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A MASTER’S THESIS

INVESTIGATION OF SIXTH GRADE STUDENTS' SPATIAL ABILITY AND SPATIAL LANGUAGE AND STRATEGIES USED IN GEOMETRICAL TASKS

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DEPARTMENT OF MATHEMATICS
AND SCIENCES EDUCATION

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ABSTRACT

MSc Thesis

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The aim of the research is to investigate the sixth-grade students' spatial abilities and spatial language and strategies used in geometrical tasks. The method of the study was the mixed research methods. As a method, convergent parallel design from the mixed research methods was used. The participants of the study were selected by the convenience sampling method. Quantitative data were collected on math test results, Spatial Ability Test (SAT) and C-test. quantitative data were collected on building 3D objects with Lego implication. In data analysis, quantitative data were used with simple and partial correlation analyzes and the analysis of qualitative data was carried out with content analysis. As a result of this study, a moderate, positive, and significant relationship was found between mathematical performance, language proficiency and spatial ability scores. Not seeing the construction stages of the object, being persistent in trying, communicating effectively are the important factors that positively affect the success in the geometrical task. Again, the control strategy was found to be one of the key strategies that boosts task success. It is recommended to teachers that in the geometric tasks to be done in the classroom, observing the construction stages of the object, being persistent in trying, and establishing effective communication stand out as important factors for students' success in geometrical tasks.

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Keywords: Geometrical tasks, Middle school students, Spatial ability, Spatial language and strategies.

ÖZET

Yüksek Lisans

ALTINCI SINIF ÖĞRENCİLERİNİN UZAMSAL YETENEKLERİ VE GEOMETRİK GÖREVLERDE KULLANDIKLARI UZAMSAL DİL VE STRATEJİLERİNİN İNCELENMESİ

Aslı Merve ALA

Erzincan Binali Yıldırım Üniversitesi
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Araştırmanın amacı, altıncı sınıf öğrencilerinin matematik derslerinde uzamsal görevlerin yeniden yapılandırılması, uzamsal yeteneklerini, geometrik görevlerde kullandıkları uzamsal dili ve stratejileri incelemektir. Çalışmanın yöntemi karma araştırma yöntemlerinden yakınsayan paralel desen kullanılmıştır. Katılımcılar kolay ulaşılabilir örnekleme metoduyla seçilmiştir. Veriler matematik sınav sonuçları, Uzamsal Yetenek Testi (SAT) ve C- testi ile 196 altıncı sınıf öğrencisinden toplanmıştır. Nicel veri analizi basit ve kısmi korelasyon analizleri ile nitel verilerin analizi ise içerik analizi ile gerçekleştirilmiştir. Çalışmanın sonucunda, matematik başarısı ile dil yeterliliği ve uzamsal yetenek puanlarının arasında orta düzey, pozitif yönlü ve anlamlı ilişki bulunmuştur. Uzamsal görevde başarıyı; denemede ısrarlı olmak, etkili iletişim kurmak ve objenin yapım aşamalarını görmek olumlu etkileyen önemli faktörler olarak öne çıkmaktadır. Yine uzamsal dil stratejilerinden kontrol stratejisi görevdeki başarıyı arttıran önemli stratejilerden biri olduğu sonucuna varılmıştır. Sınıfta yapılacak geometrik görevlerde objenin yapım aşamalarını öğrencinin görmesi, denemede ısrarlı olması ve etkili iletişim etkileyen önemli faktörler olarak öne çıkmaktadır.

2023, 127 Sayfa

Anahtar Kelimeler: Geometrik görevler, Ortaokul öğrencileri, Uzamsal yetenek, Uzamsal dil ve stratejiler.

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Aslı Merve ALA
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LIST OF ABBREVIATIONS

Abbreviations

B	Builder
D	Describer
LGS	High School Entrance Examination
MEB	The Turkish Ministry of Education
PISA	Programme for International Student Assesment
TIMSS	The Third International Mathematics and Science Study
SAT	Spatial Ability Test
SES	Socio-economic Status

1. INTRODUCTION

To make sense of daily life in our lives, we need skills such as problem-solving, communication, cooperation, creative thinking, mathematical thinking, and language proficiency, as well as spatial ability. The concept of spatial ability was first mentioned in Galton's article published in 1880 as "the power to imagine shapes vividly in mind". Definition of spatial ability by years; It has been expanded as the ability of individuals to visualize, organize and translate a shape, to imagine how an object looks from a different position, to rotate two or three-dimensional geometric objects as a whole in mind, and to recognize them in different positions (Linn and Petersen, 1985; Lohman, 1988; Van De Wall et al. 2014; Hendroanto, 2015). In short, spatial ability; is the ability to make sense of the physical properties, positions, and processes of the object in space.

In the literature, some studies reveal not only the definitions of spatial ability but also the relationship between spatial ability and sub-topics of mathematics as well as mathematics. Accordingly, there seems to be a weak or moderate relationship between spatial ability and mathematical performance (Hegarty and Waller, 2005; Newcombe, 2010; Pittalis and Christou, 2010; Passolunghi et al., 2014; Cheng and Mix, 2014). It has been revealed that there is a significant positive moderate relationship with geometry, which is the sub-learning domain of mathematics (Kyttälä and Lehto 2008; Le Fevre et al., 2010; Frick, 2019). On the other hand, spatial ability, numerical estimation, comparison of sizes (Cui et al., 2017), arithmetic fluency (Zhang, 2019), number ability (Cornu et al., 2018; Le Fevre et al., 2010), calculation (Kyttälä and Lehto 2008; Lefevre et al., 2010), problem-solving (Männamaa et al. 2012; Meyer et al., 2010) was also found to be related.

In addition to studies examining the connection between spatial ability and mathematics, research addressing the questions "how?" and "why?" in attempts to explain this relationship in more detail have gained attention recently. Some of these studies, from a biological point of view, have revealed that spatial and mathematical abilities are closely related, as they benefit from similar neurological processes in the same brain regions (Sokolowski et al., 2017; Seydell-Greenwald et al., 2017). In some studies, examining mathematics education, it has been revealed that mathematical performance increases because of the development of spatial ability (Cheung et al., 2020; Frick, 2019).

There are many explicit and implicit gains in spatial concepts in mathematics teaching programs of all education levels from preschool to universities. It is because spatial ability is both related to mathematics and subjects in mathematics and contributes to the improvement of students' success and thinking. Since spatial ability is generally associated with geometry, it is seen that spatial ability is given more weight in mathematics teaching programs, especially in the achievements of geometry and measurement sub-learning domains (MEB, 2018). However, considering that spatial ability is only related to geometry and not related to other sub-learning areas of mathematics may cause some important issues in mathematics education (success, creative thinking, establishing relationships, etc.) to be ignored. Again, considering spatial ability as a whole may cause many subjects and relationships to be ignored in mathematics education. Therefore, in recent years, many factors of spatial ability have been defined. More research has begun on their relationship to mathematics and how they relate to mathematics.

Although many factors of spatial ability have been defined, the most commonly used factors in these studies are "spatial visualization", "spatial orientation" and "spatial relations"(Lohman, 1988; Göktepe Yıldız, 2019; Shawky et al, 2021; Rahmawati et al, 2021). Spatial visualization is the ability to manipulate and move objects in mind; while spatial orientation can be defined as the ability to imagine how the image of an object is from a different position, spatial relations can be defined as the ability to turn two and three-dimensional geometric objects in one's mind as a whole and to recognize them in different positions (Lohman, 1988; Göktepe Yıldız, 2019). In research on the factors; between spatial visualization ability and solving word problems and geometry success (Lowrie, 2019); between spatial orientation ability and success in arithmetic operations, logic-spatial functions, and geometry (Frick, 2019) similarly, between spatial relation ability and mathematical operations (Città et al., 2019; Yang and Yu, 2021) were found positive relationships. In addition to studies revealing the relationships between mathematics and spatial ability and its factors, there are studies investigating language proficiency, which is thought to be related to these two concepts (Garcia et al., 2021; Chan et al., 2022).

Language proficiency is required for the sake of ensuring active participation in the lessons in teaching mathematics and in the learning processes of students, to explain mathematical concepts and to express mathematical ideas well. Understanding mathematics is through understanding the mathematical language and understanding what the concepts mean fully and clearly (Adam, 2003). Spatial concepts come to the fore in mathematical language. The concepts used in the mathematical language include number-shape names, quantitative concepts that enable comparison, and spatial concepts. Spatial language is the terminology used to describe the language used to communicate spatial concepts and spatial interactions (Gilligan-Lee et al., 2021). Studies with spatial language claim that the spatial language used by students predicts spatial ability (Pruden, Levine, and Huttenlocher, 2011; Miller et al., 2016; Simms and Gentner, 2019; Geary et al., 2021).

Spatial ability emerges with perceptions of physical objects in mind (Lohman, 1988; Wolbers and Hegarty, 2010; Chen et al, 2020). To understand how spatial ability is in mind, spatial thinking needs to be analyzed. Spatial thinking is differentiated into flexible strategy choice and meta-representational competence (Hegarty, 2010). In this study, With the goal to develop a deeper knowledge of spatial ability, it would be extremely valuable to identify distinctions in how people use spatial strategies and spatial terms to conduct geometrical tasks in relation to their levels of spatial ability.

Importance of Research

At the middle school level, students generally start to have difficulties in the sixth grade in mathematics and especially in geometry (Taş, 2020). Because for sixth-grade students; possibility, hypothesis and reasoning in logical thinking and new spatial concepts is a critical period for abstract processing (Piaget and Inhelder, 2013). The more abstract algebra concepts in the Mathematics Curriculum begin at this grade level.

In addition, for the solution of skill-based questions in the mathematics section of the High School Entrance Examination (LGS) nationally and the Program for International Student Assessment (PISA), and The Third International Mathematics and Science Study (TIMSS) exams, language skills and spatial ability plays an important role (Ünsal and Kaba, 2022). Because, parallel to understanding the verbal part of these questions, it is emphasized that they can be solved by using the association of geometric shapes and generalization of geometric ideas (Kürtüncü and Kurtuluş, 2021).

On the other hand, the relationship between mathematical performance and language proficiency differs according to the developmental levels of students (Chen and Chalhoub-Deville, 2016). For this reason, the relationship between mathematical performance and language proficiency of students studying at different grade levels should be revealed. It is important for the effective teaching of mathematics in the classroom and for increasing the success of mathematics.

It is necessary to reveal which strategies and words used or preferred by the student in each geometric task affect their performance positively or negatively. This is because of its importance for the selection and implementation of tasks for later use by teachers (Falco,2020).

Again, it is thought that revealing how the spatial and mathematical language differs according to the situations in which the students see the task (spatial object) directly or not in geometric tasks. This will help the planning and utilization of different geometrical implementations (Eliam ve Alon, 2019). Based on all these, it is aimed to determine the relationships between mathematical performance, spatial ability and language proficiency through spatial language usage in geometrical tasks . In addition, this study was designed to determine how to change them and occur various situations at the sixth-grade level, which is the critical period for students for possibility, hypothesis, and reasoning in logical thinking and new spatial concepts and abstract operations.

Purpose of the Research

The aim of this study is to examine the spatial language and spatial language strategies used by sixth grade students in spatial-geometrical tasks. Accordingly, it was planned to investigate the sixth-grade students' spatial abilities and spatial language and strategies used in geometrical tasks and especially in spatial tasks in the geometry sub-learning domains, and mathematics performance.

Research Problems

• Is there a relationship between mathematical performance, language proficiency and spatial ability and its factors?

• What is the completion status of geometrical tasks?

• How are spatial language terms used in geometrical tasks?

• Do the spatial language strategies used in geometrical tasks vary according to the spatial ability factors?

• Is there a relationship between the spatial language in which students use geometrical-verbal tasks and their mathematical performance?

Limitations of the Research

• The research is limited to sixth-grade students in the fall semester of 2021-2022.

• For the qualitative dimension of the research, the participants are limited to those whose parents are allowed to participate in the research.

• The data of the study is limited to the answers given by the participants to the data collection tools, their performances during the activity and their expressions.

Assumptions of the Research

• Participants were prevented from influencing each other, and it was observed that they filled and answered the data collection tools willingly. Therefore, it was assumed that the participants gave sincere answers and expressed their thoughts or answers without being influenced.

• During the implementation, the researcher followed the process closely and intervened in situations that would adversely affect the research. For this reason, it was assumed that the participants did not engage in behavior and interaction that would affect the outcome of the research.

• The data were collected in the fall semester when the partial effect of the pandemic continued at the end of the process. Participants completed one semester in the 4th grade and the entire fifth-grade level with distance education. In this process, it is assumed that every student benefits from distance education opportunities and learning opportunities equally.

• Since the participants were randomly selected from schools in different socio-cultural environments, it was assumed that the quantitative data represented the sixth-grade students in the province where the study was conducted**.**

2. LITERATURE REVIEW

Looking at the content of this study, examining the relationship between spatial ability, language proficiency and mathematics achievement and examining students' spatial language use and spatial language strategies are investigated. Studies examining spatial ability and mathematical performance, spatial ability, spatial ability factors, language proficiency, spatial language, and finally, spatial language strategies are included in the literature.

2.1. Research on Mathematical Performance and Spatial Ability

Weijer-Bergsmaet al. (2015) investigated the effect of visual-spatial and verbal working memory on mathematical performance. Division, subtraction, addition and multiplication operation performances were examined in different age groups of primary school students. They found that while the predictive value of visual-spatial working memory for mathematical performance decreased with increasing age, the predictor value of verbal working memory increased as age increased.

Pirrone et al. (2015) conducted a study on teaching mathematics by manipulating and imagining block play for students between the ages of 10 and 12. As a result of this research, they stated that the effect of block play on mathematics was mostly due to mental images. The children are providing regular reminders through the manipulation of blocks' imagination which allows them to create a specific shape for their many images, and simultaneously consolidate it. In this way, they can obtain similar abilities and apply basic principles of mathematics and geometry which they learn gradually in school. They concluded that spatial visualization plays a mediating role in explaining the relationship between block play and mathematical skills.

Casey et al. (2015) conducted longitudinal research about relations of spatial, algebraic and verbal skills in first-grade through fifth-grade girls. It is found that early spatial skill is a predictor of numerical skills math reasoning skills and algebraic skills. Verbal skills indirectly mathematical reasoning. Spatial skill predicts schematic representations, and computational skills when solving higher-level number and algebra problems. It is explained that when doing mathematics, students must generate mental representations.

Especially, in not well-defined mathematical problems, students must transform verbal numerical information into spatial array representations of equations of the problem.

Lauer and Lourenco (2016) examined the effects of Spatial Processing on mathematics and spatial ability at an early age in a study conducted between infants 6 to 13 months of age. In their study, they performed the measurements with the visuospatial change-detection task. Based on the results found, Spatial Processing predicts mathematical and spatial competencies. Also, early spatial processing skills supervise symbolic and math concepts at 4 years of age.

Green et al. (2017) demonstrated that children and adolescents (6 to 21 years old) correlated various mental representations, showing that fluent reasoning predicts future mathematical performance. Their research with longitudinal cohort sequential design made measurements with an interval of 1.5 years. It was found that there was a positive medium-level relationship between mathematical fluency and applied problem and language proficiency, while a positive high-level relationship was found with spatial ability.

Kovacevic (2017) studied spatial reasoning in mathematics education in teaching and learning geometry at the university level. The researcher stated that students generally lack spatial experiences not only in 3-D objects but also in 2-D objects and relations. It is important to comprehend geometrical concepts and principles first and then apply the acquired knowledge when solving spatial-based mathematical problems. Geometry education should be used as a means of developing students' spatial-visual skills and deductive reasoning in logical thinking. Graphical programs provide more complex visuals, including protector geometry. These programs can be utilized in advanced geometry education.

In the study they conducted on preschool students by Rittle-Johnson et al. (2019), they found that when language ability was controlled, spatial ability and repeated patterning and spatial ability were related and were separate predictors for mathematical success. To increase mathematics performance, especially numeracy knowledge, it has been suggested that scaffolding can be done for student development by making teacher-guided block plays implementations.

In the longitudinal research conducted by Frick on 119 students in 2019, it was found that the spatial ability in the preschool predicted the success of second-grade mathematics and geometry in the research conducted at the first and second-grade levels. They conducted research based on early spatial transformation skills and basic calculation skills. Accordingly, the ability to create mental rotation and spatial scaling arithmetic operations, numeric-logical and spatial functions as well as geometry cross-sectioning, and perspective taking allows a better understanding of abstract mathematical concepts with spatial simulations.

Mix (2019) focused on the possible reasons for the relationship between mathematics and spatial ability in his research. He concluded that the relationship between mathematics and spatial ability is valid for all spatial subskills and the entire mathematical domain. Possible reasons are the spatial ability to decode the symbolic representations in mathematics according to the spatial locations of the mathematical equations and diagrams. Secondly, creating maintaining and manipulating mathematical models with symbols (i.e., numerals and operational signs) can be done by mapping mental representations to real-world problems. Thirdly using spatial representation and tools (i.e., number line) to understand mathematical terms.

In a study including 250 third-grade students, Gilligan et al. (2019) examined the effects of extracurricular spatial training programs that consisted of implicit and explicit instructions on student spatial ability and mathematics success. For spatial ability, the effects of practicing mental rotation and spatial scaling trainings with educational videos and feedback on the success of missing terms problems, number line estimation tasks and geometry tasks were examined. A weak to medium positive correlation was found between mathematical tasks and spatial ability. Effects on proportional reasoning and mental visualization abilities, far transfer from spatial scaling and mental rotation. Except for the geometry task, they found that the spatial trainings consisting of implicit and explicit instructions did not change the effect on success.

Mix et al. (2021) conducted research on 258 first-grade and sixth-grade students. Their pretest spatial training and posttest training consist of spatial visualization training and Form perception/Visio-spatial working memory training regardless of the kinds of training and notational spacing, place value, word problems, calculation, missing terms/algebra problems, and number line estimation.

Geary et al. (2021) examined the predictors of mathematical competency in the research they carried out on students from 6 to 7 classes. They based their study on the variables of mathematical aptitudes, complex spatial abilities, verbal memory, visual-spatial and verbal working memory, mathematical anxiety, attentive behavior in class and intelligence. When 6^{th}-grade mathematics achievement was taken under control, they found that while spatial ability and in-class attention were the most important predictors for 7^{th}-grade math achievement, word reading achievement was not as a plausible predictor as these variables. The largest gains in mathematics proficiency are in the groups of participants with average-above average spatial ability.

Safrina et al. (2021), in their study on 30 students, examined spatial training and geometry problem-solving skill development in the eighth grade. The training program was performed 5 times in sessions between 80 and 120 minutes. As a result of this study, improvement was observed in students' geometry-solving skills. In addition, it was found that students with high spatial ability plan the problem-solving process more easily and understand the questions.

Wulandari et al. (2021) conducted a qualitative study on two students with IQ in the superior intelligent category, to find out which sub-domains (verbal, spatial, numerical, social science, and mechanical ability abstract thinking) are used by students with different IQs while solving mathematical problems. As a result of this research, a distinction was made according to the problem-solving stages of Polya. They found that spatial relationships and numerical ability were used together in understanding the problem and planning stages. In other stages, the participants used their abstract thinking, speed-accuracy,and numerical ability abilities.

Hawes et al. (2022) conducted a meta-analysis study about the effects of spatial ability training in mathematics. The findings are that the usage of concrete materials in training is more effective than computerized training. The training becomes more efficient by increasing age from three to twenty. Spatial training improves spatial thinking, mathematical understanding as well as mathematical performance. They suggested that spatial training is not separate from mathematics, and spatial training can be inserted in mathematics and the curriculum of mathematics should be “spatialized”.

Johnson et al. (2022) examined the relationships between spatial ability and mathematical skills according to sex, age, and socio-economic status in their study on 1592 preschool, third and sixth-grade students. Mathematics spatial performance of students in the high-income group outperformed then other groups. They argued that boys' spatial performances are better than girls’ in all age groups. Therefore, it was found that in mathematics performance of girls was better than boys, except for the preschool group. They found that the relationship between spatial ability and mathematical skills was separate but correlated as a latent structure for all variables.

2.2. Research on Spatial Ability and its Factors

Newman et al. investigated the impacts of structured block play training on spatial ability with measured brain activities in 2016. In the measurements, activity was detected in spatial processing and spatial working memory. Improvement in reaction time and accuracy was observed in group trainees. No significant improvement was detected for the mental rotation task.

Haciomeroglu (2016) conducted research on 348 high school students who took advanced calculus courses. In this research, he found that verbal-logical reasoning ability, spatial ability, and mathematical performances were significantly correlated each other. In the study, object visualization and spatial visualization were found to differ according to cognitive styles. While spatial visualizers found higher spatial abilities than object visualizers, no difference was found between their mathematical performances and verbal skills.

Bokhove and Redhead (2017) conducted a study on 85 seventh-grade students, and a training application including building a house with 3-D cubes was made. These training programs examined the effect on performance in standard mental rotation tests. The performance of the mental rotation test depends on accuracy and speed. As a result of the training, they found that while accuracy increased, there was no decrease in speed. They stated that it is difficult to explain and learn mental rotation. Since MR skill improves general mathematic ability, they suggested that trainings that improve general spatial ability should be added to the mathematics curriculum.Permatasari et al. (2018) studied the spatial ability of slow learners. Which differences they possess when learning and which aspects of spatial ability are needed and strengths for those learners. They found that when the position of objects is changed, they can describe the other shape of them. They know the materials of objects and describe them from other perspectives. However, they have struggled to rotate and describe relations with the same objects.

Lowrie et al (2019) investigated the effect of spatial reasoning skills, especially spatial visualization, on mathematical success in their study of 327 fifth and sixth-grade students. Three-week period of spatial visualization interventions was applied. They improved the mathematical performances of the intervention group in geometry tasks and word problems more than the control group. They found that there was no difference in graphic problems compared to the control group.

Hawes and Ansari (2020) examined possible relationships between spatial visualization skills and basic numerical competencies in their study. Explanatory accounts are Spatial representation of numbers, shared neural processing spatial modeling, and working memory. Moreover, they studied which spatial visualization abilities are malleable and transferable to numerical reasoning. They hypothesized that spatial training might help numerical reasoning with the following accounts. Number representations may be more precise in mental number lines. Spatial modeling may help strategy usage in numerical tasks. Shared neural processing is spatial training change and improves neural activities in numerical reasoning. In terms of Working memory, spatial training is like working memory training.

Eilam and Alon (2019) conducted research on first and fourth-grade students about spatial orientation skills namely object structure perceptive taking skills. In this study, Perspective taking performance and mathematical achievements were examined. They found that spatial orientation ability was positively correlated with Math achievements, while negatively correlated with egocentric error. It was found that, while the mathematical performance was higher with the achievements of the fourth-grade students, the spatial orientation performance of the first-grade students increased more as a result of the implementation. They found that using multiple spatial strategies when doing spatial orientation-related problem-solving improves perspective-taking performance. In addition, it was found that young participants had difficulty in imagining views from different sides in tasks with low visual hints (e.i. Dept and details of shapes).

2.3. Research on Language Proficiency

Vukovic and Lesaux (2013) investigated the relationship between linguistic skill and arithmetic performance in their study on 287 third-year students. They did mediation analysis. According to the findings of this study, general verbal skill is associated with the numerical reasoning of children. As a result, verbal skills support math comprehension and reasoning with numbers.

Chow and Ekholm (2019) examined the relationship between language ability and mathematical performance in first- and second-year students. Contrary to the studies in the literature that focused more on vocabulary, they were interested in vocabulary along with the syntax of the language (Word order rules of the languages). They found Syntax to be a powerful predictor of math performance. For receptive vocabulary, they stated that there cannot be the most predictive factor for mathematics learning for this age group.

Gomez et al. (2020) conducted a literature review examining the studies conducted between 2015-2019. The ones that contain studies about reading comprehension and mathematical performance of primary and middle school students in literature language proficiency were selected. In this study, they concluded that mathematics and reading skills are complementary skills for students. They stated that mathematical performance does not only consist of numbers and mathematical operations, but reading comprehension is required to understand relationships and solve real-word problems. They suggested that teachers should teach necessary strategies to reduce cognitive demands created by problems for students.

