermediate level in criticizing the strengths and weaknesses of counterarguments, but they could not demonstrate any success when it came to critiquing the strengths and weaknesses of their own arguments. In parallel with the findings of this study, Namdar and Demir’s (2016) investigation on scientific argumentation with Grade 5 students revealed that students were generally able to form claim, evidence, counterclaim and counterargument, but the rebuttal element was very rarely found in students' responses. In another study focusing on different elements of scientific argumentation, it was observed that in the argumentation components presented by students in an online discussion, evidence was the most common element and students were able to actively critique and negotiate by challenging each other (Choi et al., 2014). This difference might have to do with the learning environment, because these students worked online with their peers in groups while developing arguments.

When the Grade 6 students’ scientific argumentation skills were analyzed in this study, it was seen that their level of argumentation skills are mostly accumulated at Level 4 where they can construct claims, evidence, warrants, counterclaims, counterarguments, and rebuttals. Only a limited number of the students could construct counterrebuttals and critique the weakness and strength of their own arguments and counterarguments. Similar research findings also asserted that all the Grade 6 students could easily generate claims, evidence, and warrants, whereas only a few of them could not construct counterarguments and struggled to refute opposing ideas, namely rebuttals (Karamanlı, 2019). In a different research study, quite dissimilar outcomes were reported, such that students easily generated claims and warrants, then the students experienced equal difficulty in terms of creating counterargument and rebuttal, whereas forming and presenting evidence is by far and distinctly the most difficult sub-skill (Lin and Mintzes, 2010).

The Grade 7 students, the oldest and the most mature student group in this study, were the only group that could reach the highest level of scientific argumentation skills (Level 6). However, when the distribution of general student argumentation levels is considered, a large proportion of Grade 7 students are found in Level 2 and 4. This means that almost half of the students had difficulty in generating a counterargument and almost as many students had difficulty in creating a counterrebuttal, and therefore these students could not move up to the next argumentation level. Additionally, there was a limited number of Grade 7 students who had the ability to criticize the weakness of their own arguments. However, the fact that this skill can only be attained by Grade 7 students while no Grade 5 and 6 students could perform this subskill should be emphasized.

In a study of Grade 7 students' scientific argumentation skills, it was found that the majority of students at this level were successful in constructing claim, evidence, and warrant, but they experienced considerable difficulty in constructing rebuttal (Çapkınoğlu et al., 2019). Another study that investigated the scientific argumentation skills of Grade 7 students presented that students could perform claims, evidence, warrants, and counterclaims, yet no trace of rebuttal has been found before and after the intervention (Gülseven, 2020). In another study, it was identified that almost all the Grade 7 students were competent in generating evidence, and almost half of them made claims that supported their claims, and very few of these students constructed warrants (Wang et al., 2021). In another intervention study that examined Grade 7 students' scientific argumentation processes from a different perspective, it was observed that students were at a satisfactory level in persuasion, but they did not show improvement and had difficulty in challenging the argument (Canöz, 2020).

The results of that study is related to the findings of the current study, which is the difficulty of students in creating counterargument and counterrebuttal.

In general, the frequency of Grade 5 to 7 students in scientific argumentation skill levels was analyzed, and how these levels change with age was examined. The answers to the first research question showed a clear sophistication in offering scientific argumentation from Grade 5 to Grade 6. The main skill that caused this difference was found to be rebuttal, which Grade 5 students had difficulty in generating this particular argumentation element. However, even though the Grade 7 group was the only one among the others that reached the highest argumentation level, they demonstrated low skills compared to Grade 6 students in constructing arguments in science. The main reason for this finding had to do with Grade 7 students' problem with creating counterarguments.

No previous studies have examined the learning progression for scientific argumentation at these grade levels, but several studies have reported to examine scientific argumentation skills that develop with age at the middle school level. In a study in which the scientific argumentation skills of Grade 7, 8 and 9 students were examined, it was reported that Grade 7 students developed a better performance when compared with the other two grade levels (Chin and Osborne, 2010). It was observed that Grade 7 was the class with the highest percentage reaching the highest skill level, level 4. In addition, although they were older, Grade 9 students were clustered at Level 2 as a skill level, meaning that they could find it hard to generate rebuttals. The reason for this situation may have stemmed from the ethnic diversity of the students as a consequence of being located in Singapore and England (Chin and Osborne, 2010). In contrast to the present study and the one with similar results, Wang et al. (2021) conducted a study with Grade 7, 8 and 9 students and found that some argumentation skills of these students increased gradually as the students' grade level increased. Grade 9 students, who were the oldest in age, generated the highest number of claims, evidence, and warrants while Grade 8 students followed them. As the youngest grade, Grade 7 students, constructed the least number of claims, evidence, and warrants among the three groups.

