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Araştırma Makalesi / Research Paper

An Investigation of 7th Grade Students' Use of Visual Strategies in Shape Pattern Problems

7. Sınıf Öğrencilerinin Şekil Örüntüsü Problemlerinde Görsel Stratejileri Kullanma Durumlarının İncelenmesi[1]

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Abstract. This study aims to examine the use of visual strategies by 7th grade students in shape pattern problems. A case study design, one of the qualitative research methods, was used in the study. The study was conducted with 12 students enrolled in the seventh grade of a middle school. In the study, a data collection tool including 6 shape pattern problems was used. In the analysis of the data obtained in the study, the descriptive analysis method was used. It was determined that the students used the numerical explicit strategy the most while finding the rules of the patterns. In the study, it was observed that visual strategies such as constructive, transformative constructive, auxiliary constructive, deconstructive were used very little. Students mostly did not consider the structural properties of the shape in the shape pattern problems and tried to solve the problems by focusing on the numerical values in the visual. It was observed that students mostly reached the correct answers in solving the pattern problems. Based on the results of the study, it is recommended that students be supported in focusing on the structural features of shapes in addition to numerical values in shape patterns. Furthermore, highlighting the strengths of visual strategies is suggested in order to encourage students to use these strategies more effectively.
Keywords: Pattern, Generalization, Visual strategy, Shape pattern, Algebraic thinking.

Öz. Bu çalışmada 7.sınıf öğrencilerinin şekil örüntüsü problemlerinde görsel stratejileri kullanma durumlarının incelenmesi amaçlanmıştır. Çalışmada nitel araştırma yöntemlerinden durum çalışması deseni kullanılmıştır. Çalışma ortaokul yedinci sınıfta öğrenim gören 12 öğrenci ile yürütülmüştür. Çalışmada 6 tane şekil örüntüsü problemini içeren veri toplama aracı kullanılmıştır. Çalışmada elde edilen verilerin analizinde, betimsel analiz yöntemi kullanılmıştır. Öğrencilerin örüntülerin kurallarını bulurken en çok sayısal belirgin stratejiyi kullandıkları tespit edilmiştir. Çalışmada yapıcı, tamamlamaya dayalı yapıcı, dönüşüme dayalı yapıcı, yapıyı çözücü gibi görsel stratejilerin oldukça az kullanıldığı görülmüştür. Öğrenciler şekil örüntüsü problemlerinde ağırlıklı olarak şeklin yapısını dikkate almamışlar ve şekillerdeki sayısal değerlere odaklanarak problemleri çözmeye çalışmışlardır. Öğrencilerin örüntü problemlerinin çözümünde çoğunlukla doğru cevaplara ulaştıkları görülmüştür. Bu çalışmada ulaşılan sonuçlar doğrultusunda, öğrencilerin şekil örüntülerindeki sayısal değerlerin yanı sıra şeklin yapısına da odaklanmalarının sağlanması önerilmektedir. Öğrencileri görsel stratejileri kullanmaya teşvik etmek için bu stratejilerin güçlü yönleri ön plana çıkarılması da önerilmektedir.
Anahtar Kelimeler: Örüntü, Genelleme, Görsel strateji, Şekil örüntüsü, Cebirsel düşünme.

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Genişletilmiş Özet

Giriş. Örüntüler, nesne ya da şekillerin belirli bir düzen içerisinde sıralanması olarak tanımlanmakta olup (Olkun ve Toluk Uçar, 2007); sayı, şekil, tablo ya da sözel problemler şeklinde sunulabilmektedir (Ley, 2005). Bu çalışmada, özellikle şekil örüntüsü problemlerine odaklanılmıştır. Walkowiak (2014), şekil örüntülerini cebirsel düşünmeyi teşvik eden değerli araçlar olarak değerlendirmiştir. Öğrencilerin genellemeleri şekil örüntüleri bağlamında ifade etmeleri, matematiksel nesneler arasındaki ilişkileri fark etmelerini ve yalnızca nesneleri sayısal ifadelere dönüştürmekten öte, bu ilişkilerin altında yatan formüllerin anlamlarını kavramalarını sağlamaktadır. Becker ve Rivera (2005), şekil örüntülerinin farklı bakış açıları geliştirme ve genelleme stratejileri oluşturma açısından önemli olduğunu, bu yönüyle fonksiyonel düşünme becerilerinin gelişimine katkı sağladığını belirtmişlerdir. Şekil örüntülerine ilişkin genelleme problemleri, çeşitli genelleme stratejilerinin ortaya çıkmasını teşvik ederek öğrencilerin daha esnek bir akıl yürütme süreci geliştirmelerine olanak tanımaktadır (Lannin ve ark., 2006a; Rivera ve Becker, 2008; Sasman ve ark., 1999). Şekil örüntülerini genelleme problemlerinde, öğrenciler genellikle iki temel strateji kullanabilmektedir: şekil örüntüsünü sayı örüntüsüne dönüştüren sayısal stratejiler ve şeklin yapısal özelliklerine odaklanan görsel stratejiler. Görsel stratejiler kullanan öğrencilerin yalnızca sayısal verilere değil, aynı zamanda şeklin yapısına da odaklandıkları, bu sayede farklı çözüm yolları geliştirebildikleri ve fonksiyonel ilişkileri daha etkili biçimde keşfedebildikleri gözlemlenmiştir (Barbosa ve ark., 2012; Becker ve Rivera, 2006; Lannin ve ark., 2006a; Tanışlı ve Yavuzsoy Köse, 2011). NCTM (2000), öğrencilerin öğrenme süreçlerinde görsel stratejilerden yararlanmalarını önermektedir. Literatürde de özellikle şekil örüntüsü problemlerinde şeklin yapısını analiz etmeye dayalı görsel stratejilerin kullanımı tavsiye edilmektedir. Şekil örüntülerinin genellemesinde görsel stratejilerin kullanılmasının öneminden dolayı, bu çalışmada öğrencilerin şekil örüntüsü problemlerinin çözümü için görsel stratejileri kullanma durumları araştırılmıştır. Çalışmada 7. sınıf öğrencilerinin şekil örüntülerini genellemede görsel stratejileri kullanma durumlarını incelemek amaçlanmaktadır. Bu amaç doğrultusunda "7. sınıf öğrencilerinin şekil örüntüsü problemlerinde görsel stratejileri kullanma durumları nedir?" sorusuna cevap aranmaktadır.

Yöntem. Bu doğrultuda, öğrenci stratejilerini derinlemesine inceleyip değerlendirebilmek amacıyla nitel araştırma yaklaşımı tercih edilmiştir. Araştırma kapsamında, nitel araştırma yöntemlerinden biri olan durum çalışması deseni kullanılmıştır. Çalışmanın katılımcılarının belirlenmesinde, amaçlı örnekleme yöntemlerinden biri olan ölçüt örnekleme yöntemi tercih edilmiştir. Bu yöntem kapsamında, katılımcıların sınıf düzeyleri ve akademik başarıları belirleyici ölçütler olarak dikkate alınmıştır. Araştırma, 2022-2023 eğitim-öğretim yılı içerisinde, Türkiye'nin kuzeydoğusundaki bir ilde yer alan bir devlet ortaokulunun 7. sınıfında öğrenim gören 12 öğrenci (4 erkek, 8 kız) ile yürütülmüştür. Katılımcıların 4'ü yüksek, 4'ü orta ve 4'ü düşük başarı düzeyine sahiptir. Veri toplama aracı 6 şekil örüntüsü probleminden oluşmaktadır. Örüntü problemlerinin 2 tanesi genel kuralı "an", 2 tanesi genel kuralı "an+b" ve 2 tanesi de genel kuralı "an-b" (a ve b sıfırdan farklı doğal sayılardır) formatında olan şekil örüntülerinden oluşmaktadır. Verilerin analizinde betimsel istatistik kullanılmıştır.