2.3.1. Research on spatial language

Ferrara et al. (2011) investigated the examination of spatial language in block play in a study with 36 young children aged ranged from 3 to 4.5. In the research, a block play situation was created with three types of parents namely, free play with blocks, guided play, and lastly, play with preassembled structures. In the guided play, parents and children produced a higher number of spatial words. It was found that spatial words were used very lowly in material-free spatial activities compared to those performed with block play. It is suggested that since block play encourages spatial language, it will be useful for teachers to use in their lessons.

Taylor and Tenbrink (2013) studied origami folding, a spatial visualization task, in 24 undergraduate university students. With thinking aloud while solving a task, the study investigated the discourse of spatial terms and their impact on the solution of the task. The findings of this study are that using new spatial terms different from instructions helped the success of spatial tasks. As the conceptual base is developing, spatial thinking is increasing in solving spatial tasks. In this way, it is recommended that spatial concepts vocabulary, especially spatial transformations, should be included in spatial training.

Farran and Atkinson (2016) examined spatial terms and representations of spatial language in spatial categories between the ages of four and seven. According to the study conducted on 75 children, children have three levels of understanding. First, they divided the relationship between specific understanding and fixed objects, secondly, abstract understanding as generalizing the relationship to any object, and finally, assuming that prototypical and non-prototypical examples are in the same category. In the last case, they gain an understanding similar to that of adults. Spatial categories evolve as you encounter different examples. According to the findings of the research, it was found that at the age of five, in and under, on, below, behind and in front, they began to understand the third level of spatial categories at six years and older. They suggest that left and right spatial terms cannot reach the last level of spatial category development in these age groups and that these terms should be investigated.

Miller et al. (2016) studied spatial language usage in spatial recalling performance for four-aged children. They have conducted two experiments. Firstly, performance during tasks requiring intrinsic reference frames (egocentric and allocentric) was improved thanks to providing verbal encoding namely location-descriptive cues and child performances were predicted from the description of a spatial task. Secondly, drawing attention to objects' relationships nonverbally supported the performances of children less according to the first experiment. They concluded that verbally represent relationships are potentially affected by developmental changes when selecting intrinsic references in spatial recall tasks.

Tenbrink et al. (2017) conducted a qualitative study in which they examined 48 young adults (ranging from 16 to 26) communicating in a spatial dialog. In this study, they had furnishing doll houses and spatial object arrangements made. As a result of this study, it was found that the tasks in which the spatial orientation information is too high do not always acquire the desired success. In addition, they found that word production and spatial relationship and success increased when the terms were more. Another result is that using too many words and doing too many essays in non-functional arrangements has no effect on success.

Ayrancı studied the development of language in childhood in 2018. It is stated that If language skills are not too advanced, academic success may not improve. For the development of eleven- and thirteen-year old children, it may be made group-based discussions and activities that encourage the ability to express themselves.

Borriello and Liben (2018) conducted a study on 41 preschool students and examined the effects of mothers on the spatial guidance of children during block play when they provided spatial guidance. The mothers were told about spatial thinking and developmental motivations, especially while playing games. The mothers in the control group were told to play as usual. It was observed that mothers who were given instruction produced spatial words and provided spatial guidance to their children. It was found that the children in this group used more spatial words and were more engaged in the process. They found that the use of spatial language is an important way to promote spatial thinking in children.

Miler-Zdanowska (2018) examined the spatial descriptions of fifty blind children aged range from six to twelve in his research. As a result of this examination, it was determined that they followed different strategies according to sighted people, differences in presenting information, and differences in the words they used. It has been determined that Spatial Narrative differs according to the experience gained and age. For the development of this ability, precise and detailed information about spatial relations is provided. They stated that the use of different strategies while acquiring spatial information did not differ according to seeing persons in their understanding and expression of spatial relations. They found that blind and seeing persons use similar spatial words. It is stated that especially for the development of the narrative features of blind individuals, people who undertake intermediary duties (teachers, parents etc.) have important responsibilities.

Bower et al. (2020) investigated the relationship between comprehension of spatial language and mathematics and spatial skills in their study on 192 3-year-old children. They aimed to find out that spatial language has a mediator role between spatial skill and mathematical skill and how socioeconomic status and gender variables affect this relationship. According to the results, it was found that girls have higher spatial language comprehension than boys, and those with high SES have higher spatial language comprehension than the low-SES group. In the relationship between mathematical skills and spatial skills, they found that it is a mediator of spatial language comprehension only for girls.

2.4. Research on Spatial Language Strategies

Lohman (1993) stated that while performing geometrical-spatial tasks, people with high spatial ability but low verbal ability apply the same spatial strategies, which may be because these people do not need to use different strategies.

Glück and Fitting (2003) investigated the differences in the use of spatial strategies and the use of strategy while determining the level of spatial ability in their literature review. As a result of this research, they focused on analytical and holistic strategies. According to them, more time is spent on analytical strategies while using less effort. They stated that while the use of holistic strategies remained the same in difficult tasks, the number of analytical strategies increased.

Lin (2016) investigated the effect of design training on spatial ability factors and spatial strategy selection. According to their findings, spatial visualization and relations factors affected the strategy selection. However, when choosing solution strategies, he found that the design group tends to use holistic strategies and the non-design group tends to use analytical strategies. He concluded that since mental rotation test scores and holistic strategies, one of the spatial solution strategies, are positively related, the strategies affect spatial task performance.

Hegarty (2018) aimed to determine the strategies used while performing mental rotation tests in his research on 47 undergraduate students. Although it was thought that spatial transformation skills were used in the tests, it was revealed that analytic skills were also used. It was observed that the number of participants using both strategies was high. The use of the global-shape strategy has increased the accuracy. He found that most successful students avoid mental imaginary and do diminish answer choices. He suggested adding parts that can use analytical strategies to mental rotation tests.

Suh and Cho (2020) researched spatial ability and creativity in three-dimensional designs in undergraduate interior design university students. They investigated which spatial ability dimensions are necessary for designs that require in three-dimensional volumetric exploration. They examined the strategy choices of individuals with different levels of spatial ability. According to the results spatial visualization and mental rotation are correlated in generating and creating 3-d designs. They found that the participants with high spatial ability turned to the form generation strategy, while the participants with medium and low levels to the additive approach strategy.

3. THEORETICAL FRAMEWORK

In this section, to provide a comprehensive understanding of the concept of spatial ability, its development over time in the academic literature is discussed. After examining the conceptual framework, definition ranges and factors of spatial ability, spatial language and spatial language strategies have been explained.

3.1. Spatial Ability

Human beings are social creatures that are constantly interacting with their environment (Indriyani et al, 2021). While maintaining a large part of their daily life, they spend interacting with the objects around them. In this process, their first designs the interactions they experience, and after passing through mental filters, they adopt and perform the behaviors that are most suitable for their purpose (Sun, 2019).

At every moment of being mentally active, the spatial ability is used at every stage of life by making some meaning in mind according to the physical properties, functioning and positions of the objects in space (Mohiuddin, 2022). Sometimes, there is a spatial ability behind what is done unconsciously. Spatial ability, we use it when parking the car, preparing suitcases, making maps, making quantitative comparisons and trying to locate a forgotten item. In addition to these, it is also used in surgical operations, software architectures, in the opening of the satellite route, in the arrangement of the intercontinental natural gas pipeline and especially in sculpting.

While "vivid imagining in the mind" (Galton, 1880) has served as the first definition of spatial ability for years, it has been differentiated and modified over the years. Lohman (1979) ; defined spatial ability as the ability to produce and manipulate concrete objects while preserving their originality by coding, remembering, transferring, and matching spatial stimuli. Linn and Petersen (1985) defined spatial ability as a skill to present, generate and remember symbolic, nonlinguistic information. Van De Wall et al. (2014), on the other hand, defined it as being able to perceive objects from different perspectives, to create composed and decomposed of these objects in mind, and to establish the relationship between two- and three-dimensional objects. According to Hendroanto (2015), he characterized relationships as the ability to visually understand, manipulate, rearrange, and interpret. Taking into consideration all definitions of spatial ability, it is an ability to comprehend physical properties, positions as well as functions of objects in space.

3.1.1. Factors of spatial ability

There is no consensus in the components of spatial ability. When the studies conducted in the historical process are examined, it is seen that researchers generally reach a common judgment as three factors, but they differ in the naming and definition ranges of these factors. Below are the leading factors.

Barratt (1953) identified spatial components in three main components namely spatial relations, spatial visualization, and spatial orientation. Spatial relation is the ability to rotate an object around a plane or axis entirely or partly. Then, rotated objects are checked to correspond to another figure in the same plane. Spatial visualization is the ability to visualize the spatial relations of objects in dynamic situations. Spatial orientation is the ability to decide which position you are looking at objects.

Lohman (1979) defined spatial ability as three main factors, including spatial relation, spatial orientation and visualization. He stated that each factor requires mental rotation. Lohman, while defining the Spatial relation, saw it as a skill that has mental rotation as its most basic element but that allows problems to be solved quickly. Spatial orientation is a skill that helps to decide the positions of objects according to reoriented oneself and imagined perspectives in space. Visualization, on the other hand, is a skill that is usually unspeeded in two-dimensional objects and enables the resolution of relatively complex tasks. Minor factors were stated as Closure Speed, Perceptual Speed, Visual Memory and Kinesthetic. These factors are the skills required for encoding, recalling, modifying and comparing spatial stimulus, which are the most basic features for spatial thinking. He noted that these minor skills only appeared on similar tasks.

Linn and Petersen (1985) were describing spatial components as spatial visualization, mental rotation and spatial perception. Spatial visualization is an ability to manipulate complicated spatial information that demands multistep strategies. Mental rotation is rotating objects with or without speed. Spatial perception is that spatial relations are induced orientation according to the subject’s own body.

Carroll (1993) divided spatial ability into five factors, including visualization, speed rotation, closure speed, closure flexibility and perceptual speed in this research. Visualization ability is manipulating difficult and complex visual patterns or handling visual stimuli materials efficiently with no time restriction. Speeded Rotation is manipulating simple visual patterns speedily by transformation and rotation. Closure Speed comprehending and recognizing an unknown or disguised visual pattern speedily without knowing it. Closure Flexibility is noticing and uncovering Concealed Figures or disguising a visual pattern speedily. Perceptual Speed finding same visual Pictures pattern or comparing one or more patterns accurately and speedily.

In the study conducted by Uttal et al. (2013), the spatial ability factors were made differently than the previous spatial ability factors. Here, the separation is made as intrinsic vs extrinsic and dynamic vs static. If an ability contained in an object's information is necessary for classification purposes, it is referred to as intrinsic. On the other side, between objects information is what is needed; then it is called extrinsic. Objects that move in the mind are classified as "dynamic", and objects that do not move in the mind are classified as "static". Here, intrinsic vs intrinsic and dynamic vs static pairs are grouped from spatial information depending on the situation (for example, intrinsic-dynamic, extrinsic-dynamic etc.).

In this study, Lohman’s (1979) main factors are used as a based. The purpose of taking the main factors created by Lohman is that these factors have similar or close definitions in different studies (Barratt,1953; Mc Gee,1979; Linn and Petersen,1985; Maier, 1994). The fact that students' spatial ability is good in some factors does not mean that their spatial ability is good in general (Permatasari et al., 2018). For this reason, in this study, aimed not only to focus on the effect on general spatial ability and mathematical performance, but also to investigate the relationship between spatial ability factors and mathematical performance.

3.2. Spatial Language

The language of communication established by using spatial concepts and spatial relations is called spatial language (Gilligan-Lee et al., 2021). The other definition of spatial language is encoding spatial relations about pairs of objects and object parts. Spatial relations and language are encoded familiar structures in language as well as spatial relations. This encoding identified good or bad if spatial relation in the configuration of object/s is similar to prototypical structures (Hayward and Tarr, 1995). However, spatial relations encoded in spatial language and spatial relations in memory reflect the same structures (Landau and Jackendoff, 1993). In the studies conducted with spatial language in the literature, it has been concluded that the usage of spatial language predicts spatial ability. (Pruden, Levine, and Huttenlocher, 2011; Miller et al., 2016; Simms and Gentner, 2019; Geary et al., 2021).

As a result of examining how spatial expression develops in children between the ages of two and four according to different languages, it has been concluded that in Turkish it is in the following order (Johnston and Slobin, 1979). The order of development of spatial terms is as follows:

1. In (içinde), on /over (üstünde), under /below (altında), beside /next to (yanında)

2. locative with featured objects: back (arkasında), between (arasında), front (önünde)

3. locatives with featureless objects: front (önünde), back (arkasında)

The types of spatial terms used by children at the early school age (6-12 years old) while creating a spatial definition and their Turkish equivalents are given. The spatial terms used are given in Table 3.1.

Table 3.1. Kinds of spatial terms

Spatial Terms	Turkish Translations
To where, everywhere, here, over here, from here, over there, until there	Nereye, her yere, buraya, buraya, buradan, oraya, oraya kadar
High: low, near: far, topside, straight forward, by the side below	Yüksek: düşük, Yakın: uzak, üst taraf, doğru, alt taraf
Ahead of, by, beside, close by, in front of, above, below, near around, to the left, to the right	Önünde, yanında, yanında, yakınında, önünde, üstünde, altında, yakınında, sola, sağa
Drive away, exit, pour, attach, pass, reach, impact	Sür, çık, dök, iliştir, geç, uzan, etkile
Far, upper, round, square, front, close, small	Uzak, üst, yuvarlak, kare, ön, yakın, küçük

* (Miler-Zdanowska, 2018)

In Turkish, "bottom" and "top" are used on the vertical axis to convey location in Turkish. "Side", "right" and "left" are used to describe objects that are on the horizontal axis. The spatial terms "front" and "back" are used to convey the location of an object on the front axis. At the intersections of these axes, the spatial term "cross" is often used. The most used spatial words in Turkish are as follows. The most frequently used spatial terms on the vertical axis are "under" and "above". The most frequently used spatial terms on the horizontal axis are "to the left", "to the right", "on the left side" and "on the right side". Other most frequently used spatial terms were; "above left", "below left", "above right" and "below right" which are used for objects located at the intersection of their two axes (Ata, 2018).

3.3. Strategies and Spatial Strategies

Spatial thinking has two components flexible strategy choice and meta-representational competence (Hegarty, 2010). It is important to examine strategies and how students represent their spatial knowledge. This study investigates language strategies when doing spatial-verbal tasks. Students' choices of strategies guide us to get cues about spatial ability. In the problem-solving process, a strategy is like a "roadmap" that consists of describing the problem and the appropriate technique(s) in order to solve this type of task (Gahamanyi, 2010). Students must choose appropriate strategies to solve spatial problems in mathematics. Because with using strategies students gain advantages in learning mathematics and developing mathematical skills like communication, creativity, problem solving and mathematical reasoning (Tambunan, 2019). These strategies demand particular spatial abilities in the problem-solving process. In this way, their choice of strategy reveals students' thinking (Mix, 2019; Hsing et al, 2022).

Different strategies are identified in previous research while doing spatial tasks. Barratt (1953), the first systematic attempt to understand via verbal cues, studied verbal reports about individual strategies in spatial tasks. He marked strategic movements namely folding the pattern, remarking on the relationships of the parts, searching for other cues such as angle intersections, rotating the entire figure or part of it, using abstract symbols versus relating some familiar or more concrete object.

Analytic and holistic spatial strategies are the most utilized strategies (Linn and Peterson, 1985; Burin et al., 2000; Sorby, 2009; Janssen and Geiser, 2010; Cohen and Hegarty, 2012; Eilam and Alon, 2018). Analytic spatial strategy (feature comparison) is handling the task step by step, part by part, with different perspectives, analyzing non-spatial features with focusing on colors and textures. Holistic spatial strategy (global strategy) handle objects with the help of transforming, rotating and manipulating objects. Analytic and holistic solution strategies link to spatial test performance, especially mental rotation tests that holistic strategies are correlated positively, and analytical strategies are correlated negatively. Owing to designed spatial training, students begin to use more holistic strategies (Lin, 2016). These strategies are used in different types of spatial tasks like mental rotating (Linn and Peterson, 1985) and visual-spatial task (Burin et al., 2000).

Egocentric and allocentric strategies are used to identify perspective-taking differences in spatial orientation tasks like reading maps and describing landmark objects (Fernandez-Baizana, 2019). Egocentric strategy is locating and reorienting objects with respect to us. Allocentric strategy is describing anobjects with surrounding, related to other object in which independent of the viewer's position.

Spatial strategies are also analyzed with language usage in the process of the spatial problem-solving process. This part is explained in the Spatial Language Strategies.

3.4. Spatial Language Strategies

Spatial language strategies have been variously named in the literature, such as coding strategies, discourse strategies, and verbal strategies. These strategies are provided a framework for verbal cues with spatial concepts or descriptions.

Encoding strategies were identified in the study of 3-D object configuration by Kyllonen, Woltz and Lohman in 1981. They are feature analytics, figure decomposition, verbal labeling and complexity reduction strategies. Feature analytic strategy is analyzed basic features like the number of different sides, irregular side orientations and side lengths. Figure decomposition strategy is that the subject imagines lines and breaks them into smaller units such as triangles and rectangles. The verbal labeling strategy is using verbal labels to describe figures adequately. The complexity reduction strategy uses two strategies together with decomposing figures and labeling them at the same time.

Tenbrink (2011) mentioned discourse strategies in describing complex arrangements objects descriptions are coded the position of objects according to another object or area. Object-based relata are that the location of an object is related to another object. Environment-based relata use environmental features. Speaker-based relata were described location with speaker self. Other relata are coded if the description includes more than one spatial relation.

Mizzi (2017) identified spatial language strategies in constructing 3-D objects. Founded strategies are spatial metaphors, object break-down strategy, assembling strategy, cubes controlling strategy, and structure controlling strategy. Spatial metaphors are used to express spatial knowledge and information with everyday metaphors, letter-based metaphors and mathematical metaphors. Object break-down strategy is breaking objects into several parts mentally to make them simpler. the assembling strategy is used to put together decomposed parts to return the original state of objects. the rotation strategy is rotating spatial objects around horizontal, vertical and frontal axis. The cubes controlling strategy is a metacognitive strategy that checks and verifies the construction process by the controlling number of cubes or parts. Structure controlling strategy is another metacognitive strategy that describers request builders to explain the current structured spatial object, and then compare original ones. The spatial language strategies defined by Mizzi (2017) are given in Figure 3.1 below.

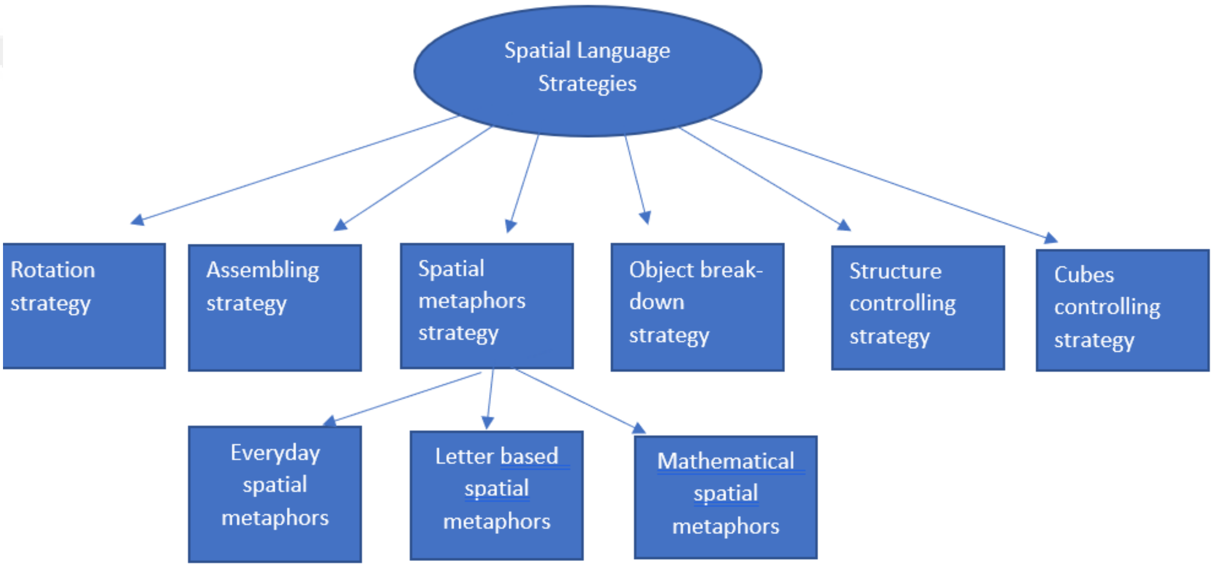


Figure 3.1. Spatial language strategies by Mizzi (2017)

Hegarty (2018) identified mental imaginary strategies and three feature-based, orientation-independent strategies with verbal protocols of participants. Mental imaginary strategies are mental rotation and perspective-taking. Feature-based, orientation-independent strategies are counting cubes, local turns, and global shapes. Firstly, mental rotation was imagining objects in which picking up objects, then turning, rotating or flipping them. Perspective-taking describes objects by imagining and looking at them from different orientations and positioning the body with respect to the describe objects. Counting cubes is to the count number of cubes in objects in different arms of them. Local turns are using directional terms (up, to the right, toward me, etc.) to explain the relative directions of the arms of the figure without rotating them. Lastly, global shape is paying attention whether the arms at the ends of the figure are parallel or vertical, or whether the three sides of the object form a plane.

In this study, the framework of Mizzi (2017) and Hegarty (2018) are assigned to identify sixth-grade students’ spatial language strategies. They are preferred because of enabling analysis of the comprehensive and broad spectrum of strategies for this study.

4. METHOD AND DESIGN

In this chapter, research methods and research design are explained in research design, the definition of population and features of participants are indicated, the used materials for research are stated instrumentation, the stages of research study progress are stated in the pilot study and the main study and lastly, data analysis are explained in detailed.

4.1. Research Design

This research investigated sixth-grade students' mathematical performance and its relationship with spatial ability and language proficiency. To better understand this relationship, the students' use of spatial language while completing geometrical tasks was also investigated.

In order to reach the research purpose, this research required using quantitative and qualitative approaches together. Despite this fact, the mixed method approach was preferred, and the convergent parallel mixed method was used as the research design. This method provides different types of information and point of view to explain both types of data (Creswell, 2014). Not only statistical data but also empirical inquiries were needed to get various sources of evidence. The combination of statistical data and participant experiences enables a better understanding of the research question in this regard; it allows research to be more extensive and creative (Creswell, 2014; Johnson and Onwuegbuzie, 2003). In this study, identifying strategies in the spatial language is required qualitative analysis, whereas it is easier to make more generalizable results about relationships between spatial ability. In addition to this, language competency and mathematical performance with quantitative analysis. For comparing and integrating results, quantitative and qualitative findings are combined and the connections between them are presented.

4.2. Participants

The participants were selected with a convenient sample method. Because it is easy to reach, and it is easy to obtain permission from schools in the city center schools. The sample selection process is decided on convenience in time and availability, economic conditions, and location for researchers (Merriam, 2013). The study was conducted in one of the city centers, a middle-sized population, in the Eastern Anatolia region. This study consists of 196 sixth-grade middle school students (N_{GIRLS} =88, N_{BOYS} = 112) from six middle schools in different social-cultural environments (low, medium and high socio-economic status) in the fall semester of 2021-2022. In school selection, it was taken into consideration that schools were accompanied and helpful to researchers in implementing research instruments. 196 students participated in the collection of quantitative data and 12 students from those participating in the collection of qualitative data.

Given that four students out of all participants (n=200) did not complete all quantitative data collection tools, the research was performed using data from the rest of them. For the second part of the research, 16 Students' parents gave permission. Four of them participated in the pilot study, and eight of them participated in the main study. The researcher selected the students who were willing to participate in the convenient sampling type for this research. The study had approval from a local university. Permissions from the Ministry of National Education and parents were obtained for the ethical study.

For all grades in middle schools, students were receiving mathematics instruction for five lesson hours a week based on the national mathematics curriculum. Moreover, mathematics course is generally given up to two hours a week as an elective course. The mathematical curriculum includes four learning subdomains namely Numbers and Operations, Geometry, Measurement, and Data Processing. Turkish lessons are given 5 to 10 lessons per week (1st -2nd grade 10 hours, 3rd-4th grades 8 hours, 5th- 6th grades 6 hours ,7th -8th grades 5 hours).