Grade 6 students showed more sophisticated scientific argumentation skills than Grade 7 students in terms of creating counterarguments and rebuttals in the current study. The underlying reason for this variation may have stemmed from the difference in the cognitive abilities of students (Means and Voss, 1996). Moreover, as stated in the context of the present study before, the academic achievement and class participation performances of the Grade 6 students in the science course are higher than the Grade 7 students. In conjunction with this, studies have shown that students with higher ability in general are more likely to engage in argumentation better (Zohar and Dori, 2003). In favor of this, another research suggests that the grade level of the students in school cannot make sure that the reasoning of the students also increases and that the factor that predicts the judgment capabilities of the students is the abilities that they have (Kuhn, 1991; Perkins, 1993).

Moreover, the low performance of Grade 7 students compared to Grade 6 students can be attributed to the distance education system that was switched to in the 2019-2020 academic year due to the Covid-19 virus. Hence, the Grade 7 students in this study completed their 5th and 6th grade education, which were the first 2 years of middle school, through distance education meanwhile Grade 6 students completed their 4th and 5th grades by distance learning at this time. The science curriculum of the Ministry of National Education aims to develop knowledge and skills in the subjects of force and motion, properties of the Moon, biodiversity and renewable energy for the 5th and 6th grade levels. The research has revealed that the distance education practices carried out during the pandemic period led to student disengagement and influenced learning, teaching, and assessment practices negatively in the science course (Chadwick and McLoughlin, 2021). Accordingly, Grade 7 students may have shown a lack of comprehension of these topics and application of the skills they were supposed to receive during distance education.

5.2. Discussion of the Second Research Question

In order to answer the second research question, the change in all students' argumentation skills in terms of complexity in different science contexts was explored. Findings from previous studies also agree that argumentation is context specific (Means and Voss, 1996). According to the results, the first task, which is about force and motion concepts under the Physical Science domain, was the most challenging task for students to generate scientific argumentation. It is the only task where the students could not even generate simple claims, and more than half of the students could construct only a claim while a limited number of students could reach to the highest level, Level 4. About this task, it can be said that students were unable to produce evidence or warrant about a physical science concept. Following the physical science task, a dichotomy about theories for the Moon formation under the Earth and Space science context was the second hardest argumentation task for students to accomplish. Scientific argumentation skill levels of the students were clustered around Level 1 and Level 2, meaning that students could mostly generate claim, evidence or warrant in this task.

In addition, the task in which students were able to reach relatively higher skill levels in argumentation was a socio-scientific topic discussing the positive and negative aspects of wind power turbines. The prominent finding of this task was that almost all the students were able to present evidence related to the topic. Finally, the task that students found easier to construct argumentation components than the other tasks was a Life Science topic on biodiversity and extinction. Although, in this task, the number of students who are on Level 1 was higher than the task on SSI, more students reached Level 4, and this was the task that the students quite frequently generated rebuttals, a difficult subskill. It is important to point out that the nature of the tasks might have affected students' responses since the number of the items as well as the type of the questions varied to some extent. In the current study, even though there were multiple items, images and questions to scaffold students' answers in the physical, earth and space, and life science themed tasks, the task on the socioscientific issue contained the least number of items overall. This situation may have influenced the participants negatively and prevented participants from giving complex and clear responses in the SSI context.

Some research studies suggested that students found it more difficult to construct elements of argumentation in a scientific context than in an SSI context, because students need very specific information when presenting elements related to a purely scientific topic (Osborne et al., 2004). The students' low level of argumentation skills in physical science and earth and space science in the current study empirically confirmed this claim. Other studies also supported this idea that SSI topics motivate participants to engage in the argumentation process due to its relevance to everyday life and thus such topics are found to be a more meaningful context for students to engage in argumentation actively (Zohar and Nemet, 2002; Lin and Mintzes, 2010). The reason that the students in this study performed better in the Life Science task may have to do with the topic about anchovy fish which was already familiar for students from their real life.

However, another study that focused on comparing students' argumentation performances in the purely science and socioscientific contexts asserted that according to overall scores of the students, there was no significant difference between these two contexts (He et al., 2019). In fact, they revealed a new perspective that students are more likely to produce arguments in a SSI topic if they have firsthand experiences with the given context (He et al., 2019). Thus, it seems that epistemic cognitions of the participants also influence students' argumentation practices. In contrary to the findings of other studies (Zohar and Nemet, 2002; Osborne et al., 2004; Lin and Mintzes, 2010; He et al., 2019), in a study involving the argumentation scores of 11-14 year old students, the topics on which the participants had the highest to lowest scores on average respectively were the concept of light, a physical science topic, followed by an earth and space science topic dealing with weather, and an SSI topic comparing wind turbine and nuclear energy (Evagorou et al., 2023).