Bulgular. Öğrencilerin örüntüleri genellemek için sayısal belirgin, yapıcı, tamamlamaya dayalı yapıcı, dönüşüme dayalı yapıcı ve yapıyı çözücü olmak üzere beş farklı stratejiyi kullandıkları tespit edilmiştir. Öğrenciler örüntüleri genellemek için en çok sayısal belirgin stratejiyi, en az ise yapıyı çözücü stratejiyi kullanmışlardır. Öğrenciler örüntülerin kurallarını bulmak için sayısal stratejileri, görsel stratejilere göre

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daha fazla kullanmışlardır. Öğrencilerin kullandığı görsel stratejiler arasında en fazla yapıcı stratejiyi tercih etmişlerdir. Görsel stratejiler arasında yer alan yapıyı çözücü stratejiyi sadece bir öğrenci kullanmıştır. Bu öğrenci de yapıyı çözücü strateji ile çözümü yarıda bırakarak doğru cevaba ulaşmayı başaramamıştır. Çalışmanın bulgularına göre tamamlamaya dayalı yapıyı çözücü ve dönüşüme dayalı yapıyı çözücü stratejilerini kullanan öğrenciye rastlanmamıştır. Ayrıca sınıf tartışmaları sırasında, grup çalışmalarında kullanılmayan stratejilerin geliştirildiği de tespit edilmiştir.

Tartışma ve Sonuç. Öğrenciler, örüntülerin kuralını belirlerken hem sayısal hem de görsel stratejilerden yararlanmışlardır. Bu iki strateji türü karşılaştırıldığında, öğrencilerin büyük çoğunluğunun sayısal stratejilere yöneldiği gözlemlenmiştir. Elde edilen bu bulgu, daha önce literatürde yer alan çalışmalarla da örtüşmektedir (Akkan ve Çakıroğlu, 2012; Becker ve Rivera, 2007; Orton ve ark., 1999; Özdemir ve ark., 2015; Sasman ve ark., 1999; Stacey, 1989; Stacey ve MacGregor, 2001; Yeşildere ve Akkoç, 2011). Öğrencilerin sayısal stratejilere yönelmelerinin temel nedenlerinden biri, bu tür stratejilere daha aşina olmaları olabilir. Ayrıca, öğrencilerin örüntüleri genelleme sürecinde şekiller arasındaki yapısal benzerliklerden nasıl yararlanacaklarını bilmemeleri de görsel stratejileri tercih etmemelerinin bir diğer gerekçesi olarak değerlendirilebilir.

Öğrenciler, örüntülerin kuralını belirleme sürecinde başlangıçta ardışık adımlar arasındaki farkı dikkate alarak yinelemeli strateji kullanma eğilimi göstermiştir. Bu sürecin devamında, yinelemeli stratejiden belirgin stratejiye başarılı bir geçiş yaparak örüntünün genel kuralını doğru biçimde belirlemişlerdir. Bu bulgu, Lannin ve arkadaşları (2006a) ile Özdemir ve arkadaşları (2015) araştırma sonuçlarıyla paralellik göstermektedir.

Öğrenciler, örüntülerin kurallarını belirlerken çeşitli görsel stratejiler kullanmışlardır. Bu stratejiler arasında yapıcı, tamamlamaya dayalı yapıcı, dönüşüme dayalı yapıcı ve yapıyı çözücü stratejilere başvurulmuştur. Elde edilen bulgular, öğrencilerin bu stratejiler arasında en çok yapıcı stratejiyi tercih ettiklerini göstermektedir. Öğrenciler kullandıkları bu stratejilerden yapıcı, dönüşüme dayalı yapıcı ve tamamlamaya dayalı yapıcı stratejiler ile doğru cevaplara ulaşmayı başarırlarken, yapıyı çözücü strateji ile doğru cevaba ulaşmayı başaramamışlardır. Tanışlı ve Yavuzsoy Köse'ye (2013) göre yapıcı stratejinin kapalı formülü y=mx+b lineer formunda olan, kolayca elde edilebilen, verilen şekillerin kenarlarında ya da köşelerinde örtüşenleri göz önüne almaksızın direkt olarak şekilsel ipuçlarından çıkarılmasıdır. Yapıcı stratejinin daha fazla kullanılmasının sebebi olarak, bu stratejinin diğer görsel stratejilere göre daha kolay olması gösterilebilir. Tanışlı ve Yavuzsoy Köse'ye (2013) göre yapıyı çözücü strateji, yapıcı strateji göre daha karmaşıktır ve geçerliliğini belirlemek için şekilsel ipuçları içerisinde kenarlarda ya da köşelerde örtüşenleri tanımayı gerektirir. Becker ve Rivera (2007), yapıyı çözücü stratejinin öğrenciler için zor olduğunu ve gruplanan nesnelerde örtüşen parçaları görmenin hemen gerçekleşemeyeceğini belirtmişlerdir.

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Introduction

Mathematics, the science of patterns and order, means discovering new methods for solving problems, applying these methods, and analyzing the solutions (Van De Walle et al., 2016). Mathematics education provides individuals with mathematical knowledge and skills relevant to daily life, as well as thinking skills such as making connections between events, problem-solving, analyzing and synthesizing, making predictions, making generalizations, and reasoning (Umay, 2003).

Algebra, one of the important areas of mathematics, is defined in different ways in the literature. According to Kieran (1992), algebra is a branch of mathematics that expresses general number relationships and their properties, symbolizes many mathematical processes such as solving equations, represents quantities with variables, and enables operations with these variables. Algebra also requires algebraic thinking (Kaya, 2015). In this context, algebraic thinking is both necessary and important for all grade levels (NCTM, 2000). Algebraic thinking is the ability to reveal relationships between variables through quantitative situations (Driscoll, 1999). Van de Walle et al. (2016) define algebraic thinking as a process that includes making generalizations using numbers and operations, expressing these generalizations with meaningful symbols, and understanding the concepts of patterns and functions. Various classifications of the components of algebraic thinking are also included in the literature. Kaput (1999) examined algebraic thinking under five main headings: making arithmetic and patterns generalizations, using symbols meaningfully, analyzing structures in number systems, studying functions and patterns, and performing mathematical modeling. The Ontario Ministry of Education (OME), 2013, divides algebraic thinking into two main categories: generalized arithmetic and functional thinking. Generalized arithmetic is subdivided into discovering relationships and properties, understanding equality as a relationship between quantities, and using symbols as variables, while functional thinking consists of generalizing patterns and using inverse operations (OME, 2013). When the definitions and classifications of algebraic thinking are examined, the concept of pattern stands out as one of the fundamental elements that stands out. NCTM (2000) emphasizes the critical importance of pattern analysis in students' algebraic thinking processes. When students acquire the ability to maintain and generalize patterns, they can effectively demonstrate their algebraic thinking skills (Smith, 2003). Therefore, students' ability to identify, maintain, and generalize patterns is essential for the development of algebraic thinking. In this context, patterns and their generalization are among the fundamental building blocks of algebraic thinking. Indeed, Zaskis and Liljedahl (2002) state that many concepts in algebra consist of generalizations of patterns, and therefore, patterns constitute the essence of mathematics.