During the Corona pandemic period, the participants were in the 4th and 5th grades, and they had to complete their education through distance education. While the data was being collected, students returned to their classes for the course. But they had to wear a mask and stay a distance being at least two meters from each other in a classroom environment.

4.3. Data collection

In this study, data will be collected through C-test, Spatial ability test (SAT), Mathematics exam results, video recordings and interview. Original version of the C-test and SAT are given in Appendix 2 and 3.

4.3.1. C-test

C-test is used for language proficiency skills for native speakers' reading abilities (Taylor, 1953). It is stated by Harsch and Hartig (2016) that the C-test, which is applied to determine the level of Turkish language proficiency, measures metacognitive strategies as well as grammar and skill. As a result of the research conducted in 2018, Demiralp developed the C-test, which was adapted into Turkish with 5 items. C-test is a cloze test that deleted words should be completed based on the meaning of contents. 5 Paragraphs have twenty "fill in the blanks" parts for word completion. Contents of items were derived from everyday life. The beginning of the test has an example sentence. C-test takes sixty minutes. Cronbach's alpha coefficient was found to be .96. The scoring of the Turkish C-test is done according to the dual system. Each answer is given 0 or 1 depending on whether it is completely correct or not. Alternative answers are considered correct if there is no change in the meaning of the sentence. If there is a typo, 0 points are given. The highest score is 100, and the lowest one is 0. Permission for C-test was given by Demiralp via email. Given some items of the C-test and their alternative answers as shown in Table 4.1.

Table 4.1. Example of alternative answers of Turkish C-test

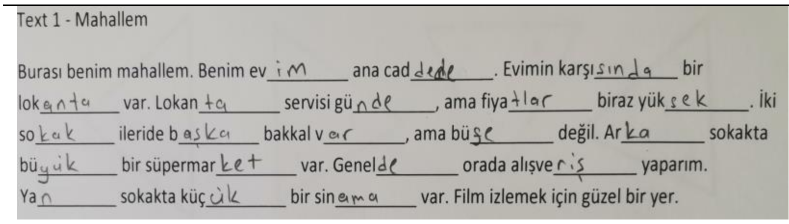
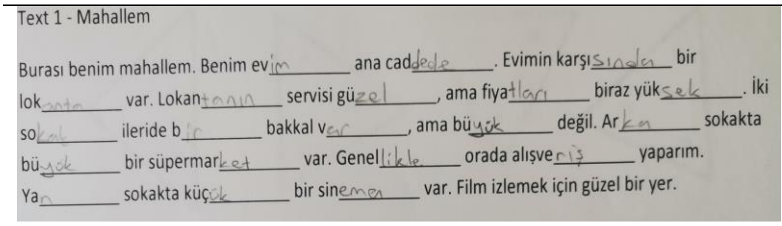
Students C-test sheets	Alternative answers
 Text 1 - Mahallem Burası benim mahallem. Benim ev_im_ ana cad_dede_. Evimin karşı_sında_ bir lok_anta_ var. Lokan_ta_ servisi gü_nde_, ama fiya_tlar_ biraz yük_sek_. İki so_kak_ ileride b_aşka_ bakkal v_ar_, ama bü_şe_ değil. Ar_ka_ sokakta bü_yük_ bir süpermar_ket_ var. Genel_de_ orada alışve_riş_ yaparım. Ya_n_ sokakta küç_ük_ bir sin_ama_ var. Film izlemek için güzel bir yer.	Bakkal ↔ Büfe Market ↔ Buffet Genelde ↔ Genellikle

Table 4.1. Example of alternative answers of Turkish C-test (continued)

Students C-test sheets	Alternative answers
 Text 1 - Mahallem Burası benim mahallem. Benim evim ana caddede. Evimin karşısında bir lokanta var. Lokantanın servisi güzel, ama fiyatları biraz yüksek. İki sokak ileride bir bakkal var, ama büyük değil. Arka sokakta büyük bir süpermarket var. Genellikle orada alışveriş yaparım. Yan sokakta küçük bir sinema var. Film izlemek için güzel bir yer.	In general ↔ Usually Bir ↔ Başka One ↔ Another

4.3.2. Spatial ability test

It was developed by Göktepe Yıldız in 2017 for secondary school students (6th ,7th, and 8th-grade students). It is a paper-pencil test. The test has twenty tree items. It consists of seven sections. It was prepared based on spatial ability components defined by Lohman in 1993. Spatial ability test (SAT) also measures factors of spatial ability, namely spatial relations, spatial visualization, and spatial orientation.

Spatial Relations: 1st and 4th sections of SAT are related to spatial relations. 1st and 4th sections are about rotating two-dimensional and three-dimensional figures. The 1st section has of 2-dimensional figures in rotating forms and the 4th section consists of 3-dimensional figures in rotating forms. In these sections, it is wanted to find out the rotating figure which is not the same as others. Question examples containing 2-D and 3-D figures activities are given in Figure.4.1.

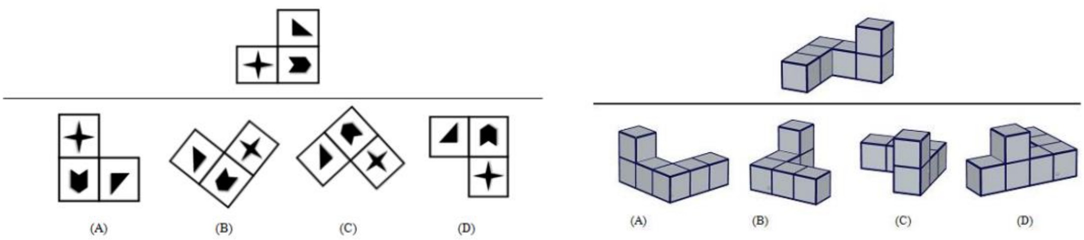


Figure 4.1. Examples of spatial relation questions

Spatial visualization: 3rd and 6th sections of SAT are related to spatial visualization. In the 3rd section, there are two-dimensional figures and possible parts of the two-dimensional object. Students decide to assemble which parts should be used to turn part into whole. For the 6th section, which two-dimensional figure is folded to make the 3-dimensional given object. Third- and fourth-part question examples Figure 4.2. given.

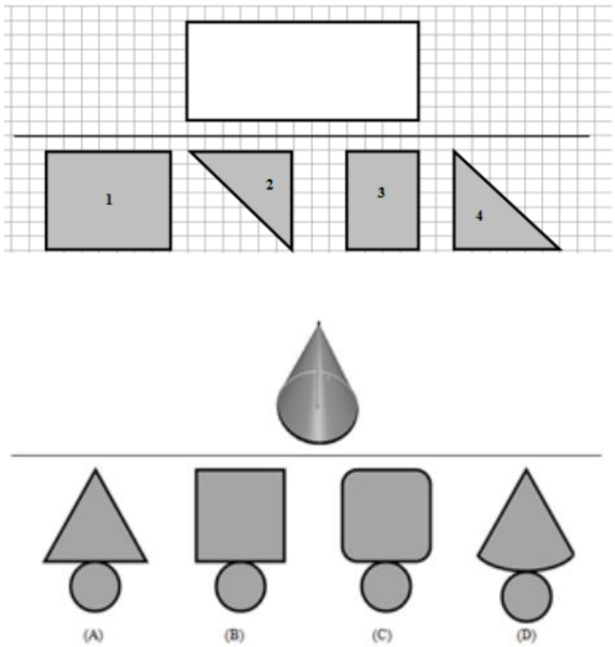


Figure 4.2. Examples of spatial visualization questions

Spatial orientation: 2nd ,5th and 7th sections of SAT are related to spatial orientation. The 2nd section consists of open-ended questions. They are about placing some objects in the center of the coordinate system and deciding and estimating the directions of objects based on the central objects. The second part question example is given in Figure 4.3.

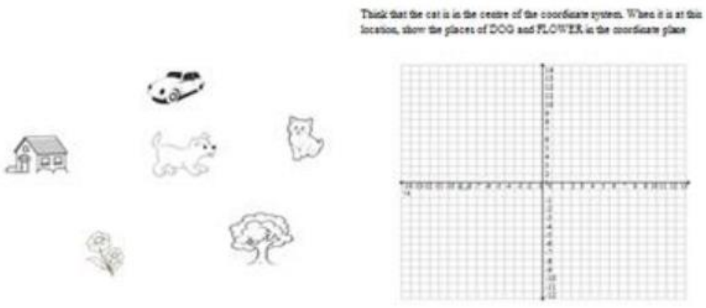


Figure.4.3. Example of second part (spatial orientation)

The 5th section is about perspectives of three-dimensional that objects. that is like somebody looking at the object's predetermined directions and finding out two-dimensional views of objects. In the 7th section, it is given upper, above, and side views of an object and students must consider of different sides of the object to find out the original three-dimensional object. The fifth and seventh section question examples are given in Figure 4.4.

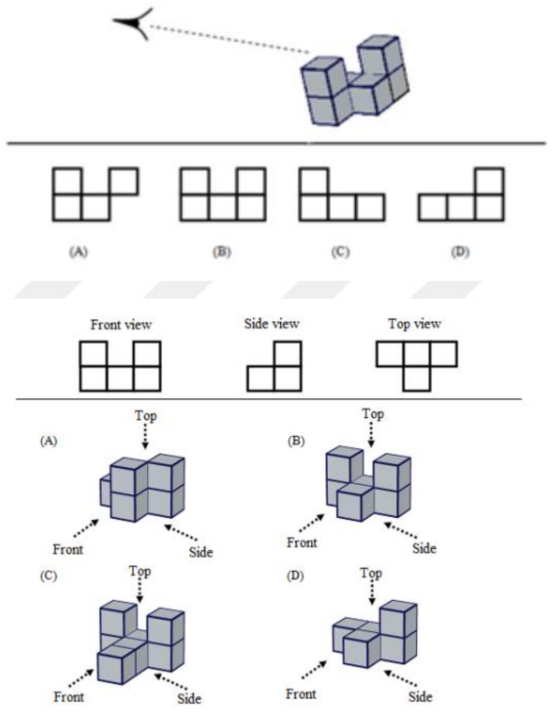


Figure 4.4. Example of spatial orientation questions

Scoring is done by giving "1" for correct answers and "0" for incorrect answers. For two open-ended questions, participants can have full scores if two figures should be placed in the coordinate system correctly. The highest score "23" and lowest score "0" can be taken from the test. Permission for C-test was given by Göktepe Yıldız via email.

4.3.3. The mathematical exam results

The mathematics exam result was the first mathematic exam in 6th grade in fall semester. Mathematics exams are prepared by their teachers. They included three main subjects namely operations with natural numbers, multipliers and multiples, as well as sets. These exams contain ten open-ended questions related to the relevant topics. This exam was administered to the participants during one lesson. During the examination process, students were prevented from influencing each other. As a result of this exam, each teacher prepared an answer sheet, and students' achievements were evaluated according to this prepared rubric. As a result of this evaluation, the lowest "0" score can be obtained, while the highest "100" score can be obtained. A high score indicates high mathematics achievement, while a low score indicates low mathematics achievement.

4.3.4. Video recordings

All groups were video recorded during the construction of 3D objects with Legos. Later, a transcription of these video recordings was made. After these transcriptions were made, the videos were checked again by the researcher to reconfirm the data. These transcriptions were analyzed by the researcher with content analysis according to the theoretical framework shown in Table 4.2.

4.3.5. Interviews

During the implementation, students were expected to fulfill eight tasks. At the end of each task, semi-structured interview questions were asked of the students. These interview questions were created after the pilot study. Since the purpose of this study is the analysis of spatial language, attention to detail is given. If there were parts in the students' explanations, prompted questions asked to be clear enough or understandable. The main point of the interview is to reveal the places where the students have difficulty during the implementation.

In the interview, the students were made to feel comfortable, and they were encouraged to say whatever came to their minds. To prevent important explanations, students are video recorded during the spatial language task. These recordings are converted into transcriptions.

4.4. Research Process

In this section, all the research the process is summarized in general. Determining the general outline of the research, data collection process, data analysis and reporting of the data were carried out respectively. The data collection process and data analysis are discussed in detail in the following sections. The research process planned and followed by the researcher is included in the figure Figure 4.5.

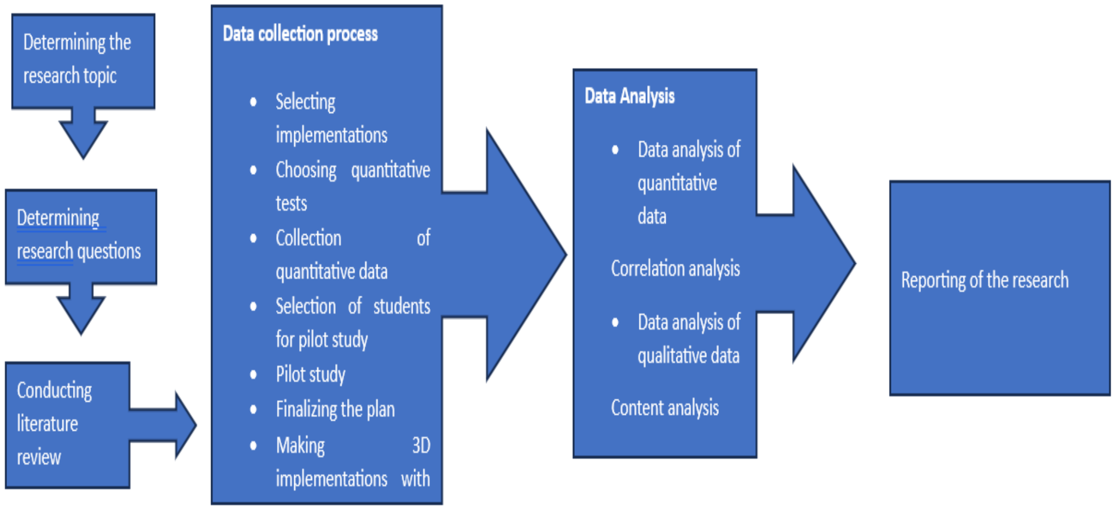


Figure.4.5. Diagram of research process

4.4. Data Collection Process

In this section, it is explained which steps were taken during data collection during the research. Following the purpose of the study, a literature review was conducted. The researcher determined the tasks and data collection tools as a result of the literature review. As a result of the evaluation made by the researcher with the domain expert, it was decided to make four different implementations. First, these four different implementations were piloted. The pilot study is explained in detail in the pilot study section. The final plan for how implementations will be put into practice and how the study data will be gathered has been specified as a result of the pilot study. These stages are respectively selecting the implementations, choosing quantitative test, collecting data from the quantitative tests, conducting the pilot study, finalizing the plan, collecting the data from the quantitative tests, selecting the students, and finally making the 3-D implementation with the selected students with Legos. The data collection stages as shown in Figure 4.6.

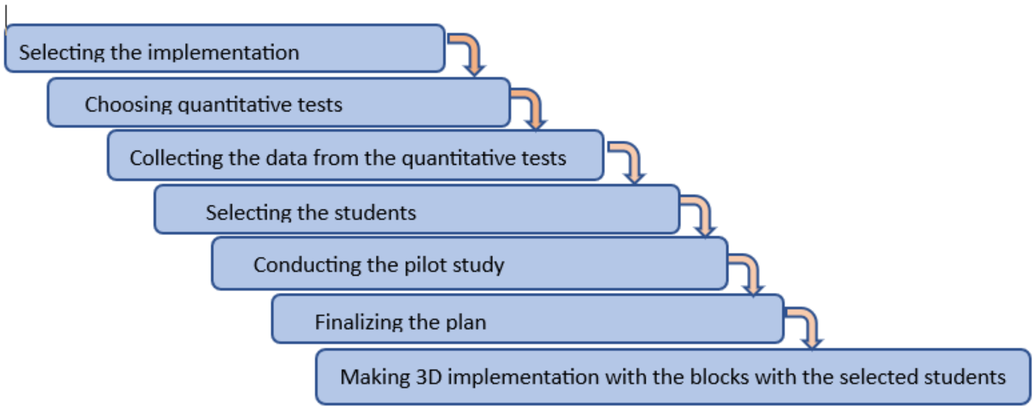


Figure 4.6. Data collection process

4.4.1. Selecting implementations

To determine the implementations, first, a literature review on spatial ability was conducted. As a result of this review, it was determined that qualitative research on spatial ability was generally carried out with paper-pen, computer-based implementations and lastly 3-D objects (Baran et al., 2007; Eilam and Alon, 2019; Bower et al., 2020). Paper pencil tests and computer-based implementations generally appear to be about reading comprehension and applying the instructions without thinking deeply. Since these situations are not suitable for the purpose of this study, these two implementation types were eliminated. Since the structure of implementations made with materials is more flexible, an implementation model was sought that would reveal the mathematical and spatial communication between individuals. In addition, for the purpose of the study, block playing games (Pirrone et al., 2015) were sought in which the students would use their imagination and manipulation skills.

In line with these purposes, four implementations in Mizzi's doctoral thesis published in 2017 were selected. These implementations include making shapes with Legos in different situations (face-to-face and backward). The practices chosen had some advantages for this research. These advantages are that it encourages group work and enables the collection of data on spatial language skills under natural conditions with the help of communication skills (in terms of sender and receiver).

4.4.2. Choosing quantitative tests

As a result of the literature search for the collection of quantitative data, it has been determined that spatial ability tests measure commonly one of the spatial ability factors (for example, spatial visualization). However, this study aimed to examine a few different factors of ability. It was decided to use the SAT, which was created by Göktepe Yıldız (2019). Because this test is based on Lohman's (1979) study and tests three separate aspects of spatial ability. This is explained in detail in the SAT instrumentation section.

In using spatial language, it is aimed to measure the general language proficiency of the students, since it is important that students convey their spatial thinking in a fluent way. For this reason, the C-test prepared by Demiralp (2018) was preferred because it provides the measurement of fluency, correct usage, and vocabulary in students' language use and is easy to apply. This is explained in detail in the C-test instrumentation section.

4.4.3. Collection of quantitative data

The collection of quantitative data was taken in two lessons. The students were informed about spatial ability in terms of its importance and where it is used. It was given great importance to answer all questions and comments. Thus, students' interest in the tests increased. The tests were applied in the classroom environment. The C-test was performed in one lesson hour. Before starting the C-test, the rules were explained, and an example of C-test content was done with the class.

SAT was applied in one lesson hour. Rules and instructions for SAT were explained. Attention was drawn to the examples before each chapter. Students encountered the coordinate system for the first time. Before the second section of the test started, the coordinate system was explained with an example. the example included their school environment. Landmarks around schools and their placements were explained on board.

4.4.4. Selection of students for pilot study

It was planned to select the pilot study students primarily according to the information obtained from the quantitative data. Permission for the study was requested from the parents of the students. No criteria were used to choose the students because there wasn't sufficient parental permission collected. The students who were given permission from their parents and the students who volunteered to participate in the study were selected.

4.4.5. Pilot study

A pilot study was conducted to test the qualitative part of the research. Four students from two different schools were chosen (N_{GIRLS} =2, N_{BOYS} = 2). The pilot study was carried out to improve the efficiency of block play implementations in terms of time and finalize interview questions.

The fact that there is no time limit for the spatial language prevented the students from feeling more comfortable in the block play and the interviews. It was done to prevent the time constraint of the students from creating a stressful environment and affecting the interaction. After the implementation was carried out with two groups, it was seen that one class hour could be sufficient for the implementation. According to students' questions and their attitudes toward the instruction, the data collection process was redesigned. Instructions were made clearer to understand.

Firstly, students made two people groups. Group members were given roles as "describer" and "builder". First of all, students were informed about block games. The rules were explained, and the students were advised to feel comfortable. In the first activity, the describer's back is turned to the builder. Thus, the builder was prevented from seeing the Lego model that was previously made and given to the describer. Hence, two spatial products were made in a way. Afterwards, the students were seated face-to-face in the second activity. Two products were built in order. Here, while the builder did not see the models, the describer was allowed to see the model made by the builder. When the describer thought something was wrong, the describer could intervene the process. At the end of all activities, interviews were conducted for each block game. In general, they were interviewed about the parts that they had difficulty in. There are three main reasons for choosing the two activities and methods used in practice. The purpose of doing the backward activity is to understand how the describer and the builder use the spatial language only when they hear it, without seeing it. The first is to reveal language use and group interactions when the describer does not see the product the builder is building. The purpose of choosing the face-to-face activity was applied to determine the impact of how describers saw the thing while it was being built on how they used spatial language. The second is to reveal language usage and group interactions when the describer sees the constructed object of the builder in the process. Lastly, the third is to reveal the similarities and differences between these two different situations.

4.4.6. Finalizing the plan

It was decided to make some changes in the main study thanks to the findings obtained in the pilot study. Describer is wanted to use spatial language dominantly during the spatial language task. However, that made collected data more insufficient, and students behaved more rigidly. So, in the main study, students were allowed to interact freely. The outline of the interview questions was created in the pilot study. In addition, the students were asked to re-tell the parts that were not understood in their explanations at the end of the implementation. As a result of the planning, the tasks of the participants and the researcher become clear. These roles are detailed below.

4.4.6.1. The role of the researcher

The researcher is the person who plans and implements the research. Before starting the implementation, the materials to be used in the process were prepared by examining the literature and taking expert opinions (spatial 3D objects with Lego and pictures of real-world spatial objects). It has decided how the main implementation will be made and how it will act as a practitioner during the implementation process with a pilot study. During the main study process, she arranged the environment and the seating arrangements. The participants were given information about the activities in the implementation. During the process, she made explanations to the participants about the questions about the process (for example, reminding them that there is no time limit, etc.). Therefore, the researcher did not interfere with or explain either the describer’s or the builder's explanations or work. Only the participants used encouraging statements while doing the activities in the process (…You have done well so far. You can tell, you can do etc.).

4.4.6.2. The role of the describer

In the group work, the 3D spatial object was given to the describer by the researcher. The describer is assigned to explain how to make the object to the builder. The describer does not show the object to the other group member. Moreover, they cannot interfere with the object's integrity.

4.4.6.3. The role of builder

In group work, a builder oversees creating the 3D object with blocks in line with the describer's instructions. During the implementation, the builder can talk to the describer about the construction process. The builder can ask the describer questions about the object.

4.4.7. Making 3D implementations with Legos with selected students

The implementation of research includes depicting 3D objects using spatial language in different ways. A quiet environment for implementation is important in data collection so, implementation was done in school libraries. At the beginning of it, the rules were explained to the students. Before starting the implementation, they were asked to express themselves freely. It was mentioned that making as many explanations as they could enrich the research. Participants were asked to choose their partners while forming the group. Because being friends in group studies increases group productivity and effectiveness overall (Zajac and Hartup, 1997). After the definitions of the roles of descriptor and builder, the students were allowed to decide on task sharing. The implementation is a description and construction of four products as a group. Legos are used to create three-dimensional objects.

Figure 4.7. The Lego models of spatial language task

The first two Lego models from the left made before are given to the describer in the Figure 4.7. The describer is given three-dimensional objects previously made of Lego. In this implementation, two kinds of activity are conducted namely backward activity and backward activity.

Figure 4.8. The seating arrangement for backward activities

Two Lego models were made with the descriptor's back facing the builder in the Figure 4.8. The other two Lego models were made in the form of students sitting face to face in the Figure 4.8 .If the descriptor did not explain enough or if the builder was confused, the builder was able to ask whatever he/she wanted. If they thought they had made a mistake, they were allowed to do it again. The group members had the authority to finish the process whether they completed it or not.

Figure 4.9. The seating arrangement for face-to-face activities

4.5. Data Analysis

In this section, data analysis of quantitative and qualitative data was mentioned. The framework of data analysis in qualitative data was explained in detail. The coding, keywords and explanations used while performing the analysis were presented in tables.