Cognitive demand also might have resulted in a difference in the students' constructing and critiquing processes in pure science and socioscientific contexts. In other words, pure science concepts usually require higher intrinsic and extraneous cognitive loads due to their complex and abstract nature, while socioscientific issue themed tasks support students' existing mental frameworks due to familiarity of the concepts with real life issues, thus diminishing the cognitive load needed for performing argumentation (Sweller, 2011; Osborne et al., 2016;).

Finally, even though the argumentation tasks included all the data needed to complete the tasks, it is important to examine the potential role of the prior content knowledge of the participants on their responses given in the argumentation tasks. For the life science task, Grade 5, 6 and 7 students were already familiar with the concepts of biodiversity and extinction taken place in the curriculum. That might be one of the reasons for students' high level argumentation skills in the life science task. Other studies also showed that students tend to have higher level skills for scientific argumentation when the concepts taught in the curriculum (Mason and Scirica, 2006; Evagorou et al., 2023). However, for the physical science task, Grade 5 and Grade 6 students had the fundamental knowledge about force and motion, whereas Grade 7 students were taught about the topic in detail in the science curriculum, yet their argumentation performances were still quite poor. Thus, this may imply that this context is the most challenging one for the participants. For the earth and space science task, the science curriculum did not contain an objective concerning the theories on the formation of the Moon, thus none of the students were taught about this topic formally. It can be explained with the analogy that even a scientist cannot produce high level arguments when he or she is encountered with an unfamiliar situation (von Aufschnaiter et al., 2008).

5.3. Implications

The findings of the present study provide insights into both science education literature and the instruction and assessment of science concepts. First of all, the study presented here serves the most detailed learning progression for scientific argumentation skills in the literature. The learning progression with 13 subskills under 3 general dimensions can act as a guide for teachers and researchers for tracking and assessing their students’ written or oral responses when they engage in scientific argumentation. In addition to its important feature as a progress path for the development of scientific argumentation skill, curriculum developers can adopt subskills for appropriate grade levels in terms of sophistication and embed in the curriculum in a specific way to be performed in the classroom environment. For instance, a teacher who aims to support her/his students to perform argumentation from easy to difficult in the first lesson uses claim, evidence, and warrant. In order to move students who have mastered these skills to the next level, he/she may gradually introduce more challenging skills such as counterclaim, counterargument, and rebuttal. Thus, zone of proximal development can be provided with scaffolding.

Furthermore, according to the results obtained from this study, research and implications can be carried out to improve the skills of generating rebuttal, counterrebuttal and criticizing the strengths and weaknesses of one's own argument, which are considered to be the highest level that students have difficulty in accomplishing.

5.4. Limitations of the Study

While conducting this study, there may be some limitations in data collection, data analysis, interpretation and discussion of the analyzed data or in general the methodology of the study. Firstly, the current study adopted a cross-sectional design that is appropriate for short term studies. Due to this method, data as the responses from the participants were collected in a short period of time. However, a longitudinal study may have included an intervention and tracked the participants' long term development.

Additionally, this study provided a learning progression model for scientific argumentation that contains multiple fine-grained subskills within the six general levels. Due to the nature of the adapted tasks, some of the tasks did not include items or questions that allowed all these subskills to be investigated or some subskills are examined in multiple tasks. Finally, the participants of this study were limited to a total 80 middle school students from Grade 5, 6 and 7 in a private school in Istanbul in the 2022-2023 academic year.

5.5. Suggestions for Further Research

By obtaining data from students in the same grade level participants as in the present study, Grade 6, 7 and 8, their levels of scientific argumentation skill can be compared with the current study's results. Additionally, another comparison can be made by conducting a study to assess the scientific argumentation skills of students from different backgrounds and evaluating them according to the argumentation levels of the current study. Finally, the subskills of older age groups for generating rebuttals, counter rebuttals and critiquing the weakness and strength of their own arguments could be investigated since the mentioned components are the most challenging ones for the participants of the current study. This may have caused a scarcity for investigating these subskills in a better way.

Instruction designers can create lesson plans to help teachers gradually improve their students' scientific argumentation skills starting from the lowest level skill, i.e. identifying claims and evidence, to the highest based on the data collected from this study.

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APPENDIX A: PERMISSION LETTERS

This section provides the permission letters given by Natural Sciences and Engineering Fields Institutional Review Board for Research with Human Subjects (FMİNAREK) and Istanbul Provincial Directorate of National Education (MEB), and the consent form for parents.