Patterns are defined as the arrangement of objects or shapes in a specific order (Olkun and Toluk Uçar, 2007) and can be presented as numbers, shapes, tables, or word problems (Ley, 2005).This study focused specifically on shape pattern problems. Walkowiak (2014) considered shape pattern problems to be valuable tools for encouraging algebraic thinking. Expressing generalizations within the context of pattern problems allows students to recognize the relationships between mathematical objects and, beyond simply converting objects into numerical expressions, to grasp the meanings of the formulas underlying these relationships. Becker and Rivera (2005) stated that shape patterns are important for developing different perspectives and generalization strategies, contributing to the development of functional thinking skills. Generalization problems related to shape patterns

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encourage the emergence of various generalization strategies, allowing students to develop a more flexible reasoning process (Lannin et al., 2006a; Rivera and Becker, 2008; Sasman et al., 1999). In generalizing shape patterns, students generally employ two basic strategies: numerical strategies, which transform the shape pattern into a number pattern, and visual strategies, which focus on the structural features of the shape. It has been observed that students who use visual strategies focus not only on numerical values but also on the structure of the shape, enabling them to develop different solution methods and explore functional relationships more effectively (Barbosa et al., 2012; Becker and Rivera, 2006; Lannin et al., 2006a; Tanışlı and Yavuzsoy Köse, 2011). NCTM (2000) recommends that students utilize visual strategies in their learning processes. The literature also recommends the use of visual strategies based on analyzing the structure of the shape, particularly in shape pattern problems. Despite the extensive body of literature highlighting the importance of visual strategies in the generalization of shape patterns, prior research has predominantly concentrated on categorizing students' generalization strategies or examining the effects of specific instructional interventions designed to promote visual reasoning. Consequently, less attention has been given to understanding the extent to which students spontaneously employ visual strategies when solving shape pattern problems, particularly at distinct grade levels. Moreover, existing studies often examine students as a homogeneous group, thereby overlooking how the use of visual strategies may vary across different academic achievement levels. This limits our understanding of how visual reasoning naturally emerges during the transition from arithmetic to algebraic thinking. Addressing this gap, the present study investigates 7th-grade students' levels of visual strategy use in shape pattern generalization by incorporating students from different academic achievement levels. By focusing on students' strategy use rather than solely on instructional outcomes, the study provides a more nuanced depiction of students' structural reasoning in pattern problems. The findings contribute to the literature by clarifying how visual strategies function as a bridge between numerical approaches and algebraic generalization at a critical developmental stage. Furthermore, the results offer empirically grounded insights for educators and curriculum developers regarding the types of reasoning students bring to pattern tasks, thereby supporting the design of learning environments that foster visual and functional thinking in alignment with curriculum recommendations. Due to the importance of using visual strategies in generalizing shape patterns, this study investigated students' use of visual strategies to solve shape pattern problems. The study aimed to examine 7th-grade students' use of visual strategies in generalizing shape patterns. For this purpose, the question "What is the level of 7th-grade students' use of visual strategies in shape pattern problems?" The question is being answered.

Method

This section provides detailed information regarding the research design, study group, data collection instruments, data collection procedure, and data analysis process.

Research design

The aim of this study is to identify the strategies that students employ when generalizing shape patterns. To explore and evaluate these strategies in depth, a qualitative research approach was adopted. Specifically, the study was designed as a case study, which is one of the widely used qualitative research methods. A case study design enables researchers to examine a particular

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phenomenon or problem in a detailed and holistic manner within its real-life context (Creswell, 2013, p. 98). In this study, the case study approach was deemed appropriate to provide an in-depth understanding of the strategies students used while engaging with shape pattern generalization tasks.

Study group

In this study, participants were chosen through criteria sampling, a purposive method of sampling. Within this method, the participants' grade levels and academic achievements were considered as the determining criteria. Since the explanation of generalizations about shape patterns with algebraic expressions is addressed at the 7th-grade level according to the Ministry of National Education (MoNE) (2018) program, the study group consisted of 7th-grade middle school students. The student groups were formed with diversity to represent different academic achievement levels. Accordingly, the students' academic achievement in mathematics and the classroom teachers' qualitative observations of the students were evaluated. Student achievement levels were determined based on their mathematics exam scores and in-class performance. Accordingly, students with exam scores between 70 and 100 were classified as "high achievement," those between 50 and 69 as "medium achievement," and those between 0 and 49 as "low achievement." In addition, students' communication skills and their ability to defend their opinions were also taken into consideration in the teachers' opinions.

The study was conducted with twelve 7th-grade students (4 boys, 8 girls) from a public middle school in a province in northeastern Turkey. Four of the participants had high achievement levels, four had moderate achievement levels, and four had low achievement levels. The students were coded according to their achievement levels as follows: S1, S4, S7, and S10 (high); S2, S5, S8, S11 (moderate); and S3, S6, S9, and S12 (low). Groups of three were formed, each containing one student from a different achievement level. The group distribution of the students and the codes for their achievement levels are presented in Table 1. The participant selection used in the study contributed to revealing how the pattern generalization process is structured at different levels of academic achievement. Including students from high, medium, and low achievement levels allowed for a comparative examination of the generalization strategies they use, potential errors, and thought processes. This resulted in findings that were more holistic and interpretable, moving beyond relying on a single student profile.

Table 1.
Success levels of students in groups

Groups	High Achievement	Medium Achievement	Low Achievement
Group 1	S1	S2	S3
Group 2	S4	S5	S6
Group 3	S7	S8	S9
Group 4	S10	S11	S12

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Data collection tools and data collection process

During the development of the data collection tool, the Ministry of National Education (MoNE) (2018) mathematics curriculum, middle school mathematics textbooks, and studies in relevant literature were meticulously reviewed, and the first draft of the data collection tool was developed accordingly. The tool was developed using studies by Becker and Rivera (2006, 2007), El Mouhayar and Jurdak (2016), Rivera (2010), and Sasman et al. (1999).

The first draft included a total of 11 pattern problems: three with rules in the "an" form, four with rules in the "an + b" form, and four with rules in the "an - b" form. To ensure the content validity of the data collection tool, the draft form was submitted to three different faculty members with expertise in the field for evaluation. Necessary adjustments were made based on the feedback obtained from the experts, and the data collection tool was finalized. These changes are detailed below. Based on expert opinions, it was decided to use six of the 11 pattern problems:

- In all pattern problems, the word "step" has been used instead of "term". This change was made to help students understand the question more clearly.
- In all pattern problems, the phrase "Find the general term" has been changed to "Find the rule of the pattern". This change was made to help students understand the question more clearly.
- In the fifth problem, the triangle pattern was created with matchsticks, as in Figure 1.
- Arrangements have been made in the drawing of the shapes to make the shape patterns in the problems more understandable.