Data collection processes were briefly summarized in this paragraph. Quantitative and Qualitative data were collected concurrently. Quantitative data was collected with SAT and C-test and analyzed with correlation. The qualitative data collection process was decided after the pilot study. The main study consists of the Lego construction of 3D objects. Content analysis is used in qualitative data analysis. Results of quantitative and qualitative data analysis obtained through merging, comparing, and relating data. Lastly, all obtained results were interpreted together. Implementation was led by the study plan in the Figure 4.10

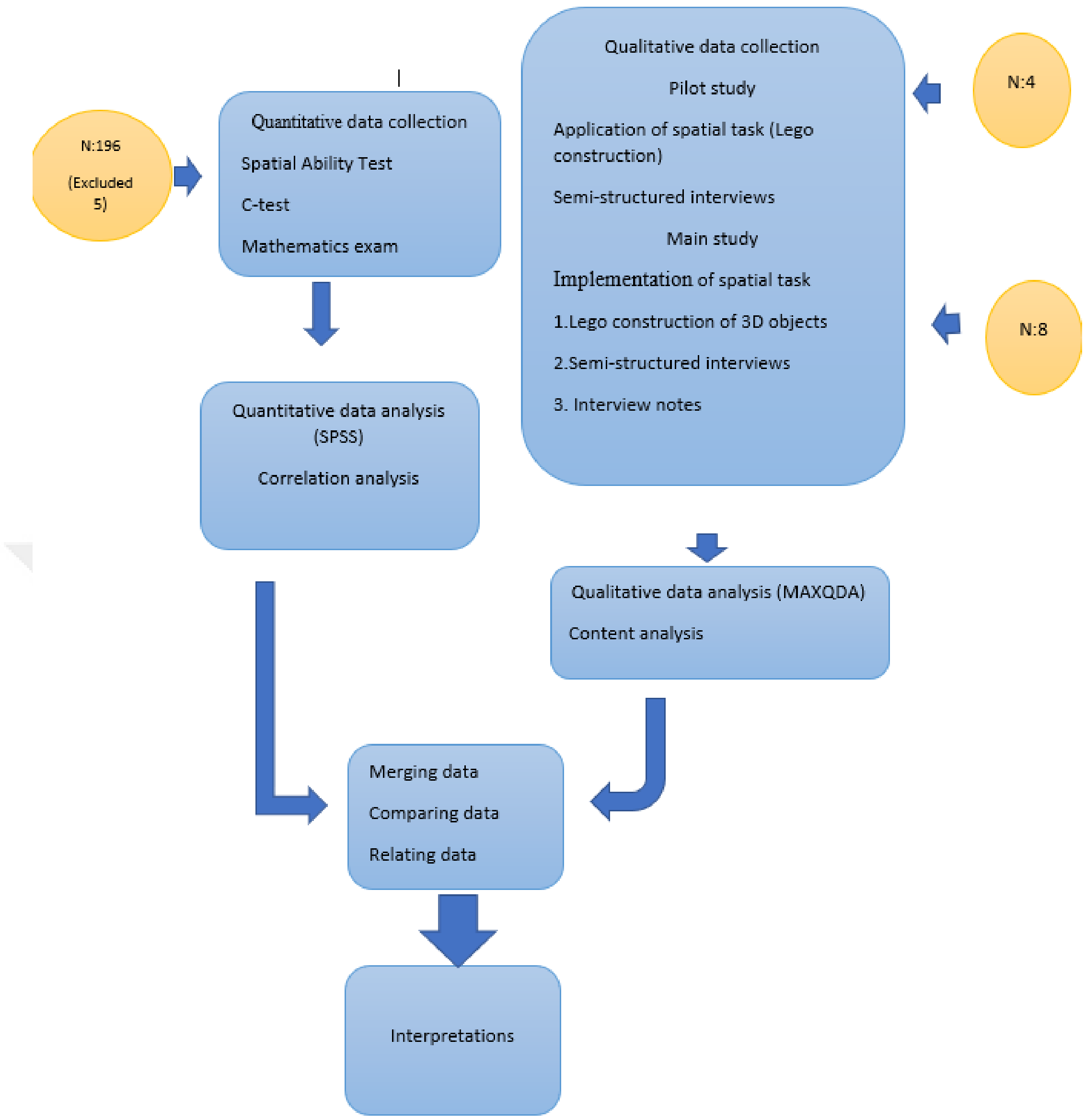


Figure 4.10. Diagram of implementation of the study

4.5.1. Data analysis of quantitative data

In this study, first of all, the scores of each of the students on the SAT and C-test were calculated. While calculating the scores, the test answer key prepared by Göktepe Yıldız (2017) for the SAT was used for scoring. While scoring, the total score for each student was calculated by giving "1" points for the correct answer and "0" points for the incorrect answer. The highest score a student can get from the SAT test is "23", while the lowest score is "0". A high score indicates high spatial ability, while a low score indicates low spatial ability. A score of “0” indicates the lowest level of language proficiency, not the absence of spatial ability.

Secondly, in the scoring of the C-test, which was prepared as a fill-in-the-blank test, the total score for each student was calculated by giving a score of "1" when correct words were written in the blanks, and "0" in cases where semantic integrity was broken, or wrong words were written. While the highest score that the student can get from the C-test is "100", the lowest score is "0". A high score indicates high language proficiency, while a low score indicates low language proficiency. A score of “0” indicates the lowest level of language proficiency, not the absence of language proficiency. These scores were loaded into the SPSS 26 program and analyzed.

To understand which analysis method, the data were suitable for the data, normality tests were applied to the data as a first step. Skewness (.06, SE=.174) and kurtosis values (-1.046, SE=.346) of mathematics scores, skewness (.573, SE=.174) and kurtosis values (-.165, SE=.346) of SAT scores have the necessary conditions for a normal distribution. When visually examined, it is observed that Mathematics exam results and SAT graphs are relatively bell-shaped distributions in histogram graphs. Again, when the box plot was examined, it was found that there were no outliers. When all these data were examined, the SAT and mathematic exam results of the data supported the assumption of normality.

It was determined that the skewness (-2.325, SE=.174) and kurtosis values (5.053, SE=.346) of the C-test scores were not in the -2/+2 range of skewness and kurtosis values. It was found that it did not provide a normal distribution. When the histogram graph was examined, it was seen that the C-test scores had a negatively skewed distribution and when the Q-Q plot with points was examined, the points formed a curve. Considering all these values, it was found that the C-test did not provide normality. Because of this situation, it was decided to perform non-parametric tests.

Simple correlation analysis was performed for the first questions in the form of “is there a relationship between mathematical performance, language proficiency and spatial ability?” and “is there a relationship between spatial ability factors “spatial relations”, “spatial orientation” and “spatial visualization” and mathematical success?” Firstly, spearman rho analysis is used to test the relationship status for the first and second research problems. As a result of this test, the correlation r coefficient was calculated. The correlation coefficient was used to describe the isolated relationship between the variables (Huck, 2011). When variables have heavy-tailed distributions or there are outliers, Spearman coefficient is preferred (de Winter et al., 2016).

Partial correlation analysis method was used for the third research question in the form of "is there a relationship between spatial ability and mathematical performance when language proficiency is controlled?". A partial correlation is defined as free of and evaluation can be made efficiently like absolute analysis reference (Erb, 2020). The reason for using Partial correlation analysis here can be explained as follows. The language proficiency in the third question influences both mathematical performance and spatial ability. By keeping this effect constant, partial correlation analysis was used to reveal the relationship between mathematical performance and spatial ability.

4.5.2. Data analysis of qualitative data

Content analysis is used for the analysis of data collected from the qualitative section of the research. In qualitative analysis, the collected qualitative data are coded, and the codes are tried to be made meaningful by categorizing them. This is making new decontextualization. By sorting out, classifying, comparing raw data, data is made more interesting and useful (Jones, 2007). The sub-problems of the research below were taken into consideration while performing the analyses.

• What is the completion status of geometrical tasks?

• How are spatial language terms used in geometrical tasks?

• Do spatial language strategies used in geometrical tasks vary according to spatial ability factors?

• Is there a relationship between the spatial language in which students use geometrical-spatial-verbal tasks and their mathematical performance?

According to these questions, the spatial discourses of the participants were examined. While describing and constructing spatial objects, Participants' discourse and utterances were analyzed with Maxqda based on Table 4.2. Language strategies in the geometrical task were utilized to investigate the usage of spatial language. Spatial language strategies were coded according to the categories on Table 4.2. The theoretical framework of data analysis was explained (See 4.5.2.1.1). Also, we added codes based on the studies of Mizzi (2017) and especially Hegarty (2018) in the framework section.

We first divided by group roles (describer and builder) and gave explanations for strategies. Although the deduction strategy in Table 4.2 was not mentioned in these two studies, it emerges from the data in this study. The deduction strategy was used as an approach in the literature (Baran et al,. 2007). However, rather than used as an “approach” concept, it was used as a “strategy” concept because it was applied at the same level as other strategies in the data for this study.

In order to make the concepts in the qualitative data more concrete, it was transformed into a table by the researcher as shown in Table 4.2. In this way, codes for the categories that form the basis of the study have been integrated so that the study can be measured and observed more. As Mizzi (2017) stated in his research, these codes were taken. Although the explanations are not very clear, the codes were created by using the expressions in the transcripts. Since Hegarty (2018) clearly mentioned the codes in his study and made examples, the codes were taken as they are.

The sections of the spatial ability test are combined with the definitions of spatial ability factors and spatial language strategies. Key coding words were determined and classified in content analysis. These categories and the process of creating them are explained in the framework of the data analysis section.

The products of the implication were also classified. The analysis was made according to these classifications. Constructed objects were divided into three groups, namely uncompleted, partially completed and completed objects. According to original objects, uncompleted ones have mostly different subparts and configurations. Partially completed objects have similar characteristics like a number of cubes with roughly similar shapes. Completed objects are the same as original objects. Scoring based on the completion of objects is scored as 2 points for completed objects, 1 point for partially completed objects, and 0 points for uncompleted objects.

Finally, the data obtained from C-test, Sat and mathematical exam scores were compared with the data obtained from group work and the reconstruction of 3-d objects, and the similarities and differences of the data were subjected to content analysis and interpreted. The content analysis aims to analyze the collected data in depth and to reach the concepts and relationships that can explain this data. While performing content analysis, similar data were brought together within the framework of certain concepts and themes, and these were arranged and interpreted in a way that the reader could understand (Creswell, 2014).

4.5.2.1. Framework of data analysis

In this study, while analyzing qualitative data, the spatial factor definitions classified by Lohman (1979) were taken as a basis. Spatial language strategies of Mizzi (2017) and Hegarty (2018) were used while creating the framework to make spatial language analysis. These strategies are used because they are in accordance with the study's purpose.

Spatial ability components (spatial visualization, spatial orientation and spatial relations) spatial language strategies (object break-down, assembling, local terms, perspective taking, rotation, deduction, cube controlling and structural controlling), explanations, spatial ability test features of items and coding the keywords on designated roles

Table 4.2. Coding keywords and explanations on designated roles in spatial language strategies

	Spatial visualization			Spatial orientation			Spatial relations	
Strategi	**Object break-down strategy**	**Assembling strategy**	**Structural controlling strategy**	**Local turns**	**Perspective taking**	**Cubes controlling strategy**	**Rotation strategy**	**Deduction strategy**
Explanations	Breaking objects into several parts mentally to make it simpler	Putting together decomposed parts to return original state of objects	Demand builders to explain structures	Using directional terms to explain the relative directions of the arms of the figures	Looking objects from different orientations and positioning body with respect to the described objects.	Counted the number of cubes in the different arms of the object	Rotating spatial object around axes	Completing subparts, different from the original product
Spatial	Folding 3d objects	Forming figures	Folding 3d objects Forming figures	2D to 3d Views from different sides	Placing objects with respect to the certain (selected) object.	3-D to 2-d Views from different sides	2-D objects rotation and 3-d rotation	–
Describer	Breaking objects into several parts mentally to make it simpler	Putting together decomposed parts to return original state of objects	Demand builders to explain structures	Using directional terms to explain the relative directions of the arms of the figures	Looking objects from different orientations and positioning body with respect to the described objects.	Counted the number of cubes in the different arms of the object	Rotating spatial object around axes.	Completing subparts, a whole different from the original product
Coding	First part, stairway, Divide, breaking into	Put it together, do it together	Explain, compute	Up, to the right, above, below, left, right	Next to me, toward me,	Counting cubes, how many cubes...?	Rotating, turning flipping the objects	Removing
Builder	Demand describers to explain parts of the object.	Asking which end arms of the object to assemble.	Explaining constructed objects.	Using directional terms to explain the relative directions of the arms of the figures	Positioning figure with respect to the describer	Counted the number of cubes in the different arms of the object	Asking which directions to rotate.	Asking what parts to remove
Coding	First part, stairway	Put it together, do it together	Explain, compute	Up, to the right, above, below, left, right	Next to me, toward me	Counting cubes, how many cubes...?	Rotating, turning flipping the objects	Which side?

"-" Means that no item in spatial ability test corresponds to the strategies

Table 4.2 was created based on the Mizzi (2017) and Heagrty (2018) explanations of the strategies and Lohman's spatial ability factor definitions and the characteristics of the spatial ability test. Strategies and test sections that were suitable for each other are matched. The categories created by matching were explained in detail below.

While performing geometrical tasks, object break down, assembling and structural controlling strategies were used by using spatial visualization ability. For the Object breakdown strategy, the mental breakdown of the spatial object was mapped to the forming figures part of the spatial test. While this strategy was being encoded, it was coded as an object break down strategy if describers and builders used terms such as “first part” and “stairway” and used codes such as “divide” and “breaking into” by naming the parts by analogy with objects from daily life. For the Assembling strategy, it was aimed to combine parts that were previously disassembled. Here, folding 3-d object items are paired with the assembling strategy, since spatial 3-dimensional objects that are made 2D in mind and given their expansions should be combined. In this strategy, when group members use words aiming to unite such as “put it together” or “do it together”, it is coded as an Assembling strategy. In the structural controlling strategy, it is aimed to control the product made in the process by explaining a part or all of the whole process. This strategy requires an understanding of the spatial object's configuration and construction algorithm. For this reason, if the participants use words such as "explain" or "compute constructed the object" in their explanations, it is coded as a structural controlling strategy.

While performing geometrical tasks, local terms, perspective-taking and cube-controlling strategies were used by using the spatial orientation capability. In the local terms strategy, directions should be used while describing the properties and position of the spatial object. In the test, it is aimed to mentally complete and recognize the 3-D object, which is given a 2-D image from one direction. For this reason, 2-D to 3-D Views from different sides part of the test were matched with the local terms strategy since directions are given as the determining feature in the items for recognition. It is coded as a local term strategy when directional terms such as “up”, “to the right”, “above”, “below”, “left”, “right” are used by the describers and builders, especially at the point of combining the parts. For the perspective-taking strategy, it is necessary to position the surrounding spatial objects relative to an object or to the individual's own body. The Perspective taking strategy was found to be appropriate since it was aimed to determine the placement positions of the other objects after the object that was asked to the center for the placement objects in the coordinate plane part of the test was placed. The perspective-taking strategy was coded in case the parts of the object are described using the terms “next to me” and “toward me” for the purpose of reference determination when using the directions by the describer and builders. In the cube-controlling strategy, it is necessary to specify how many cubes or similar parts are formed by looking at the spatial objects from different directions. In the 3-Dto 2-D Views from different sides of the test it is aimed understanding how the 3D object will look in 2 dimensions by looking only from one direction. Because it is found by counting the cubes from different directions or comparing their sizes, it is paired with the cube controlling strategy. In the discourses of the builder or describer, if the shape of the object such as “count the cubes from upper side or front view” or “how many cubes are there,” is confirmed by using the cube number, it is coded as a cube controlling strategy.

Finally, while performing geometrical tasks, rotation and deduction strategies were used by using the Spatial relation ability. Since in the rotation strategy, it was necessary to consider how the objects look after they are rotated in mind, it was compatible with 2-D and 3-D rotation parts of the test. It was coded a rotation strategy when builders or describers used "Rotating", "turning" or "flipping the objects" to describe all objects or subparts made. After dividing the spatial object into sections in the Deduction strategy, in order to describe these sections, the sections must be described as part of different and more familiar objects in mind. Matching could not be made in this test because there were no items on the part-whole relationship.

After the describer’s mind has made an object with a different and a greater number of Legos apart from the original subparts, it is coded as a deduction strategy when used in utterances to determine the exact location of the cube/s to be removed from the builder as "remove the cubes ..." and the builder as "which part" in order to resemble the original subpart.

Spatial language strategies are discussed and explained in more detail below.

4.5.2.2. Object break-down strategy

To simplify the object's structure and reduce its complexity, describers mentally divide the object into several internal components. In the geometrical-spatial task of the reconstruction method, they make it easier to describe the intended spatial object. The describer explicitly explains how the spatial object is broken down in their spatial discourse (Mizzi, 2017).

The Describer sometimes named the pieces to make them more meaningful. These namings usually contain information such as how many cubes they consist of and the objects they are similar to commonly used objects (stairway, square, column, letters, etc.) in daily life. In the example given in Figure 4.11, while the describer was describing the spatial object to the builder, the describer first divided the whole object into parts in his/her mind and the builder began to describe the parts. It is given in Figure 4.11.

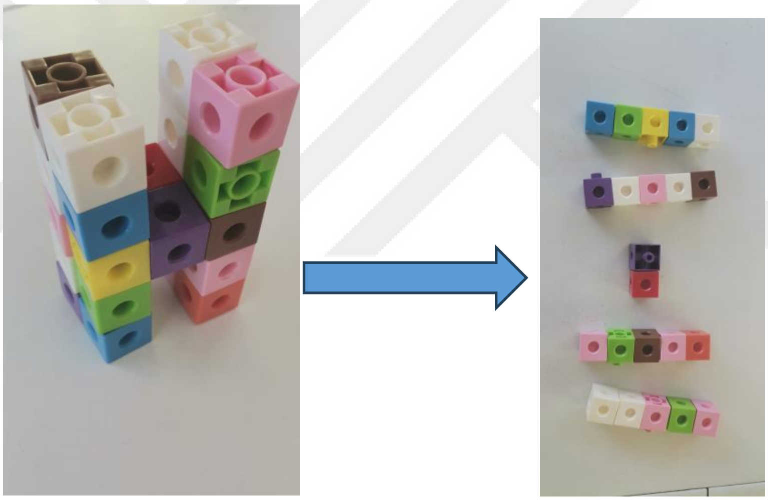


Figure 4. 11. An example of a break-down strategy

4.5.2.3. Assembling strategy

The description of how internal components are put together to construct the spatial object is another tactic used to complete the geometrical task. With this strategy, the students explain how the disintegrated spatial objects should be brought together. In the process, it is necessary to describe the spatial relationship between the spatial parts. This strategy is the continuity of the object-break-down strategy. Because participants must describe the breakdown of the spatial object into various parts first then they explain assembling these parts. In Figure 4.12., the desciber aimed to transform the whole into its original form by telling the builder how to assemble the parts he had made during the process. It is given in Figure 4. 12.

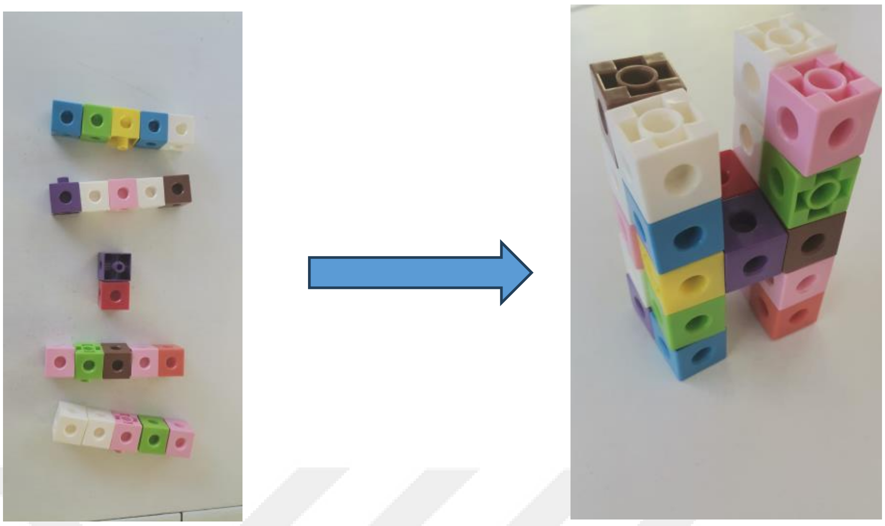


Figure 4.12. An example of an assembling strategy

4.5.2.4. Structure controlling strategy

In this strategy, the describer uses this strategy to control part of or all object from the beginning of the construction. The describer demands all information and algorithms of the construction phase. In this way, the describer can compare and define similarities and different parts of the constructed object from the original one.

4.5.2.5. Local terms

If the language used while describing the spatial product includes directional terms, it is coded as the local terms strategy. Directional terms are up, to the right, above, below, left, right, back, this side, here and under. Since the describer and the builder see the object in the face-to-face activity, the words adverbial pronouns of location (here and this side etc) are used as directional terms, and in these terms, local terms are among the strategy codes. In this case, their ability to use adverbial pronouns of location is due to the fact that the builders ask "Is this here" with their hands when they ask which side while making the object İn the Figure 4.13., the expression "lower left corner" was the use of the local terms strategy when the narrator said to the constructor in the face to face activity that "take out the cube at the bottom left of the square according to you" while describing it to the constructor. This situation is given in Figure 4.13.

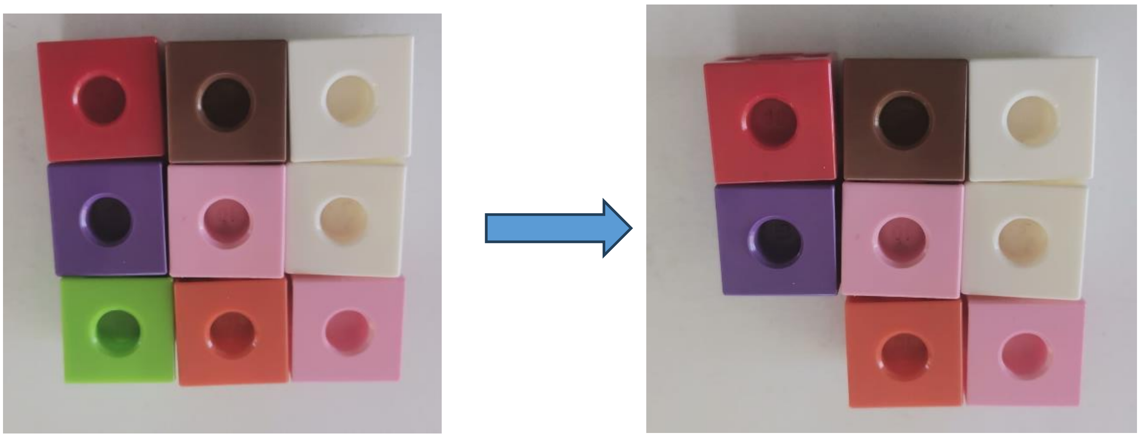


Figure 4.13. Example of a local terms strategy

4.5.2.6. Perspective taking strategy

In spatial discourse, it is the narrator's positioning himself according to fixed cubes and making his narration accordingly (Hegarty, 2018). In the perspective-taking strategy, individuals imagine that they are looking at objects from different directions. These directions must be positioned as in the coordinate plane, as upper, lower, right, left. In In Figure 4.14, the describer told the builder to explain the 3x3 square piece in more detail, “According to you, if you look from the right side, you see the same from the left side. The describer used perspective taking strategy. This situation is given in Figure 4.14.

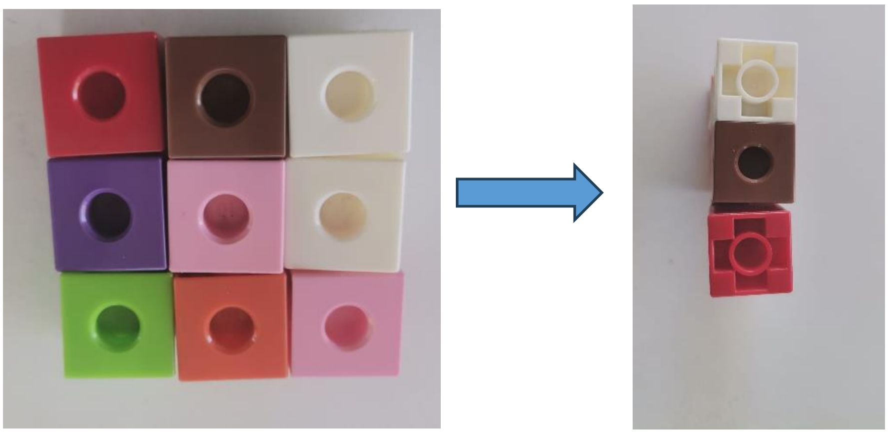


Figure 4.14. Example of perspective taking strategy

4.5.2.7. Cubes controlling strategy

Cube controlling strategy, which is another one of the controlling strategies, is trying to understand the shape and structure of the constructed object by counting the cubes. It is tried to determine the differences of the object by asking how many cubes there are from different directions. If the differences are determined, which parts are made incorrectly are checked. It is a metacognitive strategy because the whole process is reconsidered (Mizzi, 2017). In Figure 4.15., in order to confirm the accuracy of the constructed object , the builder used the cube controlling strategy when he said to the builder “how many do you see when he looks from above”, or if he says he saw six cubes, or if it was wrong, he said he saw five. The main purpose of this strategy is to continue the process by asking how many cubes there are from other directions, if it is correct, and if it is incorrect, giving information about the part of the spatial object that it was asking. This situation is given in Figure 4.15.