T.C.
İSTANBUL VALİLİĞİ
İl Millî Eğitim Müdürlüğü

Sayı : E-59090411-20-74705984 18/04/2023
Konu : Anket ve Araştırma İzni (Beyza Nur ÇELİK)

VALİLİK MAKAMINA

İlgi : a) Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün 21.01.2020 tarihli ve 2020/2 sayılı genelgesi.
b) Boğaziçi Üniversitesinin 20.02.2023 tarihli ve E-37922335-605.01-114080 sayılı yazısı.
c) Müdürlüğümüz Araştırma ve Anket Komisyonunun 06.04.2023 tarihli tutanağı.

Araştırma Konusu	: Ortaokul Öğrencilerinin Bilimsel Argümantasyon Becerilerinin Gelişiminin İncelenmesi
Araştırma Türü	: Anket
Araştırma Yeri	: Beykoz Nun Okulları
Araştırma Kişiler	: Özel Ortaokul Öğrencileri
Araştırmanın Süresi	: 2022 - 2023 Eğitim - Öğretim Yılı

Yukarıda bilgileri verilen araştırmanın; 6698 sayılı Kişisel Verilerin Korunması Kanununa aykırı olarak kişisel veri istenmemesi, öğrenci velilerinden açık rıza onayı alınması, bir örneği Müdürlüğümüzde muhafaza edilen mühürlü ve imzalı veri toplama araçlarının kurumlarımıza araştırmacı tarafından ulaştırılarak uygulanması, katılımcıların gönüllülük esasına göre seçilmesi, araştırma sonuç raporunun kamuoyuyla paylaşılmaması ve araştırma bittikten sonra 2 (iki) hafta içerisinde Müdürlüğümüze gönderilmesi, okul idarelerinin denetim, gözetim ve sorumluluğunda, eğitim ve öğretimi aksatmayacak şekilde, ilgi (a) genelge esasları dâhilinde uygulanması kaydıyla Müdürlüğümüzce uygun görülmektedir.

Makamınızca da uygun görüldüğü takdirde olurlarınıza arz ederim.

Levent YAZICI
İl Millî Eğitim Müdürü

OLUR
Dr. Hasan Hüseyin CAN
Vali a.
Vali Yardımcısı

Ek:
1- İlgi (b) Yazı ve Ekleri (11 Sayfa)
2- İlgi (c) Tutanak (1 Sayfa)

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İnternet Adresi : http://istanbul.meb.gov. tr/

Evrak Tarih ve Sayısı: 17.11.2022-98141

T.C.
BOĞAZİÇİ ÜNİVERSİTESİ REKTÖRLÜĞÜ
Fen Bilimleri ve Mühendislik Alanları İnsan Araştırmaları Etik Kurulu (FMİNAREK)

Sayı : E-84391427-050.01.04-98141 17.11.2022
Konu : 2022/15 Kayıt no'lu başvurunuz hakkında

Sayın Prof. Dr. Emine ADADAN
Matematik ve Fen Bilimleri Eğitimi Bölüm Başkanlığı - Öğretim Üyesi

"Ortaokul Öğrencilerinin Bilimsel Argümantasyon Becerilerinin Gelişiminin İncelenmesi (Examining Middle School Students' Learning Progression for Scientific Argumentation)" başlıklı projeniz ile Boğaziçi Üniversitesi Fen Bilimleri ve Mühendislik Alanları İnsan Araştırmaları Etik Kurulu (FMİNAREK)'e yaptığınız 2022/15 kayıt numaralı başvuru 07.11.2022 tarihli ve 2022/11 No.lu kurul toplantısında incelenerek etik onay verilmesi uygun bulunmuştur.

Bu karar tüm üyelerin toplantıya on-line olarak katılımıyla ve oybirliği ile alınmıştır. Onay mektubu tüm üyeler adına Komisyon Başkanı tarafından e-imzalanmıştır.

Saygılarımızla bilginize sunarız.

Prof. Dr. Tınaz EKİM AŞICI
Başkan

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BOĞAZİÇİ ÜNİVERSİTESİ
FEN BİLİMLERİ VE MÜHENDİSLİK ALANLARI
İNSAN ARAŞTIRMALARI ETİK KURULU
KATILIMCI BİLGİ ve ONAM FORMU

Araştırmanın adı: Ortaokul Öğrencilerinin Bilimsel Argümantasyon Becerilerinin Gelişiminin İncelenmesi (Examining Middle School Students' Learning Progression for Scientific Argumentation)

Proje Yürütücüsü/Araştırmacının adı: Prof. Dr. Emine Adadan / Beyza Nur Çelik

Adresi: Boğaziçi Üniversitesi, Eğitim Fakültesi, Matematik ve Fen Bilimleri Eğitimi Bölümü, Bebek, İstanbul, 34342

E-mail adresi: emine.adadan@boun.edu.tr, beyza.celik@boun.edu.tr

Telefonu: +90-212-3597371

Sayın Veli,

Yukarıda adı verilen bu araştırma çalışması Boğaziçi Üniversitesi, Eğitim Fakültesi, Matematik ve Fen Bilimleri Eğitimi bölümünden Prof. Dr. Emine Adadan danışmanlığında aynı bölümde yüksek lisans öğrencisi olan Beyza Nur Çelik ile yürütülmektedir. Aşağıda verilen bilgilendirme metnini okuduktan sonra velisi olduğunuz öğrencinin araştırmada yer almasını onaylıyorsanız lütfen formda belirtilen kısımları doldurup öğrencimizle bize ulaştırınız.