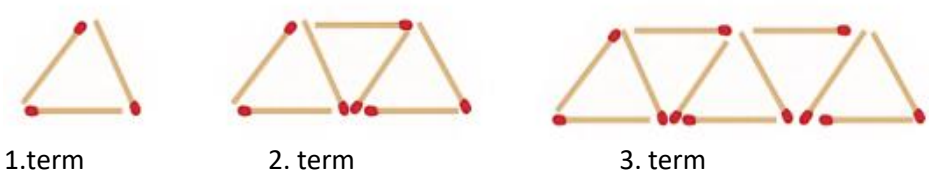


Figure 1. Figure pattern prepared as a result of expert opinion

The data collection tool for this study consisted of six shape pattern problems. Two of the pattern problems consisted of pattern problems with the general rule "an" format, two with the general rule "an+b" format, and two with the general rule "an-b" format.

Before the implementation, the students were introduced to the topic of patterns as part of the relevant course; However, no direct guidance was given on strategies for solving shape pattern problems. This aimed to encourage students to demonstrate their natural thinking in problem-solving processes. The implementation process began with the sequential presentation of pattern problems included in the pre-prepared data collection tool. After the students solved the pattern problem through group work, a class discussion was held. This process was repeated for each pattern problem, and the implementation consisted of a total of six sessions. Each session lasted approximately two class hours (approximately 80 minutes), resulting in a total of 12 class hours. In each session, all groups

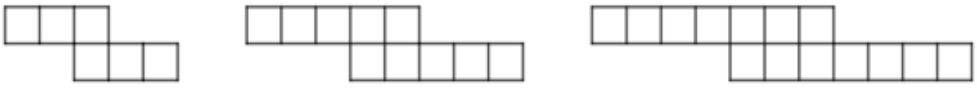
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were given the same pattern problem. Each group had 20 minutes to solve the problem. At the end of this period, the documents containing the students' solutions were collected and analyzed. Then, the strategies for each group's solution were projected on the board, and the different solution methods were presented to the class, along with student explanations. This section lasted approximately 15 minutes. A class discussion lasting approximately 30 minutes took place during the second period of the session. During this discussion, all solution strategies developed by the groups, whether correct or incorrect, were discussed. In the final phase of the class discussion, new strategies developed based on the students' diverse ideas were discussed.

Data analysis

In this study, descriptive analysis was employed to examine the collected data. The aim of descriptive analysis is to present the data obtained through interviews and observations in a systematically organized and meaningfully interpreted form for the reader (Yıldırım & Şimşek, 2016). During the analysis process, students' responses to pattern problems, video recordings of group work, and classroom discussions were analyzed simultaneously. Initially, students' responses to the pattern problems during group work were coded as True (T), False (F), or Incomplete Solution (IS). Following this stage, students' group work and video recordings were examined for each problem, and the strategies they employed were identified. The strategies students used to generalize patterns were: The analysis was determined and analyzed according to strategies found in studies by Chua and Hoyles (2010), El Mouhayar and Jurdak (2013), Lannin (2003 and 2005), Lannin et al. (2006a and 2006b), Rivera and Becker (2008), Rivera (2010), and Stacey (1989). Data analysis employed the following strategies: numerical or visual explicit, numerical or visual recursive, whole-object, numerical or visual chunking, constructive, deconstructive, transformative constructive/deconstructive, and auxiliary constructive/deconstructive. Sample solutions for the strategies used to generalize the pattern in the pattern problem given in Figure 2 are given in Table 2.

The figural patterns below consists of unit squares. There are 6 unit squares in the first term of the pattern, 10 in the second term, and 14 in the third term. Accordingly, how many unit squares should be in the eighth term of the pattern?

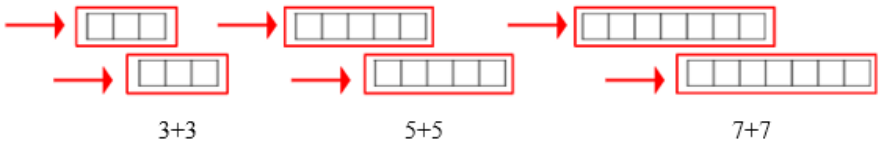
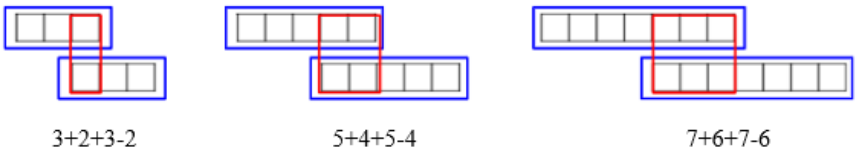
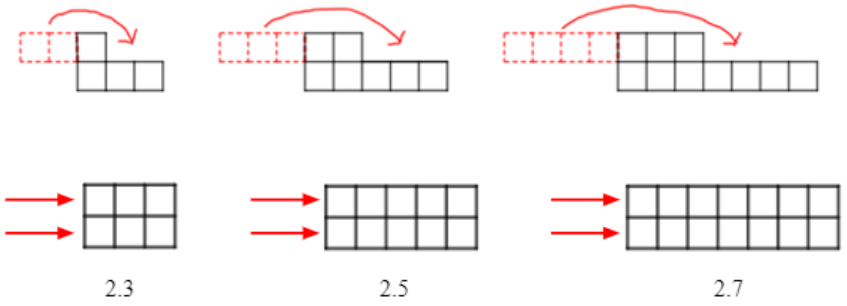


1.term 2. term 3. term

Figure 2. Figure pattern example (Adapted from Jurdak and El Mouhayar (2014))

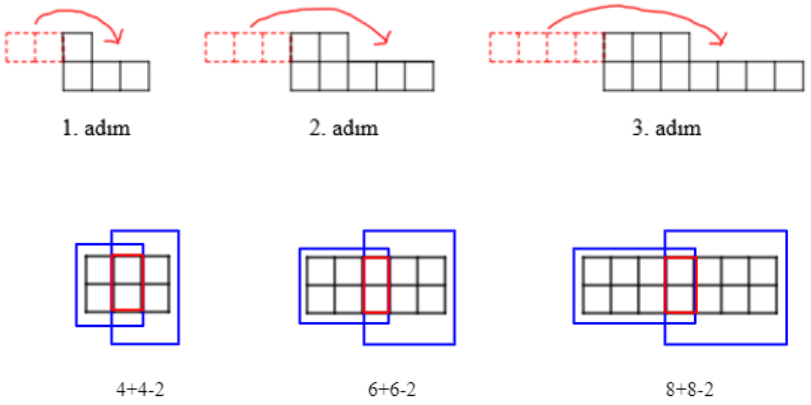
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Table 2.
Analysis framework used to classify pattern generalization strategies

Strategies	Solutions
Recursive	6, 10, 14, 18, 22, 26, 30, 34…. 8. terms 34 square unit
Explicit	1. terms 6 2. terms 6 + 4. (2-1) 3. terms 6 + 4. (3-1 … 8. terms 6 + 4.(8-1) = 34
Whole-object	2. terms 10 square unit 8. terms 4.10=40 square unit
Chunking	3. terms 14 8. terms 14+4.5=34
Constructive	 8. terms 17+17=34 square unit
Deconstructive	 8. terms 17+16+17-16=34 square unit
Transformative Constructive	 8. terms 2.17=34 square unit