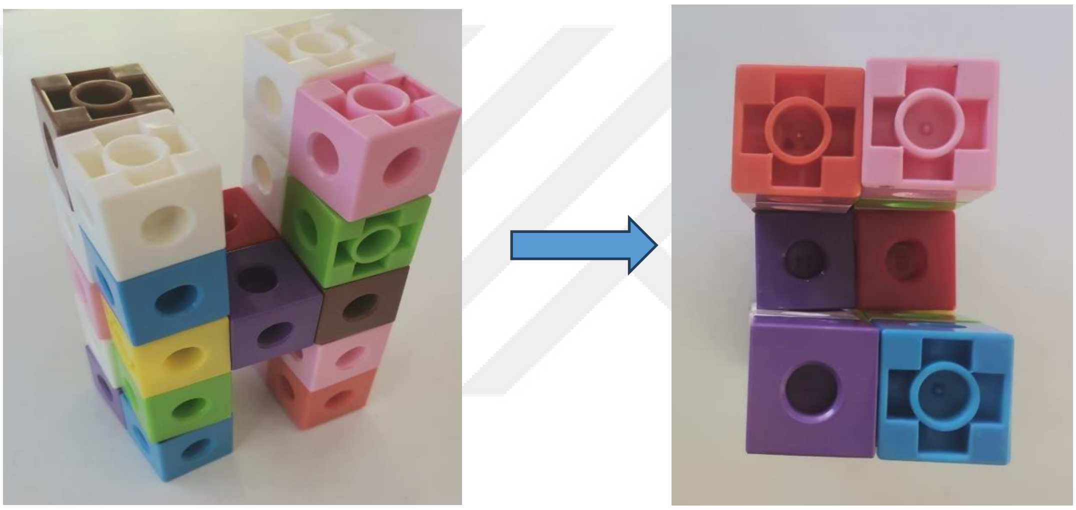


Figure 4.15. Example of a cube controlling strategy

4.5.2.8. Rotation strategy

This strategy involves imagining what objects would look like if they were rotated. It is possible to rotate spatial objects around horizontal, vertical and frontal axes. What is important here is that individuals, especially within the scope of this research, talked about desciber's turning the objects in their hands without rotating them. In Figure 4.16., after the describer asked the builder about the image of the spatial object, the builder use d the rotation strategy by saying "Turn the letter H to the left" to bring it to the position desired by the describer. This situation is given in Figure 4.16.

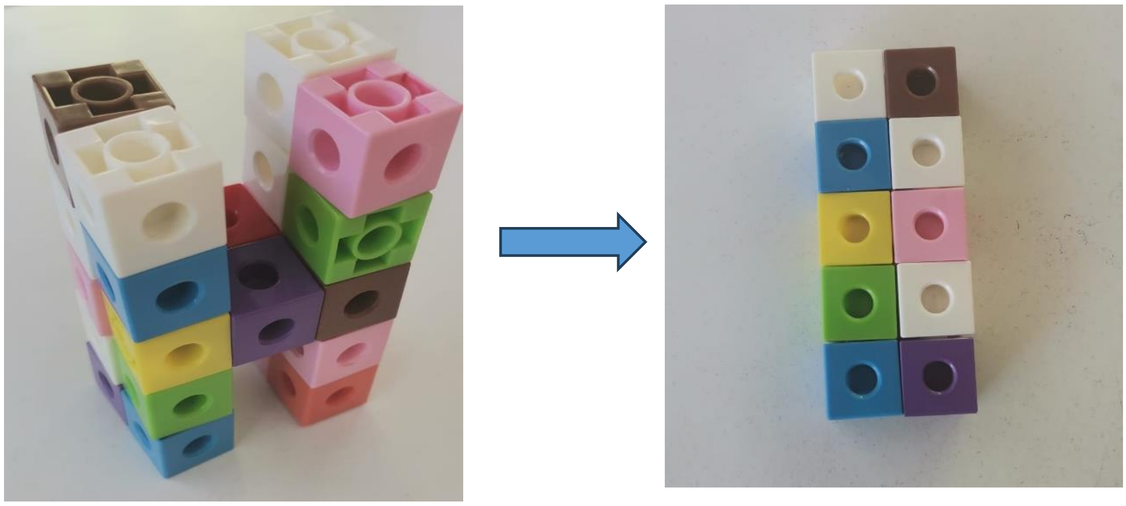


Figure 4.16. Example of a cube controlling strategy

4.5.2.9. Deduction strategy

In this strategy, the aim is to consider the object to be made as a part of a whole that is considered independent of the object. The most important feature of this strategy is the transition from the whole to the parts. When transitioning from the whole to the part, this transition is made by removing the parts. An example of this strategy is the student dialogue in Table 4.3.

Table 4.3. examination, the describer first divided the product into two parts and named these parts as “stairways”. In their first attempt, they tried to make the stairs from 3-2-1 cubes, but this method became unsuccessful. They applied this strategy after their first attempt. After the describer said to builder to construct a 3 by 3 square, then she wanted the builder to take it out of the blocks in a way that would resemble the stairway like the intended object like in Table 4.3.

Table 4.3. Deduction strategy example

English dialog	Constructed object	Turkish dialog
Amine (D): Now look, I'm going to ask you to do something else. Then we'll take out a few.	**3 by 3 square** 	Amine (D): Şimdi bak başka birşey yapmanı isteyeceğim bak. Sonra çıkartacağız birkaç tanesini.
Ayça (B): Ok.		Ayça (B): Tamam.
Amine (D): Now I'm going to ask you to make a square, but how many squares… there will be three-three and nine squares. After the square, I'll ask you to take out a few from it. At first it will be a square of nine, but how will it be three by three?	**The Constructed object** 	Amine (D): Şimdi kare yapmanı isteyeceğim ama kaçlı kare… üç tane üç tane dokuz tane kare olacak. Kareden sonra ondan birkaç tane çıkarmanı isteyeceğim. İlk önce dokuzluk bir kare olacak ama nasıl üçe üç olacak
Ayça (B): Wait.		Ayça (B): Bekle.
Amine (D): I'm waiting… did you do it, now I want you to take a square from one side to the top of my right, there will be two at the bottom, then I want you to take two squares on the other hand	**The intended object** 	Amine (D): Bekliyorum… yaptın mı şimdi senden benim sağımdan bir yanı üsten bir kare çekmeni istiyorum altta iki tane kalacak sonra diğer yandan da iki tane kareyi çekmeni istiyorum
Ayça (B): Two from the top, right?		Ayça (B): Üsten iki tane öyle değil mi?
Amine (D): You will shoot 2 from the top and one square will remain.		Amine (D): Üstten 2 tane çekeceksin bir tane kare kalacak.

4.6. Validity and Reliability of The Study

Cronbach's alpha coefficient was used to estimate the reliability of the Spatial Ability Test (SAT) and Language Proficiency Test (C-test) scores. This coefficient is commonly used in related literature to conduct reliability analysis (Huck, 2011; Tavakol and Dennick, 2011).

Cronbach's alpha coefficient of internal consistency of SAT was found to be .606. if Cronbach's alpha coefficient of internal consistency is between .60 and .70, they are accepted as acceptable according to Streiner (2003). Therefore, the internal consistency score of SAT is acceptable reliability.

Cronbach's alpha coefficient of the C-test was found to be .96. If Cronbach's alpha coefficient of internal consistency is bigger than 0.90, they are accepted as excellent (High-Stakes testing) according to Streiner (2003). Therefore, the internal consistency score of the C-test is excellent reliability.

Since qualitative research methods are used in this study, the concepts of credibility and consistency need to be examined. Ensuring credibility is provided by the following criteria (Patton, 2014). In this study, the data obtained in the implementation for triangulation were confirmed by the researcher by the interviewer. In the process of examining the data of the study, peer briefing was used. In particular, these data were discussed and examined by the expert while deciding on the appropriate themes. While collecting the data of the study, it was ensured that the points of the participants that were not fully understood by the researcher were confirmed for member checking. For prolonged involvement data collection, data for all research sub-questions were collected in this study. The existing relationships between these data were revealed (Holloway and Wheeler, 1996).

In order to increase the transferability of the research, the analysis of the collected data was made, the analysis criteria were described in detail and detailed descriptions were given. Direct quotations are included in order to increase the intelligibility of concepts and categories. To ensure long-term interaction in the study, the observer kept the application time flexible. The participant groups finished the application with their own decisions. In this situation, it is aimed to provide interaction for as long as possible.

In order to ensure the consistency of the data analysis process, the researcher and the thesis advisor discussed together how to analyze the data after the researcher discussed the collected data. The researchers decided on the analysis method considering the data. In the analysis of the data at every stage of the analysis, the thesis advisor played an active role (guided) in the creation of the conceptual framework of the analyses.

Lastly, in order to protect the information of the participants, school names and participant names were not requested by the participants during the data collection process. School numbers were used to ensure distinctiveness. In group work, nicknames were used for the participants.

The products of the implication were classified. The analysis was made according to these classifications. Constructed objects are separated namely uncompleted, partially completed, and completed objects. According to original objects, uncompleted ones have mostly different subparts and configurations. Partially completed objects have similar characteristics like a number of cubes with roughly similar shapes. Completed objects are the same as original objects. Scoring based on the completion of objects is scored as 2 points for completed objects, 1 point for partially completed objects, and 0 points for uncompleted objects.

Finally, the data obtained from C-test, Sat and mathematical exam scores were compared with the data obtained from group work and the reconstruction of 3-d objects, and the similarities and differences of the data were subjected to content analysis and interpreted. The content analysis aims to analyze the collected data in depth and to reach the concepts and relationships that can explain this data. While performing content analysis, similar data are brought together within the framework of certain concepts and themes, and these are arranged and interpreted in a way that the reader can understand (Creswell, 2014).

5. FINDINGS OF THE STUDY

In this part of the study, the findings obtained from the research, the analysis of the data and the results of the data analysis are presented. By paying attention to the sub-problems of the research, findings and comments related to the problems were included.

5.1. Findings Regarding the Relationships Between Language Proficiency, Spatial Ability, and Mathematics Achievement

In this section, the data obtained from the language proficiency test and the spatial ability test are given. The answer to the first sub-problem of the research was sought. Correlation analysis was performed to understand the relationship between Language Proficiency scores, Spatial Ability Test scores, and mathematical performance and Table 5.1. has also been presented.

Table 5.1. Correlation between variables

	Spatial ability	Language proficiency	Mathematical performance
Spatial ability	-		
Language proficiency	.410**	-	
Mathematical performance	.348**	.425**	-

According to Table 5.1, the relationship between mathematical performance and language proficiency ($r_{\textit{Math-Language proficiency}}$ =.425, $p<.01$), and the relation between language proficiency and spatial ability ($r_{\text{Language proficiency-Spatial ability}}$ =.410, $p<.01$) are positive moderate in strength statistically significant. A weak, positive, and statistically significant relationship was found between mathematical performance and spatial ability scores ($r_{\text{Math-Spatial ability}}$ =.348, $p<.01$) (Evans, 1996). This positively low correlation specified that students, who were more successful in SAT and Language proficiency test, were also likely to have high mathematical performance.

Correlation analysis was performed to understand the relationship between spatial relation, spatial orientation and spatial visualization and mathematical performance, which are the spatial ability components of Language Proficiency and are presented in Table 5.2.

Table 5.2. Correlation between variables

	Spatial relation	Spatial orientation	Spatial visualization	Mathematical performance
Mathematical performance	,294**	,236**	,182*	-

According to Table 5.2, mathematical performance and spatial relation are weakly positively correlated ($r_{math\text{-}spatial\ relations}$=.294 , $p<.01$). mathematical performance and spatial orientation are found to have the same relationship ($r_{math\text{-}spatial\ orientation}$ =.236, $p<.01$). No significant correlation (very weak) was found between mathematical performance and spatial visualization ($r_{math\text{-}spatial\ visualization}$=.182, $p<.01$).

5.2. Findings Regarding the Relationship Between Spatial Ability and Mathematical Performance when Language Proficiency Scores are Controlled

In this section, the data obtained from the language proficiency test and the spatial ability test are given. An answer was sought for the second sub-research problem of the study.

The relationship between mathematical performance and spatial ability whilst controlling for Language proficiency was analyzed and shown in Table3.

Table 5.3. Partial correlation results between mathematics and spatial ability when language proficiency score is controlled

Control variable			Mathematical performance	Spatial ability
Language proficiency	Mathematical performance	Correlation (r)	1.000	.211
		P	.	.001
		Df	0	193
	Spatial ability	Correlation(r)	.211	1.000
		P	.001	.
		Df	193	0

According to Table 5.3, when the language proficiency score is controlled, there is a significantly positive but weak relationship between spatial ability and mathematical performance (r (193) =.211, p<.01).

5.3. Findings on Completion of Geometrical Tasks

This section seeks to answer the third research sub-question. Data on students' completion of 3-d objects in implementation are presented.

5.3.1. Completion status in backward activities

In this section, results of first part of implementation are examined. In the first part of implementation, participants must construct the given objects without seeing each other. In the backward activity, the participants made two products. The describer has the original product. The Describer described the builder products without seeing the product made, as shown figure 5.1.

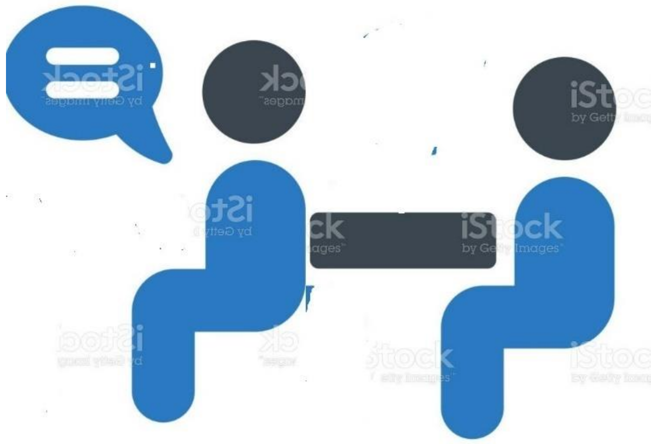
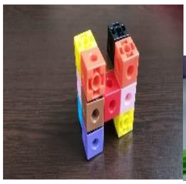


Figure 5.1. An example of backward activity

The results are given as group-based finding. Products of first activity of the implementation were shown in the Table 5.6.

Table 5.6. Products of first and second activity of the implementation (Backward activity)

	Uncompleted		**Partially completed**	**Completed**
	Low performance		**Moderate performance**	**High performance**
	Cemile &Nehir	Esra & Ece	Amine & Ayça	Yavuz & Murat
First activity				
	Cemile &Nehir	Amine & Ayça	Yavuz & Murat	Esra & Ece
Second activity				

According to the Table 1, most of participants had difficulty in completing the given tasks. Only one group out of the four completed both the first and the second activity completely. While completing both activities, two groups could not complete. For partially uncompleted tasks, 4 out of 6 constructed objects had similar features of original objects such as number of units and subparts. The unsuccessful groups made a mistake in forming the shape from the number of sub-parts.

5.3.2. Completion status in face- to face activities

In this section, the results of the second part of the implementation are examined. In the second part of the implementation, participants are positioned face-to-face. They were asked to describe the products without showing them to the builder as shown in figure 5.2.

Figure 5.2. An example of face-to- face activity

The results are given as group-based finding. Products of the second activity of the implementation were shown in the Table 1.

Table 5.7. Products of first and second activity of the implementation (face-to-face activity)

	First activity	Second activity
Products of Geometrical tasks		

According to Table 5.7., in the face-to-face activity, all groups were successful in both the first and the second activity. In face-to-face activities, students are more successful in completing geometrical tasks than in backward activities. This may be due to the direct geometrical task reflection of the communication between the describer and the builder in the group.

5.4. Findings on the Use of Spatial Language Terms in Geometrical Tasks

In this section, data on spatial terms used by participants in spatial-verbal tasks are given. An answer to the fourth research question is sought.

5.4.1. Backward activity

In the first and second backward activities, the variables used by the groups (number of spatial terms of last trial they thought they had completed the task, invested time, various spatial terms they used, the number of trials they performed, the number of the same trials and the number of all spatial terms they used) were analyzed and shown in Table 2.

Table 5.8. The quantitative variables of first and second activity of the implementation (Backward activity)

Group performance	Object Completion	invested time	# Of spatial terms of last trial	# Of differentiated spatial terms	Startegically different trials	Repeted trial	Total Trial	Total # of spatial terms
First Activity								
High	Yes	04:54	19	5	1	0	1	19
Moderate	No	05:50	16	5	1	0	1	16
Low	No	08:10	20	6	2	1	3	87
Low	No	05:40	11	7	2	0	2	26
Second Activity								
High	Yes	11:21	60	9	1	0	1	60
Moderate	No	05:29	31	5	1	0	1	31
Low	No	05:53	40	9	1	0	1	40
Low	**No**	**08:36**	**18**	**7**	**3**	**0**	**3**	**43**

According to Table 5.8. firstly, the high-performance group was able to complete the first activity. Although attempting once and using a small variety of spatial terms (N=5), but a large number of spatial terms (N=19), they still acquired success. Only a group was able to complete the product in the second activity. This group spent the most time (time= 11:21) compared to the other groups and used the most different terms (N=9) and the total spatial terms (N=60). Also, it has the highest values in each variable in the second activity in Table 2. The similarity of these two groups which had success used more spatial terms than the other groups in the last trial. When the data of completed groups were deeply analyzed, they frequently used spatial terms (bottom, right, left, in, on, attach etc.) in their explanations.

Secondly, other groups could not complete the first activity. A low-performance group spent a long time (Time= 08:10) and made a large number of trials (N=3). The group used more time than the other groups. In the second activity, both of low-performance groups also spent a lot of time and trial. They couldn't complete the given objects despite attempting too many trials and spending much time.

Thirdly, one of the low-performance groups followed a repeated strategy using the same terms to describe the configuration of objects. This means that the total number of spatial terms in their speech has repeating parts and similar term usages for those parts. In Table 5.9. (Transcript 1), the below examples are given about an explanation of the same part of the first constructed object.

Table 5.9. Explanation of examples of the same part of constructed object

English Dialog (low-performance group)	Constructed objects	Turkish Dialog
First Trial Cemile (D): Nehir there is an upper part of what you did, not below, but above. Right there exactly 4 to a side. 4 to the right, 4 to the left. Nehir (B): Yes… above or below? Cemile (D): 4 on both sides of the top and bottom.		**Birinci deneme** Cemile (A): Şimdi Nehir üstene de. Üst tarafı var ya o yaptığının üstü altı değil, üstü. Oraya tam olarak 4 tane bir tarafa sağ. Sağ tarafına 4, sol tarafına da 4. Nehir (Y): Evet… üstüne mi altına mı? Cemile (A): Üstüne de altına da her iki tarafına da 4 tane
Second trial Cemile (D):…. Look at it now. 4 Legos will come to its right. On the end side, you lined up, 2 on top and 2 on top of the other two.		**İkinci deneme** Cemile (Y): …Onun üstüne şimdi bak. Sağ tarafına 4 tane Lego gelecek. Dizdiğin uç tarafına, üstüne 2 tane öbürünün de 2 tane üstüne iki tane.

In transcriptions 1, two and trials, Cemile utilized "top", "bottom" "right" and "left" spatial terms. She insisted on using the same spatial terms and the same algorithm in her second trials were led to the same misunderstandings and confusion especially the builder.

Fourthly, in the first backward activity, one of the low-performance groups used many differentiated spatial terms (N=7). They used less numbers of spatial terms in the last trial (N=11) in their speech than other groups. They also made two trials and allocated a short time for each trial during this activity. In the second activity, although one of low-performance groups had a large variety of words high-performance, but both groups used the numbers of spatial terms less in the last trial (N=18). So, they could not complete the given objects. The reason why this task could not be completed may be because they do not repeat enough spatial terms even though they have a large number of differentiated spatial terms.

In the second activity, the large variety of spatial terms did not usually lead to failure. However, it has been observed that those who are successful have made many spatial terms at once, in a longer time than other groups.

5.4.2. Face-to-face activities

In the first and second face-to-face activities, the variables used by the groups (number of spatial terms of the last trial they thought they had completed the task, time intervals, various spatial terms they used, the number of trials they performed, the number of the same trials and the number of all spatial terms they used) were analyzed and shown in Table 3.

Table 5.10. The quantitative variables of the first and second activity of the implementation (Face-to-face activity)

Groups	Object Completion	invested time	# Of spatial terms of the last trial	# Of differentiated spatial terms	Strategically different trials	Repeated trial	Total Trial	Total # of spatial terms
First Activity								
High	Yes	01:21	6	4	1	0	1	6
High	Yes	01:28	9	5	1	0	1	9
High	Yes	02:09	15	8	1	0	1	15
High	Yes	02:33	18	6	1	0	1	18
Second Activity								
High	Yes	02:07	17	12	1	0	1	17
High	Yes	02:38	15	7	1	0	1	15
High	Yes	02:42	8	6	1	0	1	8
High	**Yes**	**04:03**	**42**	**10**	**1**	**0**	**1**	**42**

In the face-to-face activity, all the participating groups completed objects successfully in the first and second activity. All groups completed in a single trial and except for one group, it is seen that the invested time of the groups is close to each other to complete the activities. It was observed that groups that used more time to complete the activity used more spatial terms and differentiated spatial terms. In parallel, they spent more time on a variety of words and the number of spatial terms in the second activity than in the first activity. In addition, there is a group that achieves success in the first and second activities without any time difference. The reason for the long time used and the increase in the variety of words may be due to the structure of the second task. Because the second activity' construction and structure may be slightly more complex.

According to Table 1 and Table 2, the backward and face-to-face activities can be compared by the number and variety of spatial terms used, and time invested. It can be said that backward activities participants spent more time, used more spatial terms and used various types of spatial terms, but in face-to-face activities participants completed all spatial activities. It has been observed that students have more difficulty in backward-type activities than in face-to-face activities. Using a lot of time and using different words may not provide success in performing spatial activities.

Table 5.8 and Table 5.10 given the values of backward and face-to-face activities were examined. Accordingly, it was found that while the number of spatial terms used in backward activity positively affected success, it was not effective for face-to-face activity.

In the second activity, two groups using the most and least time successfully completing the spatial object were compared. Transcripts of the dialogues of the two groups who spent different times explaining the same subpart are given in Table 5.11.

Table 5.11. Example of dialog between two groups while doing the same part

Yavuz & Murat **invested time: 02:07**		**Cemile &Nehir** **invested time: 04:03**	
		Turkish translation	
Murat (A): Now make a triple wall. Yavuz(Y): Wall. I'll go like this, right? Murat(A): Yes.	Ece (A): …. No, it is not. You will combine them. Ok now put 3 on the other side. Nehir (Y): This side? Ece (A): No, on top of that. Nehir (Y): You're going to put 3 on top of it, it's not like that. Look next to the river. How is the top of you?	Murat (A): Şimdi üçlü Bir duvar yap. Yavuz(Y): Duvar. Şöyle gideceğim değil mi? böyle mi? Murat(A): Evet.	Ece (A): … Hayır öyle değil. Birleştireceksin onları. Tamam şimdi öbür tarafına da 3 tane koy. Nehir(Y): Bu tarafına mı? Ece(A): Hayır üstüne. Nehir(Y): Onun üstüne de 3 tane koyacaksın öyle değil Nehir yanına bak. Üst tarafını seni nasıl oluyor. Nehir(Y): Bu tarafım. Ece(A): Üst diyorum öbür taraf

Table 5.11. Example of dialog between two groups while doing the same part (continued)

Yavuz & Murat invested time: 02:07	Cemile &Nehir invested time: 04:03
Nehir (Y): This is my side Ece(A): I say top, the other side Nehir (Y): This side? Ece(A): The back side is the Nehir. Nehir (Y): Here? Ece (A): Yes, it's over the top.	Nehir(Y): Bu taraf mı? Ece(A): Arka tarafı Nehir. Nehir(Y): Bura? Ece(A): Evet orası üstü oluyor.