Araştırmanın amacı farklı yaş gruplarındaki öğrencilerin fen bilimleri dersi kapsamında gösterdikleri argümantasyon becerilerini incelemektir. Bilimsel okuryazarlığın önemli bir bileşeni olan argümantasyon bir konu hakkında düşünceleri ileri sürme, kanıtlarla destekleme, muhakeme yapma, eleştirme ve karşıt argümanlar geliştirme gibi öğeleri içeren bilimsel bir pratiktir. Velisi olduğunuz öğrencinin araştırmaya katılmasını onayladığınız takdirde öğrencimiz açık uçlu sorular içeren argümantasyon anket formunu tamamlayacaktır. Ayrıca, bazı öğrencilerimizle ayrıntılı açıklamalar getirmesi amacıyla yaklaşık 15 dakika sürecek bireysel görüşmeler gerçekleştirilerek onayınız dahilinde ses kaydı alınacaktır.

Bu çalışma tamamen bilimsel amaçlarla gerçekleştirilecektir. Araştırmanın herhangi bir kısmı öğrenciler için risk oluşturmamaktadır. Çalışmaya katılım gönüllülüğe dayalı olup öğrenciler çalışmadan istedikleri zaman çekilebilir ve bu hiçbir olumsuz bir duruma neden olmayacaktır. Katılımcının çalışmanın herhangi bir anında çekilmesi durumunda o ana kadar toplanan yazılı veya dijital veriler kullanılmayacak olup kalıcı olarak yok edilecektir. Ayrıca katılımcı bilgilerinin gizliliği esastır, bu nedenle her katılımcı için bir rumuz kullanılacaktır. Katılımcının kişisel bilgileri (isim vb.) hiçbir şekilde üçüncü kişi ve kurumlar ile paylaşılmayacak ve bilimsel yayınlarda kullanılmayacaktır. Çalışmaya katılım öğrencilerin notlarını hiçbir şekilde etkilemeyecektir. Ayrıca, sizden ücret talep edilmeyecek ve tarafınıza herhangi bir ödeme yapılmayacaktır.

Bu araştırmayla ilgili sorularınız için *Prof. Dr. Emine Adadan*'a ve *Beyza Nur Çelik*'e e-mail veya telefon ile ulaşabilirsiniz. Proje ile ilgili olası şikayetlerinizi Boğaziçi Üniversitesi Fen Bilimleri ve Mühendislik Alanları İnsan Araştırmaları Etik Kurulu'na ait fminarek@boun.edu.tr e-mail adresine iletebilirsiniz.

Ben, ………………………………………… yukarıda verilen bilgilendirme metnini okudum ve velisi bulunduğum ………………………………………. adlı öğrencinin katılması istenen çalışma hakkında bilgi edindim. Velisi olduğum katılımcının çalışmayı istediği zaman ve herhangi bir neden belirtmek zorunda kalmadan bırakabileceğini ve bıraktığı takdirde verilerinin silinerek herhangi bir olumsuzluk ile karşılaşmayacağını biliyorum.

Bu koşullarda söz konusu araştırmaya kendi isteğimle, hiçbir baskı ve zorlama olmaksızın velisi olduğum öğrencinin katılmasını kabul ediyorum. Bu formun bir kopyasını aldım.

Velisi olduğum öğrencinin bu çalışmaya katılmasını onaylıyorum.	
☐ EVET	☐ HAYIR

Araştırma için yapılacak bireysel görüşmeler sırasında ses kaydı alınmasını onaylıyorum.	
☐ EVET	☐ HAYIR

Katılımcı Adı-Soyadı:	İmzası:	Tarih:
Katılımcının Velisinin Adı-Soyadı:	İmzası:	Tarih:
Araştırmacı Adı-Soyadı: Prof. Dr. Emine Adadan	İmzası:	Tarih:
Yüksek Lisans Öğrencisi: Beyza Nur Çelik	İmzası:	Tarih:

APPENDIX B: SCIENTIFIC ARGUMENTATION TASKS

In this section, four argumentation tasks adapted, revised and edited by the researchers from the previous argumentation studies are presented. Each of the four tasks are based on physical science, life science and earth and space science topics as well as a socio-scientific issue. The original versions of the tasks belong to the authors noted down below.