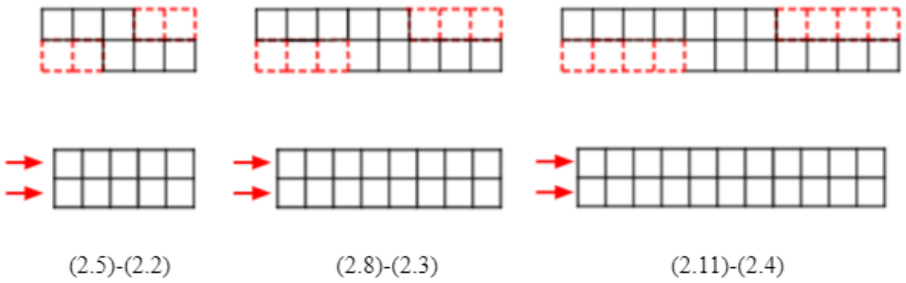
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Transformative
Deconstructive



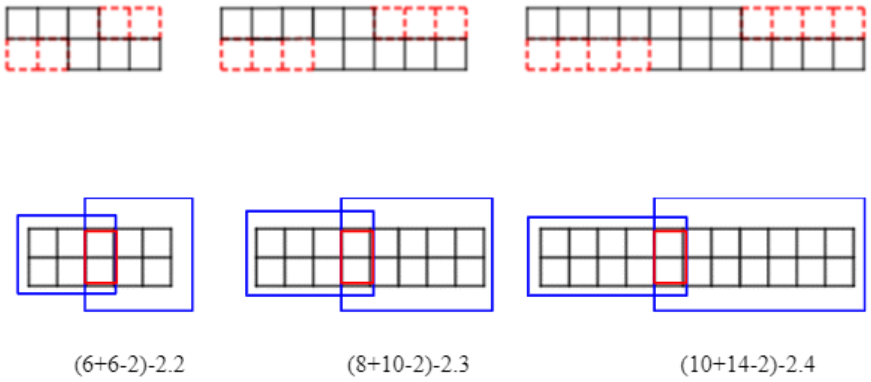
8. terms 18+18-2=34 square unit

Auxiliary
Constructive



8. terms (2.26)-(2.9) =34 square unit

Auxiliary
Deconstructive



8. terms (20+34-2)-2.9=34 square unit

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Pilot study

The pilot study was conducted at a public middle school in a province in northeastern Turkey. The study included three eighth-grade students with varying academic achievement levels (low, medium, and high). The primary purpose of the pilot study was to contribute to the planning of the main study by conducting a preliminary evaluation of the problems included in the data collection tool and the implementation process. The six pattern problems included in the data collection tool were administered to the students on two separate days. During the implementation, the students were provided with a sufficient number of blank sheets to enable them to solve the problems along with the problem sheets. Students solved the problems by discussing them in groups; this process, along with the subsequent class discussion, was videotaped. In the pilot study, it was determined that the group problem-solving process took approximately 20 minutes, and the class discussion approximately 30 minutes. Based on these timeframes, the implementation process of the main study was structured, and a total of two class periods (approximately 80 minutes) were allocated to each pattern problem.

Some technical adjustments were made based on the observations obtained during the pilot study. To avoid distracting the students, the camera was positioned so that it could not directly see the students and was set to display only the solution sheets. This same approach was followed in the main study; the students' faces were excluded from the frame, and only the sheets documenting their solution processes were recorded.

Pilot study data were analyzed using descriptive analysis methods. First, the solutions were analyzed as correct or incorrect. Then, they were analyzed according to the strategy used. This also served as preparation for the analysis of the main study data.

Furthermore, students were asked to express their thoughts out loud and exchange ideas with each other while solving the pattern problems. This approach allowed for a clearer observation of the strategies used. Since no difficulties were encountered in understanding the pattern problems during the pilot study, no linguistic or contextual changes were required in the problem statements.

Validity and reliability

In this study, long-term interaction was established with the participants to ensure internal validity (credibility). To obtain in-depth data, students' problem-solving processes were collected both through written documents and videotaped. Prior to implementation, a pilot study was conducted to anticipate potential problems that might be encountered during the study and to structure the application. The data collection tool, developed by the researcher, was revised and finalized based on the opinions of field experts and the results of the pilot study. The consensus among experts was 87%. Necessary adjustments were made until consensus was reached.

To increase external validity (transferability), the study employed detailed description and purposive sampling methods (Yıldırım and Şimşek, 2016). As part of the detailed description, the students' dialogues during the solution process of the pattern problems were directly transcribed; their solution sheets were also included as visual materials. Criterion sampling, a purposive sampling

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method, was used to select participants, and the criteria used in selecting participants were explained in detail.

To ensure the internal reliability of the study, the data obtained was presented directly by the researcher without interpretation. Furthermore, students' solution documents and video recordings were simultaneously reviewed to ensure data consistency across the data collection tools. Field experts were consulted both during the development of the data collection tool and during the analysis of the obtained data, ensuring an external perspective on the study.

Ensuring external reliability (confirmability) requires the researcher to avoid subjective judgments and to continuously verify the data obtained (Yıldırım and Şimşek, 2021, p. 295). Accordingly, the data collection tools, data collection process, and data analysis stages were explained in detail; the opinions of field experts were included in both the pilot and main implementation phases to support the confirmability of the study.

Ethics committee approval

In this study, the principles and rules set forth in the "Directive on Scientific Research and Publication Ethics of Higher Education Institutions" were strictly followed, and the actions defined under the title "Actions Contrary to Scientific Research and Publication Ethics" were avoided. Ethical approval for this study was granted by the Social and Human Sciences Ethics Committee of Recep Tayyip Erdoğan University with the decision dated 25 November 2022 and numbered 2022/267.

Results

Strategies used by the students to find the rules of the shape patterns and the accuracy of the answers they reached using these strategies are shown in Table 3.

Table 3.
Strategies students use to find rules for shape patterns

Students	1.problem	2.problem	3.problem	4.problem	5.problem	6.problem
S1	AC, C	C	TC, C	NE	NE	NE
S2	AC, C	C	TC, C	NE	NE	NE
S3	NE	NE	NE	NE	NE	NE
S4	NE	NE	NE	NE	NE	NE
S5	NE	NE	NE	NE	NE	NE
S6	NE	NE	NE	NE	NE	NE
S7	NE	NE	NE	NE	NE	D*, NE
S8	NE	NE	NE	NE	NE	A*, NE
S9	NE	NE	NE	NE	NE	NE
S10	NE	NE	NE	C, NE	NE	NE
S11	NE	NE	NE	C, NE	NE	NE
S12	NE	NE	NE	C	NE	NE

(AC: Auxiliary Constructive, C: Constructive, TC: Transformative Constructive, NE: Numerical Explicit, A: Auxiliary, D: Deconstructive, *: Incomplete Solution)

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As presented in Table 3, students employed five distinct strategies when generalizing patterns: numerical explicit, constructive, auxiliary constructive, transformative constructive, and deconstructive. Among these strategies, the numerical explicit strategy emerged as the most frequently utilized, whereas the deconstructive strategy was employed the least. Figure 3 illustrates the dialogue and corresponding actions of Group 2 members, who successfully arrived at the correct solution to the fifth problem by employing the numerical explicit strategy.