Table 5.11. In a shorter time, it was seen that the group used the term "wall", describing the general and whole object first, while describing the 3 by 3 square piece. Because of this situation, it is seen that this group uses a holistic approach while describing the object. On the other hand, it is seen that the other group uses an analytical approach in a narrative from the part to the whole. Although this group spent a lot of time examining, they used more spatial terms (over, another side etc.) in spatial disclosure.

Considerin all the data, it can be said that the chosen approaches and strategies have more impact on success than the terms used in face-to-face activities. For this reason, spatial language strategies should also be examined to make sense of geometrical tasks.

5.5. Findings on the Use of Spatial Language Strategies

In this section, data related to the answer to the fifth research question are presented. Findings of spatial language strategies used according to different activity types (Face-to-face and backward) are given.

5.5.1. First backward activity

In this section, the findings of the spatial language strategies used by students in the first backward activity are given. The deduction strategy, which is one of the strategies examined in the findings, was used only in one activity and by a group and was not included in the other tables.

In the activity, the spatial ability factors (spatial visualization, spatial orientation, and spatial relation) spatial language strategies (object break-down, assembling, local terms, perspective taking, rotation, cube controlling, and structural controlling) strategies are determined by the roles of the participants (builder and describer) and the performance status of the groups (low, moderate, high) has been examined and shown in Table 5.12

Table 5.12. Strategies used in the first backward activity according to the performance of groups and roles of participants.

Spatial ability	**Strategies**	**Low-performance groups**				**Moderate performance**		**High performance**	
		Describer	**Builder**	**Describer**	**Builder**	**Describer**	**Builder**	**Describer**	**Builder**
Spatial visualization	**Object Break Down**	✓	-	✓	-	✓	-	✓	✓
	Assembling	✓	-	✓	✓	✓	-	✓	✓
	Structural Controlling	✓**	-	✓*	-	✓	-	-	-
Spatial orientation	**Local Terms**	✓	-	✓	✓	-	-	✓	✓
	Perspective Taking	✓	✓	-	-	✓	-	-	✓
	Cubes Controlling	✓	✓	✓	-	✓	✓	-	✓
Spatial relations	**Rotation**	-	-	✓	✓	✓	✓	-	-
	invested time	08:10		05:40		05:50		04:54	

*✓ means strategy used.
** means strategy used in a part of the product.
*- means strategy not used in the product.

According to Table 5.12., strategy preferences were given in face-to-face activities. It has been observed that each group uses the object break-down, assembling strategies examined under the theme of spatial visualization, and local term and cube control strategies examined under the title of spatial orientation. On the contrary, in the high-performance group, it was observed that the builder used more active strategies than the describer. If this situation is detailed, it has been observed that the moderate performance group uses all strategies except the local terms of the describer, and the builder is partially successful by using the rotation and cube controlling strategies. It was noted that although the describers in the low-performance groups used more strategies than those in the successful group, they were unable to accomplish it. When the strategies used by the builders were examined, it was observed that 10 of the 12 strategies were the same as the strategies used by the describers. This is because students may have been affected as they interact with each other in their spatial dialog. In terms of the describer, it is seen that the high number of strategies does not guarantee success. The main reason for this may be that the builders are not active enough; on the contrary, the describers are more active. An example of this situation is Table 5.13. It was also given by a builder's statement, "If I had asked more questions… (more active)".

Table 5.13. Dialog example of Describer’s self-criticism

English dialog	**Turkish dialog**
Murat (D): The letter H. Sir, I can't find it...	Murat (A): H harfi. Hocam ben yapamıyorum bunu…
Interviewer: Try to explain, for example, you said the letter H, for example, tell me...	Görüşmeci: Anlatmaya çalış... mesela H harfi dedin söyle mesela …
Yavuz(B): Does smallness become greatness? How many inches from bottom to top?	Yavuz(Y): Küçüklüğü büyüklüğü oluyor mu?.Aşağıdan yukarı kaç santim?
Murat(D): Upwards 5…	Murat(A): Yukarıya doğru 5

When Table 5.13 is examined, it is understood that the describer has difficulty. In this case, without wasting time, the builder started to help his friend and direct the situation with questions. Due to his friend's passive behavior in explaining, Yavuz, the builder, tried to take responsibility of for the role of describer with his questions.

5.6.2. Second backward activity

In this section, the findings of the spatial language strategies used by the students in the second backward activity are given.

In the second backward activity, the use of spatial ability factors (spatial visualization, spatial orientation and spatial relation), spatial language strategies (object break-down, assembling, local terms, perspective taking, rotation, cube controlling and structural controlling) depends on the roles of the participants (builder and describer). The performance status of the groups (low, moderate, high) was examined and shown in Table 5.14.

Table 5.14. Strategies used in the second backward activity according to group performances and roles of participants

Strategies		Low-performance groups				Moderate performance		High performance	
		Describer	Builder	Describer	Builder	Describer	Builder	Describer	Builder
Spatial visualization	Object-Break Down	✓	-	✓	-	✓	✓	✓	-
	Assembling	✓	✓	✓	-	✓	✓	✓	-
	Structural Controlling	-	-	✓**	-	-	-	-	-
Spatial orientation	Local Terms	✓	✓	✓	✓	✓	-	✓	✓
	Perspective Taking	-	-	✓	-	-	✓	-	✓
	Cubes Controlling	✓	-	✓	-	-	✓	-	✓
Spatial relations	Rotation	-	-	✓	-	-	-	✓	-
	Deduction	-	-	✓	-	-	-	-	-
	Invested time	05:53		08:36		05:29		11:21	

*✓ means strategy used.
** Means strategy used in a part of the product.
* – means strategy not used in the process.

Examining Table 5.14. for the backward activity, it was seen that all groups used object break down and assembling strategies, local term and cubes controlling strategies as in the first and second activities. In this activity, after dividing the spatial object used by a describer into sections, he used the deduction strategy, which is defined as describing the sections as part of different and more familiar objects in the mind, to describe these sections, but the builder could not understand the strategy used by the describer. Therefore, the use of this strategy did not contribute to group performance. Again, similar to the first activity, it was seen that the least used strategies were the rotation and deduction strategies spatial relation factor, and the structural controlling strategy of the spatial visualization strategies. When we look at the strategy use of high-performance group in the difficult backward activity, it is seen that the builder uses more active strategies than the describer. It was seen that the moderate performance group used all strategies except the local terms of the describer, and the builder was partially successful by using the rotation and cube controlling strategies. It was observed that low-performance groups used more strategies than the successful group, but they were not successful against it. When the strategies used by the builders were examined, it was observed that 6 out of 10 strategies were the same as the strategies used by the describers. This is because students may have been affected as they interact with each other in their spatial dialog. It has been observed that if the builders are not active enough, they have difficulty completing the object even if the describer is active.

When Tables 5.12 and 5.14 are examined together, they used the structural controlling strategy in the first and second backward activities to control the entire object in the group that was partially successful in the first activity. In the unsuccessful group, the structural controlling strategy was used to control the accuracy of the part of the object instead of the whole object. In the second activity, the group completing the object has done structural controlling for the control of the entire object. In addition, in the group that could not complete it, it was found that they used it when describing the part of the structural controlling object. When the cube controlling strategy is examined, it was found that the builders of the two groups that completed the Object and the two groups that partially completed the Object used this strategy in both activities. It has been seen that cube controlling and structural controlling strategies are used in the creation of the structure and the final stage while providing the controls.

When the successful and semi-successful groups of groups are examined, the structural and cube controlling strategies may increase the success of the effect of the structural controlling strategy on the control of the object made. Cube controlling strategy, on the other hand, may increase the success because it allows the 3-D object to be thought of as 2D and simplifies it by separating it into units.

Secondly, although the group that could not complete the object used two more strategies in the first activity than in the second activity, and even preferred the strategies they did not use in the first activity, they could not complete the object in both activities. In the group that completed the object, it was observed that they did not make any changes in their strategies in either of the activities. While completing the first activity, they were able to partially complete the second activity.

5.6.3. First face-to-face activity

In this section, the findings of the spatial language strategies used by the students in the first face-to-face activity are given.

The use of spatial ability factors (spatial visualization, spatial orientation and spatial relation), and spatial language strategies (object break-down, assembling, local terms, perspective taking, rotation, cube controlling and structural controlling) in the first face-to-face activity depends on the roles of the participants (builder and describer) and the performance status of the groups (low, moderate, high) and are shown in Table 5.15.

Table 5.15. Strategies used in the first face-to-face activity according to group performances and roles of participants

Factors of spatial ability	Strategies	Completed							
		Cemile &Nehir		Esra & Ece		Amine & Ayça		Yavuz & Murat	
		Describer	Builder	Describer	Builder	Describer	Builder	Describer	Builder
Spatial visualization	Object Break Down	✓	-	✓	-	✓	-	✓	-
	Assemblin g	✓	-	✓	-	✓	-	✓	-
	Structural Controllin g	-	-	-	-	-	-	-	-
Spatial orientation	Local Terms	✓	✓	✓	✓	✓	✓	✓	✓
	Perspectiv e Taking	-	✓	-	-	-	-	-	-
	Cubes Controllin g	-	-	-	-	-	-	-	-
Spatial relation	Rotation	-	-	✓	-	✓	-	-	-
	invested time	02:33		01:28		01:21		02:09	

*✓ means strategy used.
** means strategy used in a part of the product.
* - means strategy not used in the process.

When Table 7 is examined, it is seen that all groups completed the products in this activity. Local terms strategy has been used by both describers and builders. When examined in terms of time, it was observed that the groups that finished in a shorter time compared to the other groups used the rotation strategy of spatial relation.

5.6.4. Second face-to-face activity

In this section, the findings of the spatial language strategies used by the students in the second backward activity are given.

In the second backward activity, the use of spatial ability factors (spatial visualization, spatial orientation and spatial relation) and spatial language strategies (object break-down, assembling, local terms, perspective taking, rotation, cube controlling and structural controlling) depend on the roles of the participants (builder and describer) and the performance status of the groups (low, moderate, high) and are shown in Table 5.16.

Table5.16. Strategies used in the second face-to-face activity according to completion categories of the product and roles of participants

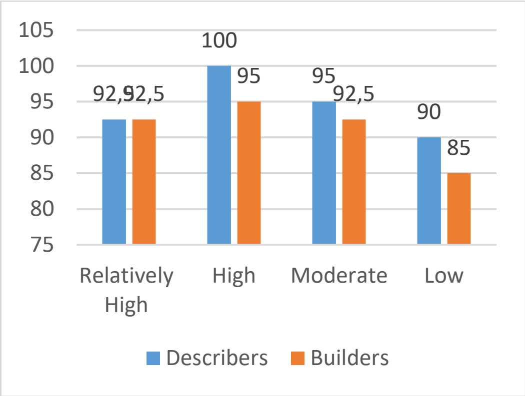
Factors of spatial ability	Strategies	Completed							
		Cemile &Nehir		Esra & Ece		Amine & Ayça		Yavuz & Murat	
		Describer	Builder	Describer	Builder	Describer	Builder	Describer	Builder
Spatial visualization	Object Break Down	✓	-	✓	-	✓	-	✓	-
	Assembling	✓	-	✓	-	✓	-	✓	-
	Structural Controlling	-	-	-	-	-	-	-	-
Spatial orientation	Perspective Taking	✓	-	-	-	✓	-	-	-
	Local Terms	-	✓	✓	✓	-	✓	-	✓
	Cubes Controlling	✓	-	-	-	-	-	✓	-
Spatial relation	Rotation	✓	✓	✓	-	✓	-	-	-
	Invested time	04:03		02:38		02:42		02:07	

*✓ means strategy used.
** means strategy used in a part of the product.
* - means strategy not used in the process.

When Table 5.16 is examined, all groups completed the products in the second face-to-face activity. Object break-down, assembling and local terms strategies were used by all groups. It was determined that the time used by the groups and the number of strategies increased according to the face-to-face first activity. Considering the invested time, it was found that the participants had more difficulty, and in parallel, the number of strategies increased.

When Tables 5.12, 5.14, 5.15 and 5.16 are considered together, it was determined that students' strategy use in the backward activity was more than in the face-to-face activity. It was determined that there was no change in the number of strategies (except the deduction strategy) in both of the backward activities. It was observed that the number of strategies used in the face-to-face activity was higher in the second activity, which was more difficult than the first activity, compared to the first activity. It was determined that spatial orientation and spatial relation strategies were used more than spatial visualization strategies in both backward and face-to-face activities. In back-to-back activity, ten out of 12 strategies were found to be the same strategy for group members, while six out of 12 strategies were found to be the same in face-to-face activity. It was found that spatial orientation strategies were the most common of these strategies. Although there was a decrease in the number of strategies used in the face-to-face activity compared to the backward activity, all groups completed the object. The reason for this is the immediate correction of mistakes in face-to-face activity. Thus, it has been found that it is easier and more difficult than the backward activity.

The comparison and analysis of success states (relatively high, high, moderate and low) to language proficiency scores (0-100) and spatial ability scores (0-23) are given in Figures 5.3 and 5.4.



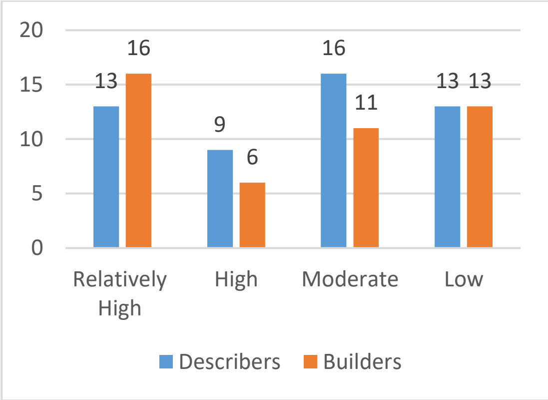


Figure 5.3. Language proficiency scores by groups

Figure 5.4. Spatial ability scores by groups

When Figure 5.3 and Figure 5.4 were examined, it was determined that the Esra and Ece group, one of the most successful groups in group activities, was the distinguishing feature of the highest language proficiency score. When the other successful group Yavuz and Murat characteristics were examined, it was determined that they had the highest spatial ability scores. When we look at the more unsuccessful groups, it was seen that the difference between the spatial ability scores of the Cemile and Nehir group, which had the lowest language proficiency score, and the spatial ability scores of the amine and Ayça groups. As it can be understood from here, it is thought that one of the language proficiency or spatial ability scores should be high and the other should have an average degree in the group to achieve success in geometrical task activities.

6. CONCLUSION AND DISCUSSION

In this section, firstly the results obtained from the research findings are given, then the similarities and differences of these results with similar research results in the literature are discussed.

The results obtained from the quantitative data in the research are as follows. It is seen that there is a moderately positive and significant relationship between mathematical performance and language proficiency, and spatial ability scores. This result is consistent with the findings of Geary et al. (2021) on sixth and seventh-grade students and Haciomeroğlu (2016) on high school students revealing a significant positive and moderate correlation between mathematical performance, language proficiency, and spatial ability. However, Zhang and Lin's (2018) research on preschool students regarding spatial ability and mathematical performance partially support the current result. Their result supports the conclusion that language proficiency and spatial ability are predictor variables on mathematical performance in primary school students in the study conducted by Weijer-Bergsma et al. (2015). Conversely, Green et al. (2017) conducted a study on a group consisting of children and adolescents. While the correlation coincides with the result of being in a positive direction, it is seen that it does not overlap in terms of size since it is at the high and above levels.

The relationship between mathematical performance and factors of spatial ability, spatial relations, and spatial orientation has been found to be positive, but at a moderate level. However, it seems that there is no relationship between mathematical performance and spatial visualization. As a result of the relationship between mathematical performance and spatial orientation, Eilam and Alon (2019) coincide with the result of their study at the primary school level that there is a positive weak correlation between mathematical performance and spatial orientation. The reason for this overlap may be that the sixth-grade curriculum and its applications have more spatial ability-related topics (i.e. geometrical shapes, mental manipulation of variables and locating numbers on mental number lines), as revealed by Eilam and Alon.

It was concluded that there is a correlation between mathematical performance and spatial relations. With this result, Gilligan et al. (2019) agree with the result that there is a weak and above-level correlation between spatial relations (mental rotation) and mathematical performance. This finding also supports the research of Wulandari et al. (2021), which found that spatial skills have an impact on problem-solving, one of the fundamental elements of mathematical performance The conclusion that there is no relationship between mathematical performance and spatial visualization in this research contradicts the conclusion of Hawes and Ansari (2020) that the most important factor affecting mathematical success is spatial visualization. When the language proficiency score was controlled, the strength of the significant positive relationship between spatial ability and mathematical performance decreased, but the level did not change. This can be shown as evidence that language proficiency has a significant effect on mathematical performance and spatial ability. The result lines up with the findings of studies controlling language proficiency conducted by Casey and colleagues (2015) on first-year female students and Georges et al. (2021) on preschoolers. Again, according to the study by Szucs et al. (2014), controlling the general language proficiency of third and fourth-grade students, it is in line with the conclusion that there is a relationship between spatial ability and mathematics. The same study contradicts the conclusion that mathematical performance and language proficiency are not related to reading comprehension, which is a sub-dimension of language proficiency.

The results obtained from the qualitative data in the research are as follows. When the describer did not see the object that the builder had made, groups failed or had difficulty achieving success. This failure can be seen as the inaccuracy of the figures created with these parts rather than the number of parts used in the figures. The study of Eliam and Alon (2019) coincides with the conclusion that young students have difficulty imagining the views of objects from different directions in tasks where visual cues for perspective-taking skills (spatial orientation) are low. The finding of the study by Miler-Zdanowska (2018) is parallel with the result that the precise and detailed explanations about the environment to visually impaired children positively affect their performance regarding spatial relations.

However, they achieve success when the describer sees the builder's object in the process. This may be because when the describer encounters a situation that goes wrong in the process, immediate feedback is given to the builder. This finding is consistent with research done by Ferrara et al. (2011) on preschool students, which showed that success increased when parents provided the necessary guidance and feedback during a guided block play activity.

It was concluded that the group using more spatial terms was successful in studies where the describer builder did not see the objects. With this result, it should be taken into account that the task where the describer does not see it is more difficult than the task done face-to-face. The research of Yang and Pan (2021) with preschool students is consistent with the result that children who construct high-construction structures use more spatial languages (terms) and achieve success. In addition, this result coincides with the result of Miller (2016) that spatial language use develops spatial ability. At the same time, this result supports the conclusion that there is a relationship between mathematical performance and spatial ability, and even language proficiency, which was revealed with quantitative data in this study.

The fact that students use a small number of words may be due to their not knowing the concepts exactly. Miller et al. (2016), in their study on 4-year-old children, found that spatial orientation (intrinsic reference frame) performances increased as location-descriptive cues were given in the task of remembering the location of spatial objects. As a possible reason for this situation, Miller et al. (2016) argue that while language is conveying spatial information, it also conveys relational information and draws attention to spatial relationships. Based on this result, it coincides with the conclusion that the use of spatial words and knowledge is important for spatial performance.

The group that was generally successful continued to insist on a single trial, even if they spent more words or time. When the unsuccessful ones were examined, they still failed, although they tried in two or three trials. It is seen that the unsuccessful groups tend to try other ways in the smallest disagreement without seeing the result. This result coincides with the result of Lajoie's (2018) research on adults, that individuals in the less skilled group (humanities and Phys master's students) in the spatial orientation task change more strategies. This may be because, as Lajoie (2018) revealed, less skilled groups cannot reach the right result by trying different strategies in geometrical tasks and cannot use these strategies efficiently.

Groups that failed in geometrical tasks by over-trying continued to use the same words in these different trials. Interestingly, the use of concepts and words is the same or similar when students change the trial at the slightest disagreement. This result supports the result obtained from the quantitative data in this study that there is a positive correlation between language proficiency and spatial ability. Again, this result is in line with the research conducted by Hayward and Tarr (1995) on undergraduate students and the theory of prototype categorization (use prototypes and examples to categorize information) stated by Spicer and Sanborn (2019). However, this result contradicts the result of Miller et al. (2016) that as the number of trials increases, descriptive clues about spatial objects performed in geometrical tasks increase.

It was found that the unsuccessful groups were not successful even if they spent more words and time. The result of this study coincides with the result of the research conducted by Tenbrink et al. (2017) on young adults. This may be due to the nature of geometrical tasks with unfamiliar features as Tenbrink et al. (2017) mentioned. This result shows that the abundance of words and time used in geometrical tasks does not guarantee success.

It has been determined that the spatial language used by the group members is meaningful to each other, increasing the group's success. Mizzi (2017) coincides with the result of his research on fifth-grade students. This might be because, as Mizzi (2017) found, people with similar spatial abilities communicate spatial information more effectively when completing spatial language tasks. Although the spatial words used in the face-to-face activity are less than the spatial words used in the backward activity, success is achieved. The reason for this may be the meaningful and appropriate use of terminological words to ensure productive and effective communication, as Ryve et al. (2013) revealed in their research with sixth-grade students.

It was observed that group members used more similar strategies in the backward activity than in the face-to-face activity. The reasons for using similar strategies in the backward activity may be because they needed more understanding and confirmation (Roberts, 2006). After all, the described object was not seen. On the contrary, since the object described in face-to-face activity is seen and intervened by the describer during construction, it may be because the builder focuses more on the correction task during the intervention process (Holen and Sortland, 2022) and focuses less on strategy. While doing the activities, it was found that both group members (builder and describer) used spatial orientation strategies most actively.

It was concluded that a high number of strategies, whether in back-to-back activity or face-to-face activity, does not guarantee success. This result is in parallel with the result of Mizzi (2017) who according to his research, every spatial strategy used will not be useful in spatial communication. Again, Lajoie (2018) coincides with the result of his research that the group that failed the geometrical task used these strategies ineffectively despite choosing a large number of strategies. One of the reasons for this may be that the concepts and words used by the describer in the strategies they choose, as Mizzi (2017) mentioned, contain ambiguity for the builders. Secondly, it may be because the chosen strategy is not suitable for that situation even if it is known beforehand (Baran et al., 2007). On the other hand, the result of this study contradicts the result of the study by Eliam and Alon (2019) and Suh and Cho (2020) that increasing the number of strategies increases geometrical task performance. Moreover, object break-down, assembling and cube-controlling strategies are basic strategies since all groups use them while performing the activity. However, this result partially contradicts Hegarty (2018), stating that the cube-controlling strategy in mental rotation tasks is ineffective and time-consuming.

It has been concluded that the structural controlling of spatial visualization strategies is an important strategy that affects the success in both the construction phase and the evaluation of the structure. This finding is in line with Lajoie's (2018) research on adults, which found that those who are successful in geometrical tasks use the structural controlling strategy and the verifying strategy. However, this result contradicts the conclusion that the structural controlling strategy affects geometrical task performance less than other strategies in the study of Mizzi (2017) on fifth-grade students. Although the Structural controlling of spatial visualization strategies is effective in the completion of the object, it has been determined that it does not affect the success when used to describe any part of the object during the construction phase. This result is supported by Hegarty's (2018) research on undergraduate students and Peña et al. (2008) in their research on adults, with the result that strategies in which the object is considered as a whole increase accuracy and overall performance. According to Brown and Chandrasekaran (2014), control strategies are redesigned strategies used to protect the efforts made. The result of the research is that the whole object can be controlled only by reviewing the whole process.

It has been concluded that the strategy that supports the completion of other strategies in completing geometrical tasks is the local terms strategy in the spatial orientation strategy. This result is consistent with the result of Yang and Pan (2021), in their research with preschool students, that students mostly use spatial location terms strategy while playing block play. Again, it coincides with the result of Mizzi (2017) that the local terms strategy is used when performing geometrical tasks to reduce spatial uncertainty. On the other hand, Tenbrink et al. (2017) dispute the finding of the study with adults that there is no relationship between success in the geometrical task and the local terms strategy.