1. Physical Science Topic (McNeill, 2011)

2. Earth and Space Science Topic (Bailey, Girtain, & Lombardi, 2016)

3. Life Science Topic (Palermo, 2017)

4. Socio-scientific Issue (Karamanlı, 2019)

Ad Soyad: **Sınıf:** **Tarih:**

EN GÜÇLÜ ARGÜMANI OLUŞTURABİLİR MİSİNİZ?

Öğrenciler farklı değişkenlerin bir arabanın hızını nasıl etkilediğini test eden bir dizi deneyler yapıyorlar. Deneyler tamamlandıktan sonra öğrencilerden aşağıdaki soruyu cevaplayacakları bir argüman yazmaları isteniyor:

"En hızlı giden bir arabayı nasıl tasarlayabilirsin?"

Bu soruya cevap arayan bir öğrenci olduğunuzu düşünün. Aşağıda verilen seçeneklerden en güçlü argümanı oluşturmanıza yardım edecek olanları yuvarlak içine alınız.

İDDİALAR:

Aşağıdaki iddialardan BİR tanesini seçiniz.

A. Benim arabam en hızlı gider, çünkü onu sağlam bir şekilde yapabilirim.

B. En hafif olan arabayı en büyük kuvvetle çekersem en hızlı giden benim arabam olur.

C. Arabamın hızlı gitmesi belli bir sürede ne kadar mesafe gittiğine bağlıdır.

KANITLAR:

Aşağıdaki kanıtlardan İKİ tanesini seçiniz.

A. Yaptığımız deneyde aynı mesafeyi giden iki arabadan; bir blok ağırlık taşıyan arabanın 1 saniyede, üç blok ağırlık taşıyan arabanın ise 3 saniyede gittiğini ölçtük.

B. Deneyde arabalarımızı dikkatli bir şekilde tasarladık ve gerçekten hızlı gittiler.

C. Bazı araba şirketleri en hafif arabaları üretirler, çünkü bu arabalar daha hızlı gider.

D. Masanın bir ucundan diğer ucuna 1 halatla çektiğimiz araba 7 saniyede giderken, 5 halatla çektiğimiz arabanın 2 saniyede aynı mesafeyi gittiğini gözlemledik.

E. Grup olarak, bir gün deneme yaptığımız arabanın sürekli bozulması dışında, arabamızı tasarlarken ve test ederken çok eğlendik.

F. Deneylerimiz hafif olan arabaların daha hızlı gittiklerini gösterdi.

ARGÜMANIMI DESTEKLEYECEK AÇIKLAMALAR:

Aşağıda bulunan açıklamalardan BİR tanesini seçiniz.

A. Yaptığımız deneyler sonucu elde ettiğimiz veriler bize en hızlı arabayı nasıl yapabileceğimizi gösterdi. Veriler en hafif yükü taşıyan arabaların hızlı gittiğini ve en büyük kuvvetle çekilen arabaların hızlı gittiğini gösterdi. Dolayısıyla arabamızı buna uygun olarak tasarlayıp, yapmalıyız.

B. Ünlü araba şirketlerinin ürettiği ve yarışlarda kullanılan arabaların hafif ve motorlarının güçlü olduğunu biliyoruz. Böylece biz de arabamızı aynı şekilde tasarlamalıyız. Arabamız hafif yüklü olmalı ve büyük kuvvetle çekilmeli.

C. Arabanın hızı, masa boyunca kaç saniyede gittiği ölçülerek bulundu. Daha az blok taşıyan araba daha hafif bir yüke sahipti ve daha hızlı gitti. Birden fazla halat tarafından çekilen araba daha büyük bir kuvvetle çekildi ve daha hızlı hareket etti.

1. Şimdi yukarıda yaptığınız seçimleri ve kendi deneyimlerinizi kullanarak en hızlı giden aracı nasıl tasarlayabileceğinizi açıklayan bilimsel argümanı oluşturunuz.

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2. Bir arkadaşınız sizin fikrinize karşıt bir düşünce sunsaydı bu ne olurdu?

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3. Sizinle aynı fikirde olmayan karşı görüşteki arkadaşınızı ikna etmek için en iyi yanıtınız ne olur?

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4. Arkadaşınızın size cevabı ne olurdu?

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Ad Soyad: **Sınıf:** **Tarih:**

HAMSİ BALIĞI HAKKINDA BİR TARTIŞMA

Son yıllarda Karadeniz'deki hamsi balığının popülasyonu yani topluluğu hakkında çeşitli araştırmalar yapılmaktadır. Araştırmaların amacı Karadeniz'deki hamsi balığının durumunun veya neslinin tehlikede olup olmadığını tespit etmektir. Araştırma sonuçlarından bazıları kanıt kartlarında yazılı olarak verilmiştir.