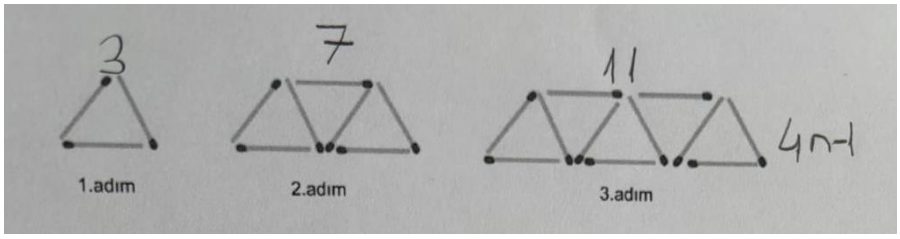


Figure 3. The numerical explicit strategy used by members of Group 2 to find the rule of the pattern

S5: There are 3 matchsticks in the first step of the pattern, 7 in the second step, and 11 in the third step. The pattern increases by four.
S4: Yes, first we'll write 4n. If we replace "n" with 1, it becomes 4.1=4. But there are 3 in the first step. So we subtract 1.
S5: Okay, so it's 4n-1.
S6: Yes.

According to the dialogue above, the students transformed the shape pattern into a number pattern by finding the number of matchsticks in the given steps of the pattern. Since the difference between the consecutive steps of the pattern was 4, the students determined that the coefficient of n was 4. Then, by substituting 1 for n, they found the rule of the pattern: 4n-1.

The dialogue and the operations performed by the members of Group 4, who used the constructive strategy in the fourth problem and reached the correct result, are shown in Figure 4.

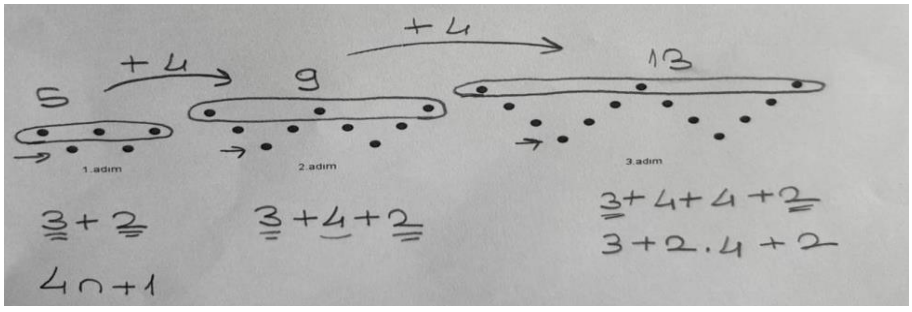


Figure 4. The constructive strategy used by members of Group 4 to find the rule of the pattern

S10: We can do it by counting from the side. When we look at the horizontal rows in the first step, there are 3+2 dots. In all steps, there are 3 dots in the first row.
S11: There are always 2 dots in the bottom row.

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S10: The 3 dots in the top row always remain constant.
S12: 2 is also always constant.
S10: Yes, there are always 3+2 dots.
S11: In the second step, there are 4 dots in the middle.
S12: In the third step, there are 2 rows in between and 4 dots in each row.
S11: Yes, there is another 4. So, 4+4=8. We need to find a rule for the order of the steps.
S10: 4 is added. But the number of 4s added has changed. We added 4 in the second step. We added 2.4 in the third step. Therefore, 3.4 must be added in the fourth step. A 4 is always added after the first step. But how can we create a rule from this?

According to the dialogue above, the students divided the shapes in the first three steps of the pattern into horizontal rows with no common elements. They then attempted to establish the rule by considering the number of dots in the horizontal rows. They determined that the number of dots in the top and bottom horizontal rows was constant for all steps of the pattern. They also determined that the number of dots in the intermediate horizontal rows was four. However, they were unable to generalize this idea to the nth step of the pattern or to establish the rule. The students, who had used the constructive strategy correctly up to this point, were unable to continue the strategy. After this stage, the following dialogue took place between the researcher and members of Group 4.

S10: Teacher, we thought so, but we couldn't continue.
R: What did you think?
S10: In every step of the pattern, there are numbers 3 and 2. Because of the rows above and below. And because of the rows in the middle, there are numbers 4.
R: Okay, let's write down the parts you found.
S10: 3+2, 3+4+2, 3+4+4+2. Except for the first step, the number of 4s added always increases. 2 and 3 are always present anyway.
R: Okay, can you generalize these expressions?
S10: The 3s and 2s are constant, and the 4s are added by one less than the order of steps.
S11: Yes, in the third step, we need to add two 4s. If we add 4s by one less than the order of steps in the first step, we have 0 4s, meaning we haven't added any.
S10: (n-1) 4s are added.
R: Yes, you found 3 and 2 to be constants. You also found the number of 4s to be (n-1). What can you say about the rule of this thought pattern?
S10: Then 3+(n-1).4+2.

The above dialogue between the researcher and members of Group 4 demonstrates that the students correctly identified the pattern rule using the constructive strategy.

The transformative constructive strategy was employed by Group 1 members S1 and S2 in solving the third problem, resulting in a correct solution. The dialogue and interactions between these group members during the problem-solving process are presented in Figure 5.

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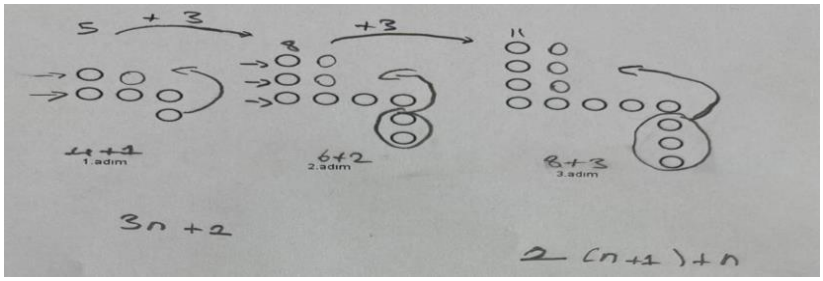


Figure 5. The transformative constructive strategy used by members of Group 1 to find the rule of the pattern in the third problem

S1: I think I found something. But I don't know how to write it. For example, if we move the bottom circle to the top in the first step.
S2: So, there are 4 circles and one next to it. If we move the bottom circles to the top in the second step, there are 6 circles and two next to it.
S1: Yes, if we do the same in the next step, there are 8 circles and three outside. That's +3. I can't figure out how to write that. Let's ask the teacher.

The dialogue above shows that the students moved the circles in the lower right corner of the shapes to the upper left corner. This action corresponds to a transformative strategy, as they positioned the given shapes in a way that made it easier to find the rule or desired step of the pattern. They then tried to associate the number of circles in the newly created pattern steps with the steps of the pattern, but they were unsuccessful. Subsequent to this stage, a dialogue was conducted between the researcher and the students.

S1: My teacher, we found something, but we don't know how to write it. For example, we moved the circle below up here, so there are 4, and one is left here. Since there are 4, that means we added 3 more than the step sequence and also added the step sequence. And for the other steps... (He didn't continue talking).
R: Looking at the figure, can you count the 4 circles here in a different way?
S1: We can count the rows sideways. There are 2 rows, and each row has 2 circles. We could say "2.2 = 4" for the number of circles. But then we need to add 1. So, we added the step sequence.
R: So, how do you calculate the other steps?
S2: There are 3 rows, and each row has 2 circles. That makes 2.3.
R: Okay, how many are left after these?
S2: There are 2. Then we add 2. So, it's 2.3 + 2.
S1: Yes, we're actually always adding n. There is always a factor of 2.
R: What would you say about the other factor?
S1: 1 more than the step order.
R: What is the rule in this case?
S1: Then 2.(n+1) +n.