It was concluded that in the difficult activities, the students increased the number of strategies and created new strategies to find solutions for creating the object. Examples of these new strategies are the so-called deduction strategy, which is not explicitly stated in the basic studies (Kyllonen et al., 1981; Glück and Fitting, 2003; Tenbrink, 2011; Mizzi, 2017; Hegarty, 2018) but is used explicitly by a builder. After dividing the spatial object into sections, the spatial language strategy, which is defined as describing the sections as part of different and more familiar objects in mind, can be shown to describe these sections. It coincides with the result of the research (Özçakır and Çakıroğlu, 2022), which states that strategies are produced and developed while performing geometrical tasks. The result of the strategies used in difficult tasks is consistent with the result of Baran et al. (2007) that "deductive approach" strategies are used in difficult two-dimensional geometrical tasks.

Again, the results of Tzuriel and Egozi (2010) and Hsing et al. (2023) accord with the results of an increase in both the number and the variety of strategies used in the activities in which the students reported that they had difficulty. Finally, this result is in line with the result of Glück and Fitting (2003) that there is an increase in the number of spatial ability strategies as more manipulation of spatial information is needed in difficult tasks.

7. RECOMMENDATIONS

In this section, suggestions are made by using the results of the research.

Suggestions to researchers:

• "What kind of interaction between the describer and the builder in the face-to-face activity have?" should be investigated in more depth

• Considering that the unsuccessful groups made more than one attempt, it is recommended that researchers ask students to explain why they are giving up on the paths they have chosen while collecting data.

• How the relationship between this variable and which variable affects which variable should be investigated in more detail.

• For communication between speaking parties to be efficient, the describer's descriptions in geometrical tasks should be as rich in spatial information as possible. At the same time, the builder must have advanced imagination abilities to understand the spatial relationships between the parts of the spatial object and process spatial information correctly. This may be because, as researchers Miler-Zdanowska (2018) and Eliam and Alon (2019) say. However, it is recommended to investigate this situation in more detail.

• While performing geometrical tasks, it is recommended to investigate in more detail the result that students give up on trials and insist on using the same spatial words while starting new trials.

• It is thought that the conflict of the results of the strategies used by the students in the study and the results of some studies in the literature can be effective on different variables, strategy and performance. B ecause of this, in geometrical tasks, it is recommended to investigate in which situations and which spatial strategy affects success more when selected and changed.

• "Does the effectiveness of the control strategy change as the age and class level of the individuals increase?" It is recommended to investigate the question.

Suggestions to teachers:

• For the development of spatial language,teachers are advised to make students explain the shapes to the students in the classroom.

• The fact that the unsuccessful groups had repeated explanations using the same words brought about that the teachers may also fall into such repetitions in their expressions. The fact that teachers focus on the terms they use in their explanations, especially from a conceptual point of view, increases the success of the students. It is recommended that they use different concepts and words and explain them.

•In the study, each group completed the object made in the face-to-face activity.It is recommended to have a face-to-face activity for students to have positive attitudes when starting block play activities with groups.

• Teachers can include both face-to-face and backward activities in their teaching.

• As revealed by Tzuriel and Egozi (2010), it can be recommended to perform back-to-back spatial activities with students in the classroom, in line with the conclusion that activities that are difficult in geometrical tasks increase students' success.

• In the backward activities, it is recommended that students' geometrical tasks be described more concretely (letter h, column, etc.) and have them done while creating small subparts.

• It is recommended that students do activities that require them to be persistent until they conclude their attempts in geometrical tasks. If they are giving up on the paths they have chosen, they are advised to ask them to explain why they are giving up.

• Moderate relationship between mathematical performance, language proficiency, and spatial ability. It is recommended to consider when planning, developing and implementing activities.

• It is recommended to create a discussion environment in the classroom about the reasons why students chose the strategy and if they made any changes, why they changed it.

• It is recommended to design activities that will use basic strategies (break-down, assembling and cube controlling) in geometrical tasks and to make in-class applications.

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APPENDIX

APPENDIX

APPENDIX 1: The Research for the Thesis Study

Ala, Asli Merve, ve Bekdemir Mehmet (2022) "Dil yeterliliği, Uzamsal Yetenek ve Matematik Başarısı", ***International Education Congress*** (EDUCONGRESS), 561-562.

APPENDIX 2: C-test

Turkish C-test

Text 1 – Mahallem

Burası benim mahallem. Benim ev_________ ana cad_________. Evimin karşı_________ bir lok_________ var. Lokan_________ servisi gü_________, ama fiya_________ biraz yük_________. İki so_________ ileride b_________ bakkal v_________, ama bü_________ değil. Ar_________ sokakta bü_________ bir süpermar_________ var. Genel_________ orada alışve_________ yaparım. Ya_________ sokakta küç_________ bir sin_________ var. Film izlemek için güzel bir yer.

Text 2 – Danielle Clausen

Danielle Clausen Danimarkalı. Otuz sekiz yaş________. Evli ve iki çoc_________ var. İki yıl_________ Türkiye'de yaş_________. İki y_________ daha kal_________ istiyor. Eş_________ Peter, Danimarka'nın Türk_________ konsolosu. Danielle de, haft_________ üç gü_________ konsoloslukta vi_________ bölümünde çalı_________. Çocukları, Anna ve Eric, öz_________ bir lis_________ okuyor. Danielle anadi_________ dışında İngi_________, Almanca ve Fran_________ konuşuyor. Türk_________ ise zor bul_________. Ama Danielle'in ak_________ bir Türkçesi var. Danielle Türkiye'de yaşamaktan çok memnun.

Text 3 – Istanbul

İstanbul, Türkiye'nin kuzey batısında, Avrupa ile Asya kıtaları üzerinde uzanır. Dünyada iki kıt_________ birbirine bağl_________ tek ke_________ olan İstanbul, Türkiye'nin ve Avrupa'nın e_________ kalabalık şehr_________. Kent ülk_________ kültür, san_________ ve eko_________ başkentidir. Türkiye'de bul_________ ulusal ve uluslar_________ şirketlerin ge_________ merkezleri b_________ kentte y_________ alır. İstanbul, tar_________ ve coğ_________ konumu i_________ kozmopolit b_________ yapıya sahi_________. Birçok tiy_________, sinema ve kül_________ merkezi vardır. İstanbul'da her yıl çeşitli konserler, festivaller ve fuarlar düzenlenir.

Text 4 – Anakent Koleji

Anakent Koleji, öğrencilerini geleceğe tam olarak hazırlamayı misyon edinen bir kurumdur. Okulumuzda yab_________ dil öğret_________ büyük ön_________ verilir. Öğren_________ İngilizce ve Alm_________ dillerini sı_________ ortamında ve aktiv_________ yoluyla öğren_________. Bu sür_________, hazırlık sınıfl_________ başlayarak 12. sın_________ kadar de_________ eder. D_________ öğrenme konus_________ en öne_________ etkinliğimiz Yab_________ Diller Kulü_________. Bu ku_________ küresel kon_________ hakkında uluslar_________ çalışmalar yapar. Yabancı bir dili etkin bir şekilde kullanma adına kulüp çalışmalarımız önem taşır.

Text 5 - Motivasyon

Motivasyonu yüksek bir öğrenci derslerine daha fazla çalışır. Daha i_________ öğrenir ve da_________ başarılı ol_________. Dolayısıyla ula_________ istediği hede_________ daha hı_________ bir şek_________ ve da_________ kolay ula_________. Öğrencinin hede_________ ulaşmasında motiva_________ önemi ç_________ büyüktür. Öğret_________ sevmek de motiv_________ artıran b_________ faktördür. B________ nedenle öğret________ kendini öğrenc_________ sevdirmesi, onl_________ rol mo_________ olabilmesi önemlidir. Bunu yapabilmek için verdiği sözleri tutması, öğrencileriyle iyi ilişkiler geliştirmesi gerekir.

Text 6 – Koku ve Tat

Koku alma duyunuz tat duyunuz ile bağlantılıdır. Yiyeceğin koku_________ alamadığınızda muhte_________ tadını da alamaz_________. Bu dur_________ yeterince ye_________ yememenize ve ki_________ kaybetmenize ne_________ olur. Vücu_________ ihtiyacı ol_________ besinleri alamad_________ için vit_________ ve min_________ eksikliği gi_________ bazı sağ_________ sorunları yaşar_________. Koku almam_________ ruh hali_________ de etkileyebilir. Çiç_________, gıda ve ben_________ kokular si_________ yaşam sevinci verir. Bu kokuları almamanız ise kendinizi üzgün veya depresif hissetmenize neden olabilir.

Text 7 – Bilim Kadınları

Türkiye'deki bilim kadınları hakkında yapılan hemen her araştırma kimi ilginç olguların altını çizer. İlk ola_________, üniversitelerin far_________ kademelerinde y_________ alan kadın_________ oranı s_________ derece yüks_________. Sadece öğr_________ ya da asis_________ düzeyinde değ_________, öğretim üy_________ ve yöne_________ kadrolarındaki kadın_________ oranı da b_________ hayli kabar_________. Bununla ber_________, bilim kadı_________, kadın olma_________ dolayı he_________ hemen hiçb_________ ayrımcılığa uğramad_________ dile getirmektedirler. Bu saptamayı takip ettiğimizde 1930'lardan bu yana bir süreklilik buluruz.

Text 8 - Kültürel Mekân

Mekânın, kültürel süreklilik açısından gerekli olduğu gerçeği göz önüne alındığında, diğer alanlarda olduğu gibi halk oyunları alanında da kültürün üretildiği ve aktarıldığı kültürel mekânların üstlendiği işlevin irdelenme gereği kaçınılmazdır. Bu nok_________ halk oyunl_________ yaşatıldığı ve gel_________ kuşaklara aktar_________ kültürel mekân_________ yok ol_________ çekincesi, kült_________ de yok ol_________ çekincesini berab_________ getirir. Gelen_________ temsillerde önce_________ olan mekâ_________, günümüz koşull_________ küresel ve ye_________ etkilerle değiş_________. Bu ned_______ kültürel ve mekâ_________ farklılaşma ve çeşit_________ hızlanmıştır. Bun_________ birlikte, ya_________ koşullarındaki hızlı değişim, evrensel kültür ile yerel kültürler arasındaki çelişki, kültür ve mekân etkileşiminde yeni boyutlar yaratmış ve gelenek yeniden biçimlenen bu mekânlarda yaşatılır hâle gelmiştir.

Thank you!

APPENDIX 3: Spatial Ability Test

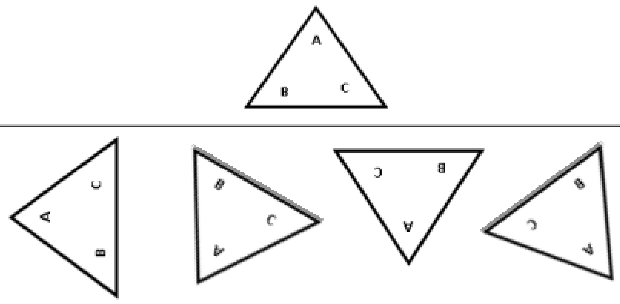
Ad Soyad:

UZAMSAL YETENEK TESTİ

1. Bölüm

Bu bölümde çeşitli nesneler ve onların döndürülmüş hallerini gösteren şekiller bulunmaktadır. Her bir soruda çizginin üstünde 1 şekil ve altında 4 şekil bulunmaktadır. Çizginin altındaki şekillerden 3 tanesi bu şeklin döndürülmüş hali, 1 tanesi ise değildir.

Örnek: Aşağıdaki soruda seçenekteki şekillerden hangisi çizginin üstündeki şeklin döndürülmüş hali **değildir**?

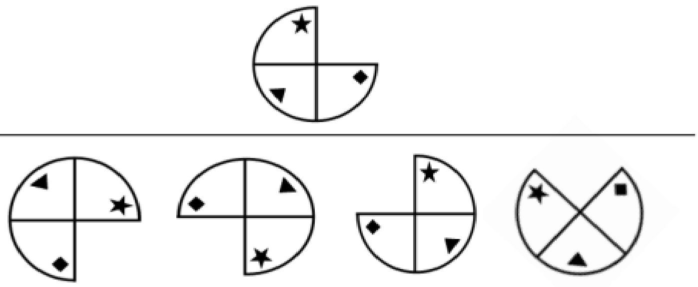


(A) (B) (C) (D)

A, C ve D seçeneklerindeki şekiller yukarıdaki şeklin döndürülmüş halleridir. B seçeneği şeklin döndürülmüş hali değildir.

Bu bölümdeki soruları örnekteki gibi çözünüz ve çizginin üstündeki şeklin döndürülmesi ile ***elde edilemeyen*** *şekli bulunuz.*

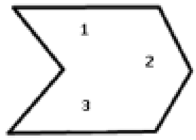
1.

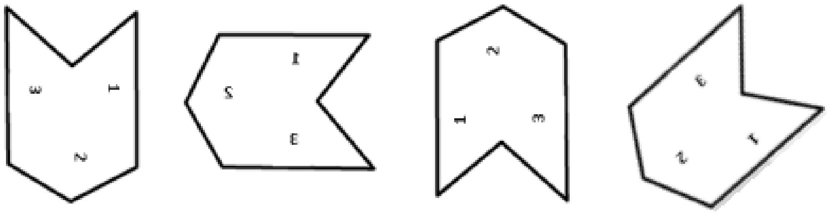


(A) (B) (C) (D)

1

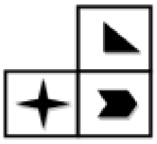
2.

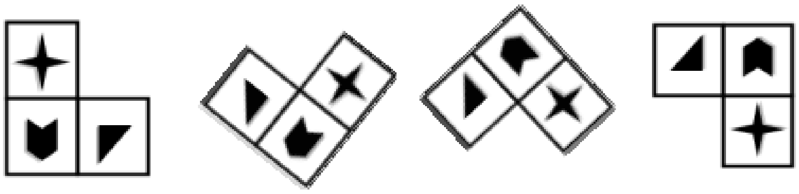




(A) (B) (C) (D)

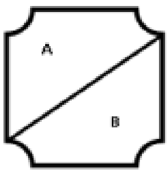
3.

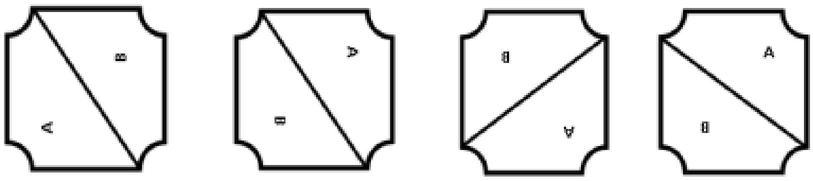




(A) (B) (C) (D)

4.



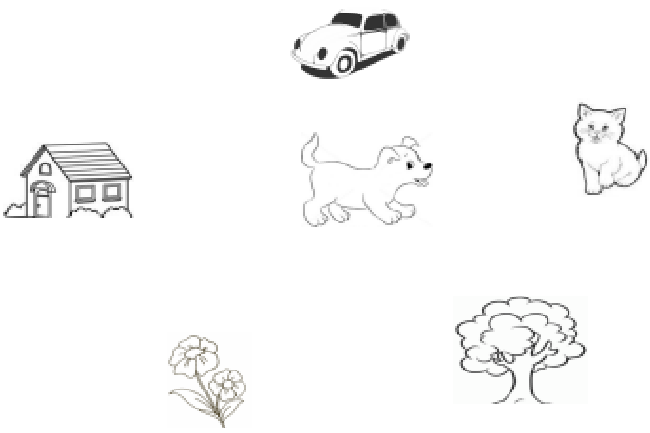


(A) (B) (C) (D)

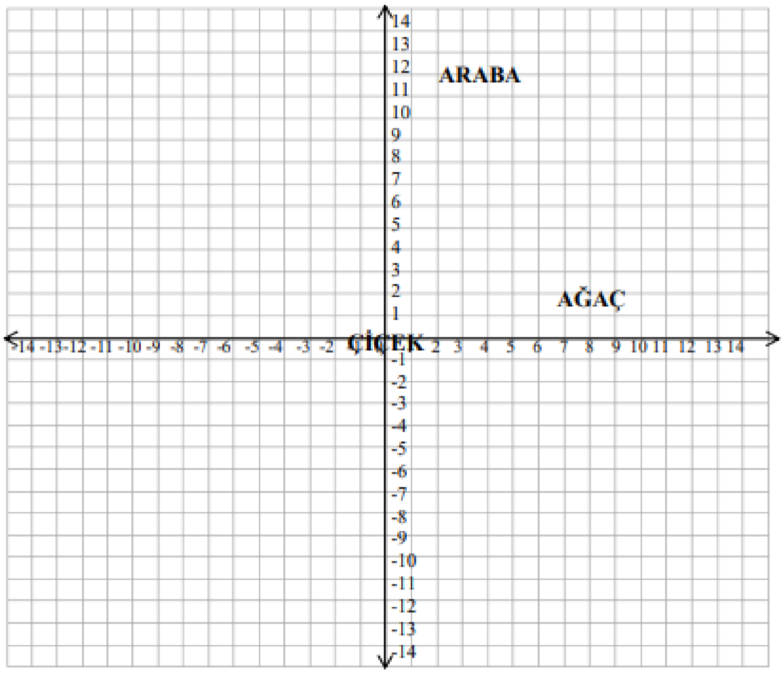
2. Bölüm

Bu bölümde çeşitli nesnelerden oluşan bir resim ve bazı nesnelerin aralarındaki yönleri belirlemek amacıyla bir "koordinat sistemi" verilmiştir. Soruları cevaplarken, bir nesnenin koordinat sisteminin merkezinde olduğunu hayal etmelisin. Merkezdeki nesnenin konumuna göre verilen diğer iki nesnenin yerini **tahmini olarak** belirlemeli ve koordinat sistemine yerleştirmelisin.

Örnek:

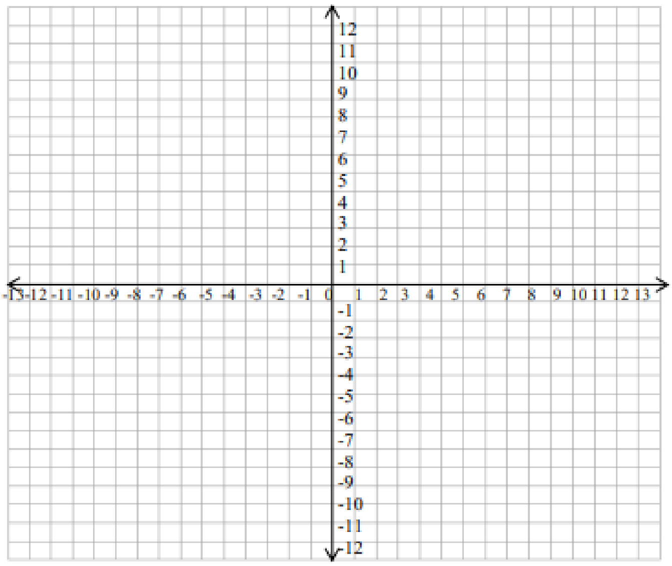


ÇİÇEĞİN koordinat sisteminin merkezinde olduğunu hayal et. Bu konumda iken **AĞACIN** ve **ARABANIN** yerini koordinat düzlemi üzerinde göster.

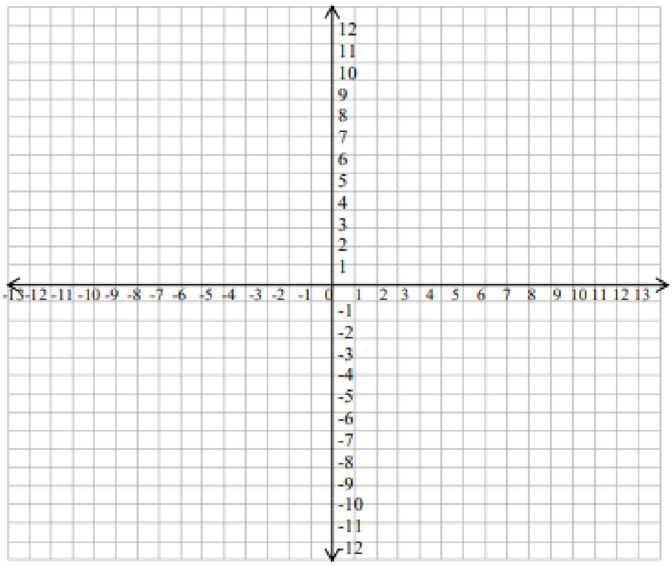


Bu bölümdeki 2 soruyu örnekteki gibi çözünüz ve istenilen nesneleri koordinat düzlemi üzerine yerleştiriniz.

1. KEDİNİN koordinat sisteminin merkezinde olduğunu hayal et. Bu konumda iken **KÖPEĞİN** ve **ÇİÇEĞİN** yerini koordinat düzlemi üzerinde göster.



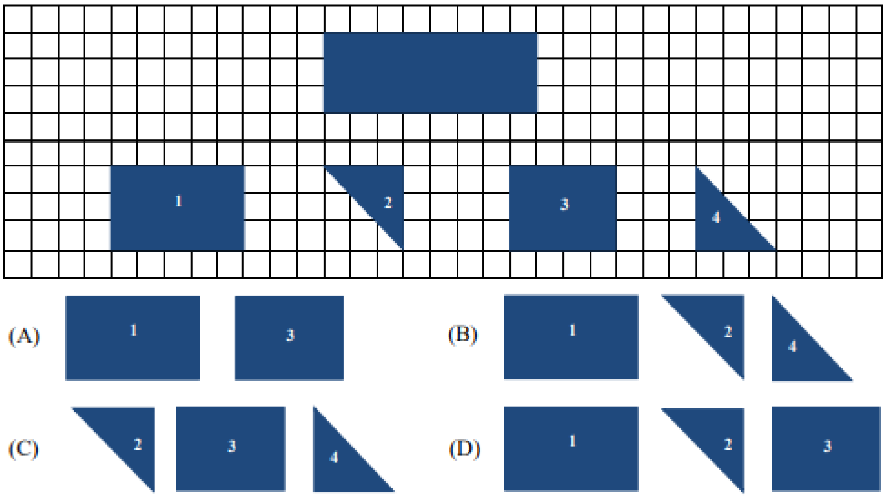
2. ARABANIN koordinat sisteminin merkezinde olduğunu hayal et. Bu konumda iken **EVİN** ve **AĞACIN** yerini koordinat düzlemi üzerinde göster.



3. Bölüm

Bu bölümde çizginin üstünde bir şekil ve altında onu oluşturabilecek çeşitli şekiller bulunmaktadır. Çizginin altındaki şekiller **boyutları değiştirilmeden** üstteki şekli oluşturmak için **döndürülebilir**. Ayrıca şekillerin birbirleri ile **çakıştırılmaması** gerekmektedir. ***Soruları cevaplarken kareli düzlemin birimlerini dikkate alınız.***

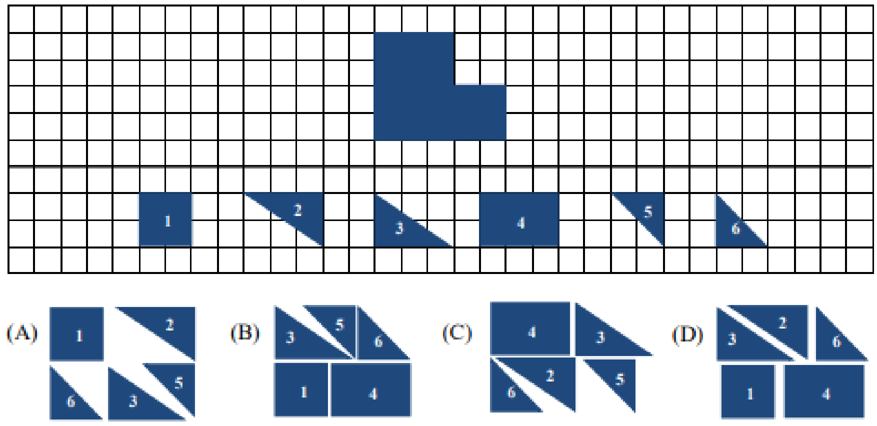
Örnek: Çizginin üstündeki şekli oluşturmak için aşağıda verilen şekil setlerinden hangisinin kullanılması gerekir?