1. Buna göre Karadeniz'deki hamsi balığının neslinin tükenip tükenmediğine dair bir iddiada bulun.

İDDİA: Bence ____

2. Verilen kanıt kartlarını 2 gruba ayırın: iddianızı desteklemek için uygun olanlar ve iddianızı desteklemek için uygun olmayanlar. Kararınıza göre kanıt numaralarını aşağıdaki tabloya yerleştirin.

UYGUN OLANLAR	UYGUN OLMAYANLAR

3. İddianız için gerekçelerinizi yazın. Başka bir deyişle, kanıtın iddianızla nasıl bağlantılı olduğunu açıklayın.

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4. Senin iddianın tam tersini savunan birinin iddiası ne olurdu?

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5. Karşıt argümanda bir hata bulun. Başka bir deyişle, karşıt argümandaki zayıflık ne olabilir açıklayın.

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6. Karşıt argümanı güçlendirecek kanıtlar var mı?

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7. Bu kanıtlara karşı açıklamaların ne olurdu?

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8. Senin argümanını zayıf veya eksik yap özellikler var mı?

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9. Bunları nasıl savunabilirsin?

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KANIT KARTLARI

Kanıt 1:
Balıkçı teknelerinin sayılarındaki artış ve gelişen teknoloji aşırı avcılıkla birleştiğinde olgun balıkların sayısı oldukça azdır.

Kanıt 2:
Balıkların ölüm nedenleri, yaşlılık, başka canlılar tarafından yenme, salgın hastalıklar, su kirliliği, besin yetersizliği ve avcılıktır.

Kanıt 3:
Aşırı avcılık baskısı altında olan hamsi balığı, Gıda, Tarım ve Hayvancılık Bakanlığı tarafından 1989 yılında avlanabilir boyun 9 cm'ye çıkarılması ile genç hamsi sayısının arttığı ve iyileşmenin olduğu görülmüştür.

Kanıt 4:
Karadeniz, özellikle hamsi olmak üzere denizlerden elde edilen üretimin yaklaşık olarak %76'sını karşılamaktadır.

Kanıt 5:
Yaşanan sıcak hava koşullarının balıklara üreme ve gelişme anlamında pozitif etki yapması sebebiyle genç balık grubunun arttığı görülmüştür.

Kanıt 6:
Hamsi balığı hızlı büyüyen ve yaklaşık 1 yaşında olgunluğa erişen bir balık olmasının yanında büyüme hızı ve büyüme performansı yıllara ve bölgelere göre farklılıklar gösterebilmektedir.

Kanıt 7:
Petrol kirliliği, Karadeniz kıyı ekosistemlerini tehdit etmeye devam etmektedir.

Kanıt 8:
2014-2015 av sezonunda avlanan hamsi sayısının normal değerden daha yüksek, yani av baskısı altında olduğu tespit edilmiştir.

Ad Soyad: **Sınıf:** **Tarih:**

AY'IN OLUŞUMU

Bilim insanları bir şeyleri açıklamak için modellemeler yaparlar.

Aşağıda Ay'ın nasıl oluştuğuna dair yapılan iki tane model ve açıklamaları verilmiştir.

Model A: Ay daha önce Güneş Sistemi'nde dolaşan bir nesneydi ve Dünya'nın çekim etkisine kapılarak çevresinde dolanmaya başlamıştır.

Bu modeli destekleyen bir kişi aşağıdaki argümanı sunuyor:

"Çok eskiden Güneş Sistemi'nde ve Güneş'in etrafında serbest şekilde hareket eden birçok cisim vardı. Bir gezegen yakınındaki cisimlerin bir kısmını çekip kendi yörüngesinde dolandırabilirdi. Bu şekilde Ay Dünya'nın yerçekimiyle yakalandı ve şimdi Dünya'nın etrafında dönüyor."

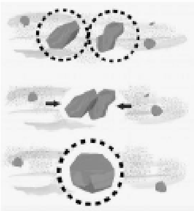
Model B: Ay büyük bir cisim ile Dünya'nın çarpışması sonucunda oluşmuştur. Bu şekilde ikisinden de ayrılan parçacıklar Ay'ı meydana getirmiştir.

Bu modeli destekleyen bir kişi aşağıdaki argümanı sunuyor:

"Çok eskiden Güneş Sistemi'nde ve Güneş'in etrafında serbest şekilde hareket eden birçok cisim vardı. Bu parçacıklar, taşlar ve kayalar birbirleriyle çarpışıyorlardı. Büyük bir cisim Dünya'ya çarptığında bazı parçalar fırlayarak etrafa saçıldı ve Ay'ı oluşturdu."