The dialogue above demonstrates that the students used the constructive strategy to find the number of circles in each step. They divided the shapes corresponding to the sequence of steps in the

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pattern into pieces with no common elements. They then related the number of circles in the separated pieces to the sequence of steps in the pattern. Finally, they found the rule of the pattern algebraically as "2.(n + 1) + n." In this problem, the students used the constructive strategy based on transformation. First, they transformed the shapes that make up the steps of the pattern into a new shape that would allow them to find the rule more easily. Then, they divided this new shape into pieces with no common elements.

The auxiliary constructive strategy was used in the first problem by S1 and S2, members of Group 1, and the correct result was achieved. The dialogue and the sequence of operations performed by Group 1 members are illustrated in Figure 6.

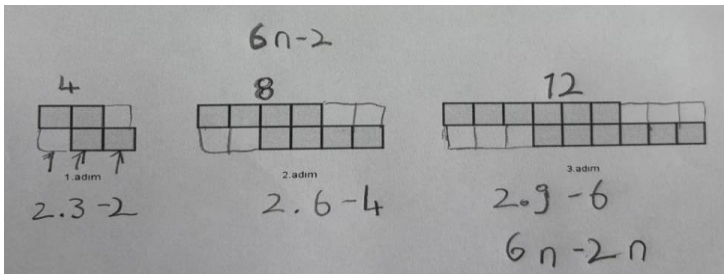


Figure 6. The auxiliary constructive strategy used by members of Group 1 to find the rule of the pattern in the first problem

S1: Can we do this by completing the shape?
S2: Yes, we can.
S1: In the first step, we need to add 2 squares. If we subtract the parts we added, we need to subtract 2 in the first step. So, the formula becomes 6n-2 (The students created a rule based on the first step alone, without looking at the other steps of the pattern).
S2: But we need to subtract 4 in the second step.
S1: We made a mistake; it doesn't work like this then.

According to the dialogue above, the students completed the shapes into rectangles by adding unit squares to the shapes in the given steps of the pattern. It appears that S1 created a rule after completing the shape in the first step, but did not test this rule for the other steps of the pattern. S1's mistake was corrected by S2. The students were unable to establish the rule for the pattern based on these new shapes they created and asked the researcher for help. The following conversation took place between the researcher and the students.

R: According to the strategy you're considering, how many square units do you need to subtract in the first, second, and third steps?
S2: We need to subtract 2 in the first step, 4 in the second step, and 6 in the third step.
R: How do you translate this into a rule?
S2: My teacher, I always thought we should subtract the same number.
R: In this case, what can you say about the number we'll subtract?
S2: Therefore, at each step, we must subtract twice the number of steps. This way, we can find the number of unit squares at each step.

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S1: In this case, the number of unit squares in the first step is found using the expression 2.3-2. The number of unit squares in the second step is found using the expression 2.6 - 4.
S2: Yes, so we'll subtract twice the number of squares for each step. So, 2.3.n - 2.n is equal to (6n - 2n).

In the above dialogue between the researcher and S1 and S2, the students found the rule for the new pattern they created using the constructive strategy. It appears that while finding the rule, they divided the new shape they created into two parts using expressions such as 2.3 and 2.4. They then subtracted the squares they added using expressions such as 2.3-2 and 2.4-4. This way, they found the rule for the pattern as "6n - 2n." The strategy used by the students has been identified as an auxiliary constructive strategy. First, the students completed the given shape into a new shape whose rule they could more easily find. Then, they divided the number of squares in these new shapes into pieces corresponding to the step sequences of the pattern, so that they had no common elements. Therefore, it was decided that this strategy was used.

In the sixth problem, Group 3 members S7 and S8 attempted to apply constructive and auxiliary strategies; however, they were unable to complete the solution using these approaches. The dialogue between these members of Group 3 is presented below.

S7: We can count the shapes one vertically and one horizontally. For example, in the first step, there are 3 circles horizontally and 2 vertically. In the second step, there are 7 circles horizontally and 4 vertically. We've counted one circle twice. We'll have to subtract it later. I don't know how to continue.
S8: We can also do this by adding circles to the shapes. If we add circles to the empty spaces in the first step, there are 6 circles in total. That's 4+2. In the second step, we need to add 18 circles. In the second step, there were 10 circles initially, and then we added 18 more. That's 28 in total. If we add circles to the empty spaces in the third step, we add 50. There were 16, and when we added 50 more, there were 66. But when you think about it this way, there's no rule.

According to the dialogue above, S7 divided the shapes corresponding to the sequence of steps in the pattern into pieces with common elements. This way of thinking corresponds to the deconstructive strategy. However, S7 could not determine how to continue the solution with this strategy. When the other group members did not offer any ideas, the solution was left unfinished. S8, on the other hand, was seen to have first completed the shape corresponding to each step in the pattern. He then subtracted the number of circles he added later from the number of circles in the newly formed shape. He did this for the first three steps of the pattern, but not for the remaining steps. With this thought, he believed he would not be able to find the rule, so he was unable to complete the solution.

In the class discussion in which all students participated, the researcher wrote the problems on the board. Students explained the solutions they developed in their group work.In the class discussion, only one strategy was encountered, beyond the strategies students used in the group. This

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strategy was a transformative constructive. This strategy was also encountered in the class discussion of the second problem. In the class discussion of the second problem, a transformative constructive strategy was used, differed from the strategies used in group work. The interaction between the researcher and the students, along with the steps involved in implementing the transformative constructive strategy, is presented in Figure 7.

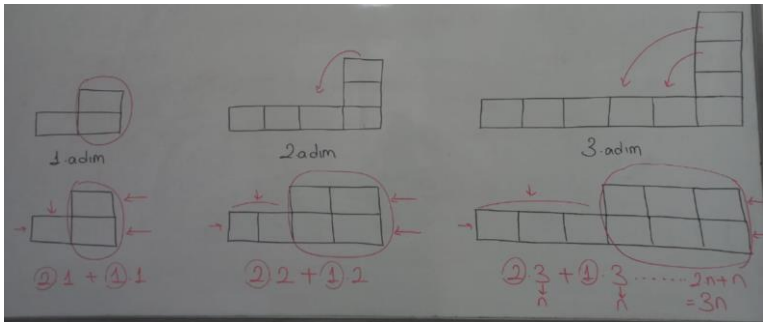


Figure 7. Transformative constructive strategy emerged in the class discussion of the second problem

S4: We can find the rule by changing the places of the shapes. The number of shapes in the first step is 2.1 + 1. In the second step, when we move one rectangle up and down, the total number of rectangles becomes 2.2 + 2. If we move the two rectangles up and down in the third step, the number of shapes becomes 2.3 + 3.
S5: The first factor, 2, is present in each step. The second factor increases by 1. In fact, the second factor is the order of the steps.
R: With this in mind, how can we find the rule?
S5: We need to multiply 2 by the order of the steps.
R: So, what can you say about the number of rectangles left out?
S5: One rectangle was left out in the first step, two in the second step, and three in the third step. So, we need to add the number of steps. So, our rule becomes 2n + n = 3n.

From the dialogue above, it is seen that the students used the transformation-based strategy by changing the places of the rectangles in the second and third steps of the figure. As can be seen in Figure 7, the students changed the places of one rectangle in the vertical row of the shape corresponding to the second step of the pattern and two rectangles in the vertical row of the shape corresponding to the third step. Then, they divided the rectangles forming the figures into pieces with no common elements. They then correlated the number of rectangles in these pieces with the step order to determine the correct pattern rule. This strategy is a transformative constructive strategy. Because they first transformed the shapes corresponding to the steps of the pattern into new shapes that could more easily identify the pattern rule. They then divided these new shapes into pieces with no common elements.

Conclusion, Discussion and Recommendations

Students used both numerical and visual strategies to find the rules of the patterns. When comparing these two types of strategies, it was observed that the majority of students preferred

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numerical strategies. This finding is similar to the results of previous studies in the literature (Akkan and Çakıroğlu, 2012; Becker and Rivera, 2007; Orton et al., 1999; Özdemir et al., 2015; Sasman et al., 1999; Stacey, 1989; Stacey and MacGregor, 2001; Yeşildere and Akkoç, 2011). Despite encountering shape patterns, students used visual strategies in a limited and largely superficial manner. Visual approaches requiring the analysis of structural features of the shape were rarely used. Instead, students resorted predominantly to counting-based procedures, even when structural relationships could facilitate more efficient and meaningful generalizations. These findings suggest that students' interaction with visual information is primarily numerically oriented rather than structurally oriented. One of the main reasons students prefer numerical strategies may be their greater familiarity with these strategies. Furthermore, students' lack of understanding of how to utilize structural similarities between shapes in the process of generalizing patterns may be another reason for their failure to use visual strategies. However, using the structural properties of shapes in patterns not only supports the generalization process but also makes significant contributions to the development of algebraic thinking (Yeşildere İmre et al., 2017).

It was observed that students frequently converted shape patterns into number patterns when attempting to determine the general rule. This transformation was primarily achieved by attending to the numerical values of the geometric elements at each stage of the pattern, after which the general rule was expressed using a numerical explicit strategy. This tendency aligns closely with prior research reporting that students often privilege numerical representations over structural analysis in pattern generalization tasks (El Mouhayar and Jurdak, 2016; Markworth, 2010; Özdemir et al., 2015; Yeşildere İmre et al., 2017). The literature suggests that such a preference may stem from students' limited conceptual understanding of how structural relationships within shape patterns can be used to support generalization, leading them to rely on more familiar numerical procedures. In addition, several studies have emphasized the influential role of instructional materials in shaping students' strategy choices. In this regard, the present findings are consistent with those of Elbir and Özmen (2023), who reported that mathematics textbooks recommended by the Ministry of National Education (MoNE) predominantly emphasize numerical aspects of patterns and provide limited opportunities for students to engage with alternative, visually or structurally oriented strategies. Taken together, these results indicate that both students' prior experiences and the nature of curricular materials contribute to the widespread use of numerical explicit strategies in shape pattern generalization.

In the process of determining the rule of the patterns, students initially tended to employ a recursive strategy by focusing on the differences between consecutive steps. Subsequently, many students were able to transition from a recursive strategy to an explicit strategy, enabling them to correctly determine the general rule of the pattern. This progression from recursive to explicit reasoning is consistent with findings reported in previous studies (Lannin et al., 2006a; Özdemir et al., 2015). For instance, Özdemir et al. (2015) reported that students first identified the constant difference between consecutive steps in pattern problems with rules of the form an, $an + b$, and $an - b$. They then interpreted this constant difference as the coefficient a and, by substituting a specific term value for n, determined the constant term ($+b$ or $-b$) based on the corresponding pattern step. Similar reasoning processes were observed in the present study, indicating that students' successful use of explicit strategies often builds upon their initial recursive reasoning.

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Students used various visual strategies to determine the rules of the patterns. Among these strategies were constructive, auxiliary constructive, transformative constructive, and deconstructive strategies. Among these strategies, students most frequently preferred the constructive strategy. While students were successful in reaching correct answers with the constructive, transformative constructive, and auxiliary constructive strategies, they were unable to reach the correct answer with the deconstructive strategy. According to Tanışlı and Yavuzsoy Köse (2013), the constructive strategy's closed formula is the linear form y=mx+b, which can be easily obtained, and is derived directly from the shape clues of given shapes, without considering overlaps at the edges or corners. The reason for the increased use of the constructive strategy is that it is easier than other visual strategies. According to Tanışlı and Yavuzsoy Köse (2013), the deconstructive strategy is more complex than the constructive strategy and requires recognizing overlaps at the edges or corners within the shape clues to determine its validity. Becker and Rivera (2007) stated that the deconstructive strategy is difficult for students and that identifying overlapping parts in grouped objects is not readily apparent. Furthermore, Becker and Rivera (2007) concluded that none of the students participating in their study were able to develop the deconstructive strategy on their own. In this study, the difficulty and complexity of the deconstructive strategy was cited as the reason for using the deconstructive strategy only once to find the pattern rule, leaving the solution incomplete. Students were able to reach the correct answer once each using the transformative constructive and auxiliary constructive strategies to find the pattern rules. These strategies are based on changing the structure of the shape. Becker and Rivera (2007) recommend transforming shapes into simpler, more recognizable forms when a rule cannot be easily found in a pattern of shapes.

In this study, class discussions in which all students participated were found to be effective in revealing different strategies. This result is consistent with the results of Lannin et al. (2006a). In class discussions, a transformation-based constructive strategy emerged in finding the rule of patterns, different from the strategies identified in group work. This can be explained by the fact that class discussions provide a suitable environment for the emergence of different strategies in problem solving and their positive impact on the development of students' thinking skills. Furthermore, the emergence of different strategies in class discussions can be explained by the fact that they arise from student-teacher interaction (Lannin et al., 2006a). The literature indicates that discussion-based approaches are effective in developing students' higher-order cognitive skills (application, analysis, synthesis, and evaluation) (Bloom et al., 1956); It is known that it provides students with the opportunity to reveal their knowledge by improving their ability to comprehend, analyze and interpret subjects (Binbaşıoğlu, 1994) and develops students' skills such as listening, questioning, expressing ideas, criticizing, synthesizing and evaluating (Sarıgöz, 2013).

The following recommendations were made in line with the results obtained in the study. This study found that students predominantly used the numerical explicit strategy in figuring out shape rules, while they used visual strategies that require using the structure of the shape very little. Students should be encouraged to focus on the structure of the shape as well as the numerical values in the shape patterns. To encourage students to use visual strategies, the strengths of these strategies can be highlighted. At the same time, examples that allow the use of different solutions in addition to the numerical properties of the patterns can be used in the textbooks used by students.

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Teachers' use of visual strategies for patterning and their awareness of their strengths and weaknesses could be investigated. The findings of the present study indicate that students' use of visual strategies in shape pattern generalization varies across individuals and achievement levels. However, the study focused solely on students' strategy use and did not examine the instructional practices that may influence the development of these strategies. Therefore, future research could investigate teachers' use of visual strategies in pattern-related instruction, as well as their awareness of the strengths and limitations of such strategies, in order to better understand how classroom practices support or constrain students' visual reasoning.

How different countries' curriculum and textbooks address the topic of patterns and what strategies they include in solving pattern-related problems could be investigated. As students' opportunities to engage with visual strategies are strongly influenced by curriculum materials, future research could focus on comparative examinations of curricula and textbooks across different countries to explore how pattern topics are addressed and which generalization strategies are foregrounded. Such investigations may provide insights into the degree to which curricular and textbook structures systematically promote visual and structural approaches to pattern generalization.

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