KANITLAR

Kanıt 1: Kaya yığınları gezegen oluşumları sırasında birleşirler. Toz ve diğer parçacıklar bir merkez etrafındaki yörüngede dolanırken çarpışmaya başlar. Şekil 2 bu çarpışmaları göstermektedir. Bu parçalar çarpışmanın ısısı nedeniyle birleşerek daha büyük parçalar oluşturur. Bu kar tanelerinin bir kartopu yapmak için bir araya gelmesine benziyor. Bu parçalar birleşmeye ve daha da büyük nesneler oluşturmaya devam ederler. Birçok çarpışmadan sonra bir gezegen ve diğer cisimler oluşmuş olur.



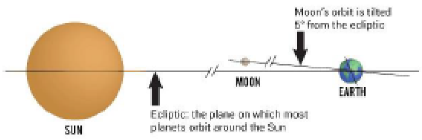
Şekil 1: Credit to Wright Seneres

Kanıt 2: Dünya ve Ay'ın yüzeylerine yakın yerlerdeki maddeler birbirine benzer. Tablo 1 ikisinin yüzeyine yakın maddelerin miktarlarını göstermektedir.

Tablo 1: Dünya ve Ay'ın yüzeylerine yakın bölgelerdeki madde miktarları (yüzdelik)

Element	**Dünya**	**Ay**
Oksijen	44 %	43 %
Magnezyum	23 %	19 %
Silikon	21 %	21 %
Demir	6 %	9 %

Kanıt 3: Ay'ın Dünya'nın etrafındaki dönme eğimi Dünya'nın ve diğer gezegenlerin Güneş'in etrafındaki dönme eğiminden farklıdır. Şekil 2'de görüldüğü gibi Ay yalnızca Dünya'nın çevresinde dönmeye odaklanmıştır.



Şekil 2: Dünya ve Güneş yörüngeleri Credit: Wright Seneres

SORULAR

1. Hangi modele daha çok katılıyorsun?

<u>İDDİA</u>: Bence Model __ daha iyidir çünkü

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<u>KANIT</u>: Benim kanıtım

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<u>AÇIKLAMA</u>: Verdiğim kanıt iddiamı destekliyor çünkü

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2. Diğer modelin neden iyi olmadığını düşünüyorsun?

Diğer modeldeki sorun

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Bunun için sunduğum kanıt

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Diğer modeli iyi yapabilen özellikleri

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Ad Soyad: **Sınıf:** **Tarih:**

RÜZGAR ENERJİ SANTRALLERİ

Rüzgârdaki kinetik enerjiyi önce mekanik enerjiye daha sonra da elektrik enerjisine dönüştüren sistemdir. Bir rüzgâr türbini genel olarak kule, kanatlar, rotor, dişli kutusu, jeneratör (alternatör), elektrik-elektronik elemanlardan oluşur.
Rüzgar enerjisi temiz ve yenilenebilir bir enerji kaynağı olup hava kirliliği ve sera gazları emisyonu yoktur. Yakıt ücreti olmadığından ve işletme masraflarının azlığından dolayı ekonomik bir enerji kaynağıdır. Uzak kırsal yerleşme merkezleri, deniz fenerleri, yüksek ve ulaşılması zor bölgelerdeki sosyo-ekonomik amaçlı tesislere, bu yolla elektrik enerjisi sağlamaları bakımından da çok avantajlıdırlar. Bulunduğu yerlerde tarım ve hayvancılık faaliyetleri yapılabilir.
Rüzgâr miktarına bağımlı bir enerji olduğu için sadece yeterli rüzgârın bulunduğu alanlarda kurulabilir. Rüzgâr türbinlerinin gürültülü çalışmalarından dolayı gürültü kirliliğine neden olmaktadır. Belirli bir alan içinde, radyo, TV ve diğer haberleşme dalgalarını olumsuz etkilemektedir. Genellikle ormanlık alanlara kurulduğundan ve yıldırım düşmelerinde parçalanıp yangın çıkarma risklerine sahiptir. Denizde kurulduğunda deniz ekosistemine zarar verir. Yüksek hızla dönen pervaneleri ile, kuşların, yarasaların, böceklerin ve arıların ölümlerine sebep olmaktadırlar.

1. Bu durumda siz rüzgâr enerji santrali kurulacak yerde yaşayan bir vatandaş olsaydınız yeni bir rüzgâr enerji santrali kurulmasına izin verir miydiniz?

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2. Kararınızı desteklemek için kanıtlarınız nelerdir?

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3. Seçtiğin kanıtlar kararını nasıl destekliyor?

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4. Sizinle aynı fikirde olmayan karşı görüşteki arkadaşınızı ikna etmek için en iyi yanıtınız ne olur?

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5. Arkadaşınızın size cevabı ne olurdu?

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