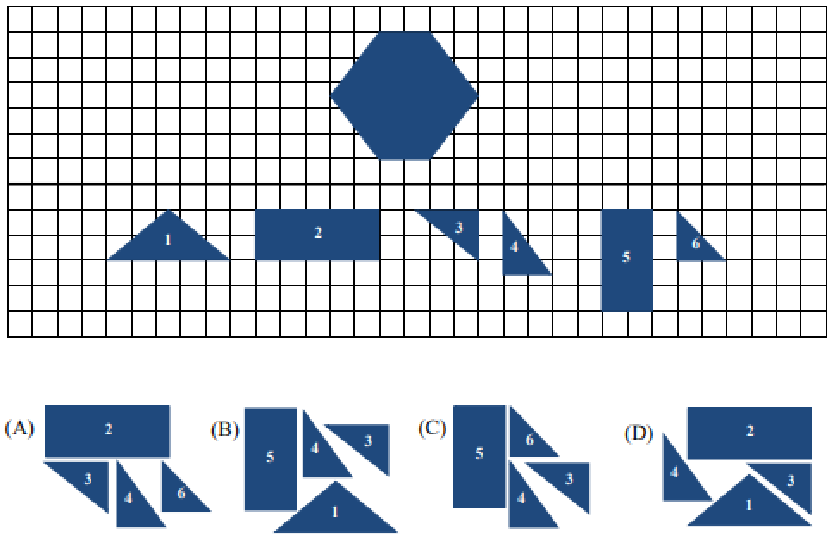
Çizginin üstündeki şekli elde etmek için B şıkkındaki şekil setini kullanmak gerekir.

Bu bölümdeki soruları örnekteki gibi çözünüz ve her bir soru için hangi şekil setinin kullanılması gerektiğini bulunuz.

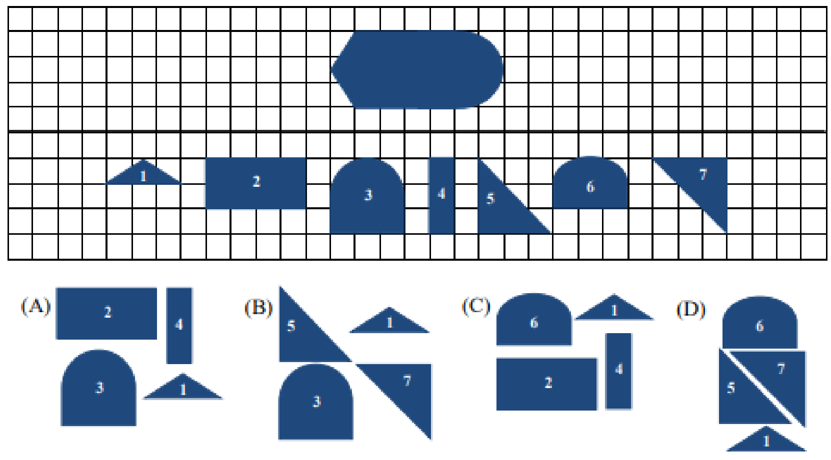
1.



2.

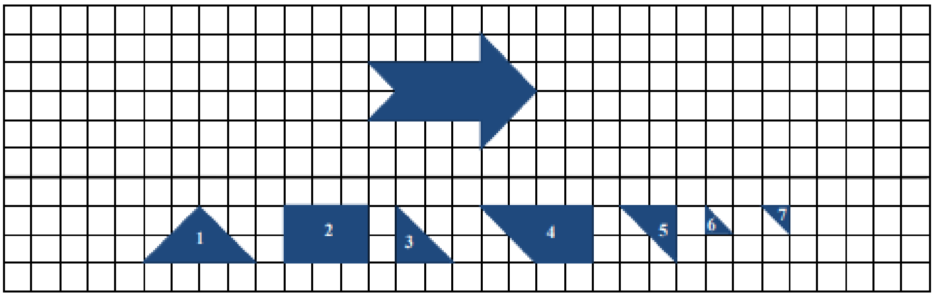


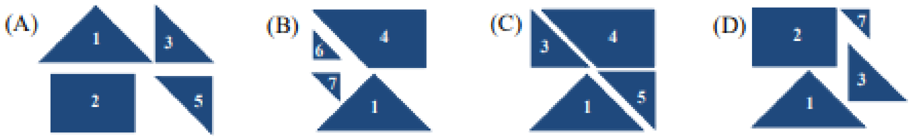
3.



6

4.



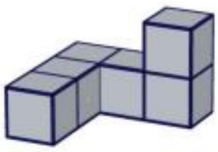


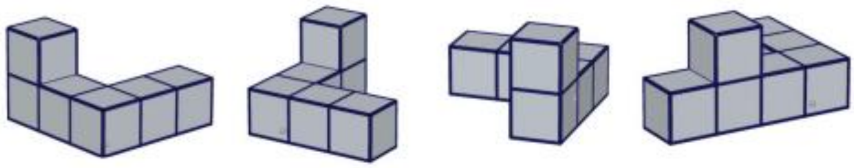
7

4. Bölüm

Bu bölümdeki sorularda çizginin üstünde 1 şekil ve altında 4 şekil bulunmaktadır. 3 seçenekteki şekil çizginin üstündeki şeklin aynısı olup çeşitli açılardan döndürülmesi ile oluşmuştur, 1 seçenekteki şekil ise farklı bir şekildir.

Örnek: Çizginin üstündeki şekil ile **aynı olmayan** şeklin bulunduğu seçeneği işaretleyiniz.



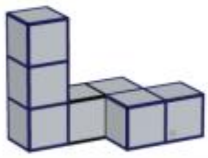


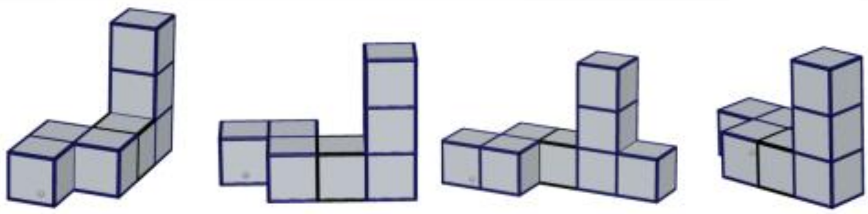
(A) (B) (C) (D)

A, B ve C seçeneğindeki şekiller yukarıdaki şeklin döndürülmüş halleridir. D seçeneğindeki şekil ise farklı bir şekildir.

Bu bölümdeki soruları örnekteki gibi çözünüz ve çizginin altındaki şekillerden hangisinin yukarıdaki şekil ile aynı olmadığını işaretleyiniz.

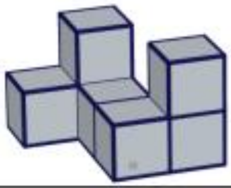
1.

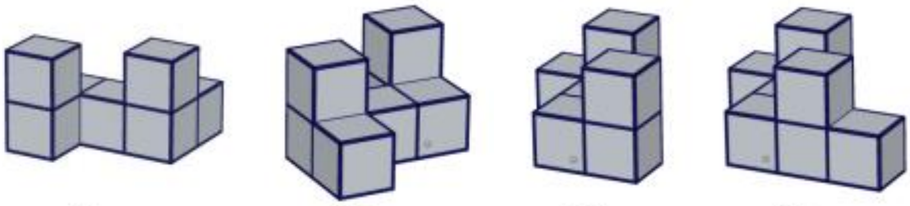




(A) (B) (C) (D)

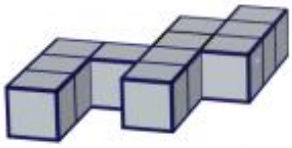
2.

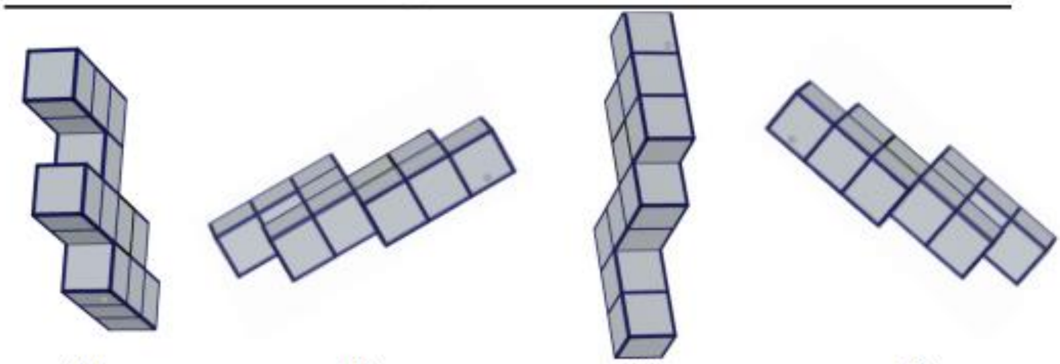




(A) (B) (C) (D)

3.



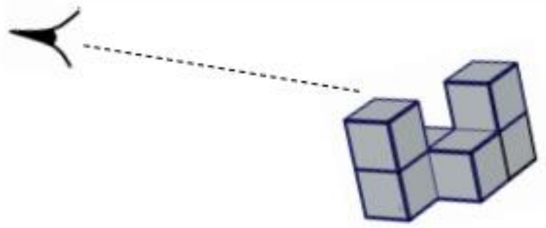


(A) (B) (C) (D)

5. Bölüm

Aşağıda göz ile gösterilen yerde bulunan bir kişi küplerden oluşan şekillere bakmaktadır. Kesikli çizgi, bakış açısını göstermektedir. Bu yapılara gösterilen yerden bakan bir kişinin nasıl gördüğünü bulunuz.

Örnek: Çizginin altındaki şekillerden hangisinin verilen yapının bakış açısına bağlı olarak görünümü olduğunu bulunuz.

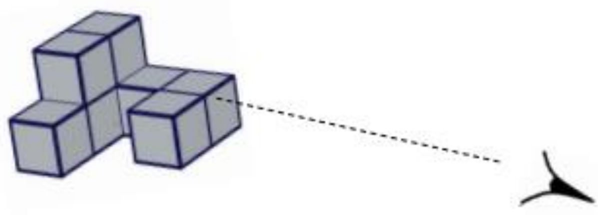


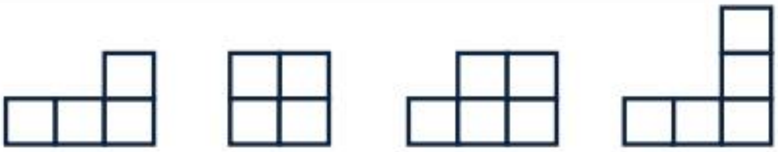
(A) (B) (C) (D)

Yukarıdaki sorunun cevabı B seçeneğidir. Verilen şekle istenilen bakış açısıyla bakıldığında altta 3 küp sıralanmaktadır, sağda ve solda üst üste ikişer küp bulunmaktadır.

Aşağıdaki soruları örnekteki gibi çözünüz ve çizginin altındaki seçeneklerden hangisinin yukarıdaki şeklin bakış açısına bağlı olarak görünümü olduğunu bulunuz.

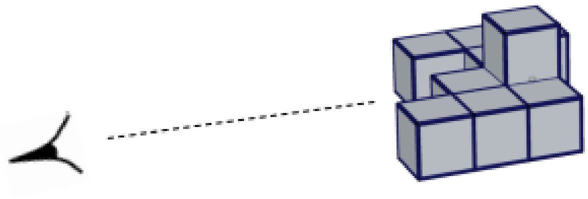
1.

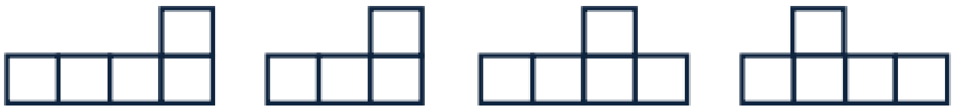




(A) (B) (C) (D)

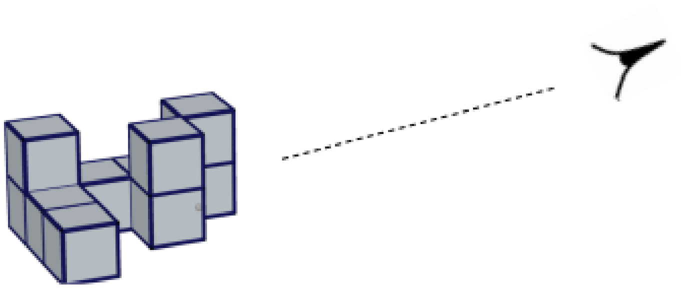
2.

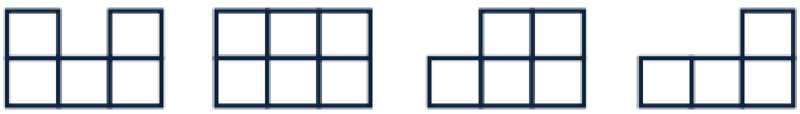




(A) (B) (C) (D)

3.



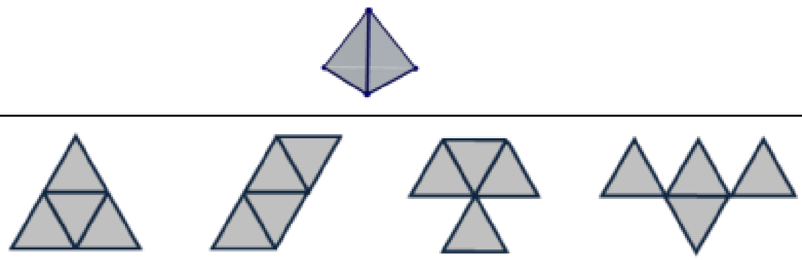


(A) (B) (C) (D)

6. Bölüm

Bu bölümde çeşitli nesneler ve açınımlarını gösteren şekiller bulunmaktadır. Çizginin altındaki şekillerden üç tanesinin katlanmasıyla verilen şekil elde edilmektedir. Diğer şekil ile ise farklı bir şekil elde edilmektedir.

Örnek: Aşağıdaki soruda seçeneklerden hangisinin katlanmasıyla çizginin üzerindeki şeklin **oluşturulamayacağını** bulunuz.

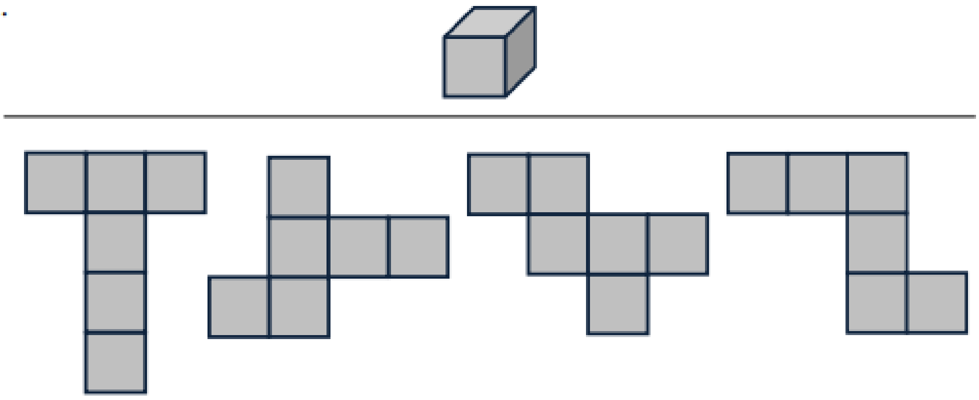


(A) (B) (C) (D)

A, B ve D seçeneklerinin katlanması ile çizginin üstündeki şekil oluşurken, C seçeneğinin katlanması ile oluşmamaktadır.

Aşağıdaki soruları örnekteki gibi çözünüz ve seçeneklerden hangisinin katlanmasıyla çizginin üzerinde bulunan şeklin elde ***edilemeyeceğini*** *işaretleyiniz.*

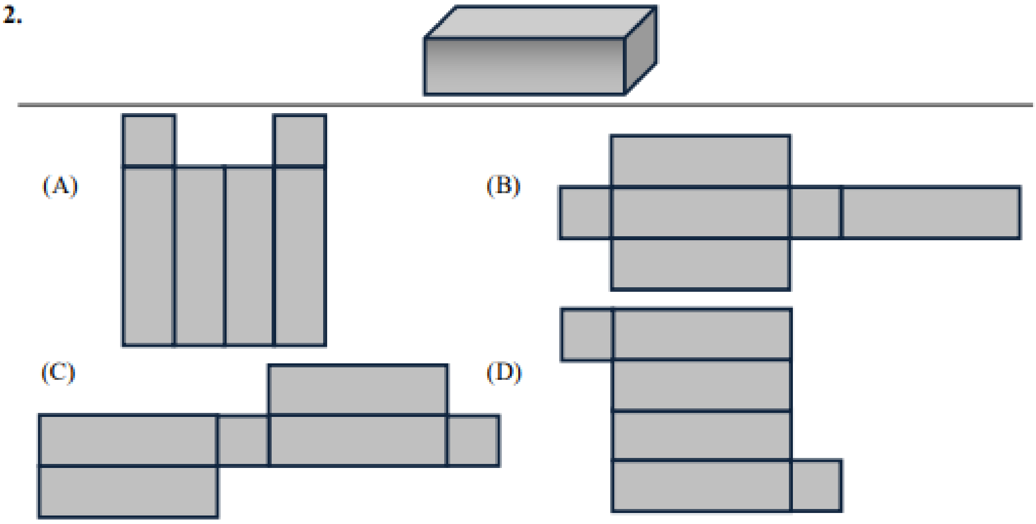
1.



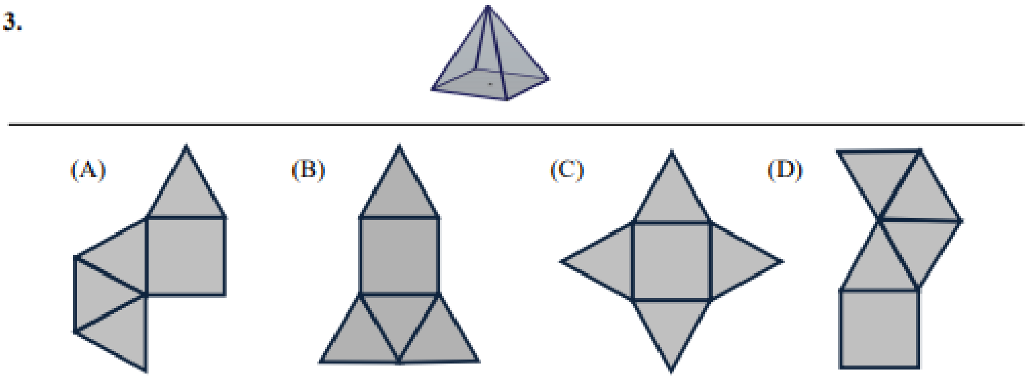
(A) (B) (C) (D)

12

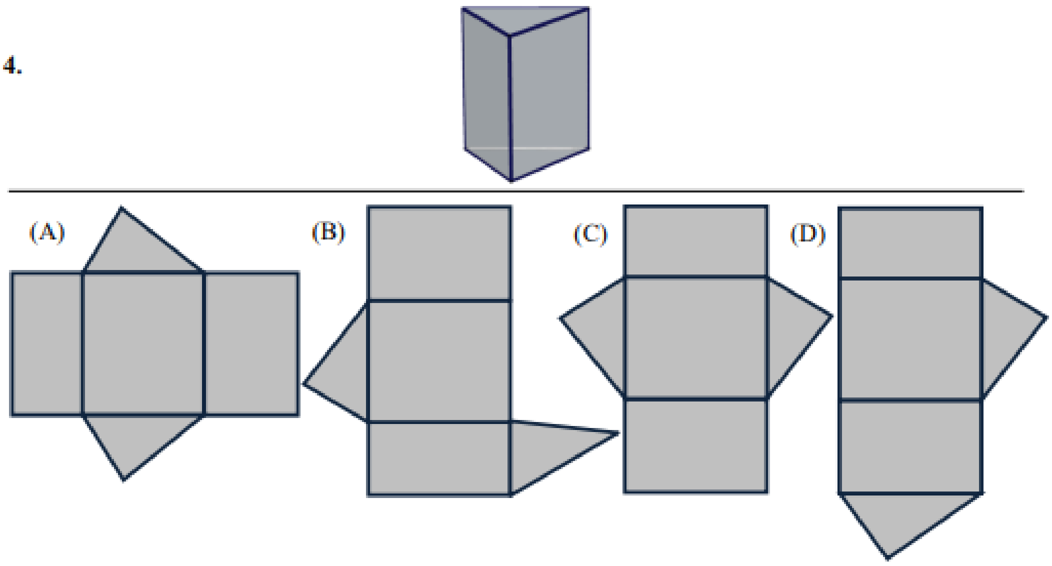
2.



3.



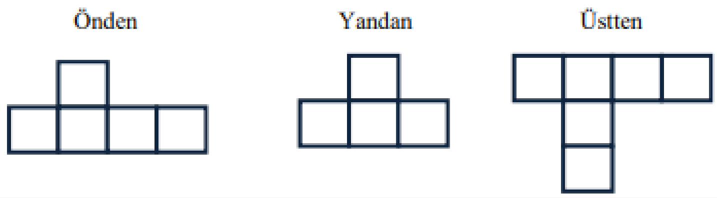
4.

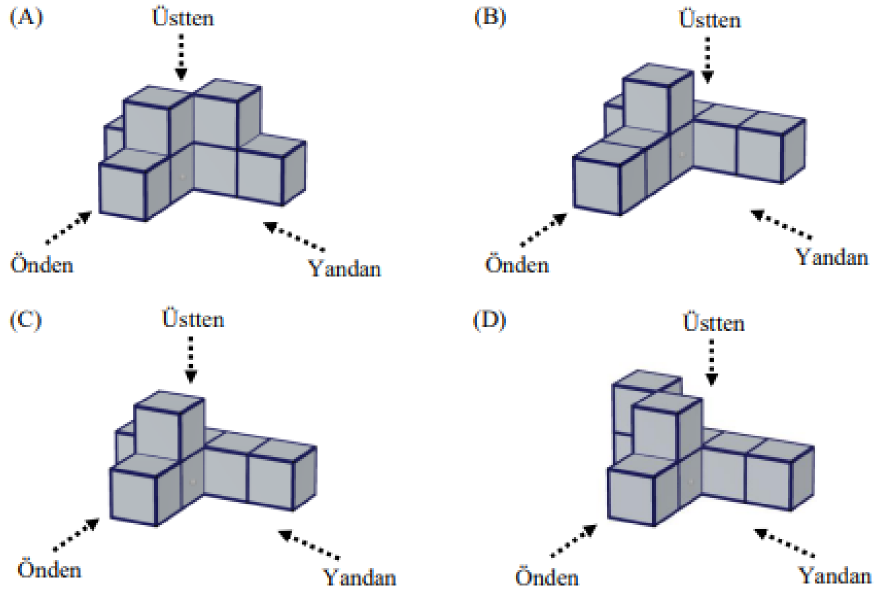


7. Bölüm

Bu bölümdeki sorularda çizginin üzerinde bir şeklin önden, yandan ve üstten görünümü ile çizginin altındaki seçeneklerden birinde şeklin kendisi verilmektedir. Üç farklı yönden görünümünü dikkate alarak şekli bulunuz.

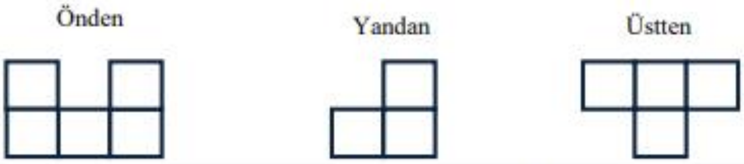
Örnek: Aşağıdaki soruda önden, yandan ve üstten görünümleri verilen yapıyı bulunuz.



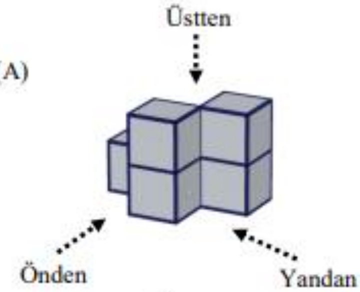


Önden, yandan ve üstten görünümü verilen şekil C seçeneğinde yer almaktadır.

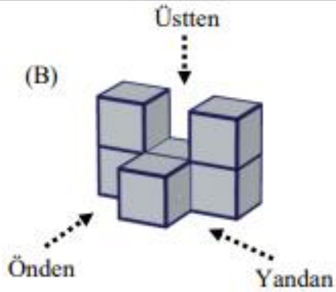
1.



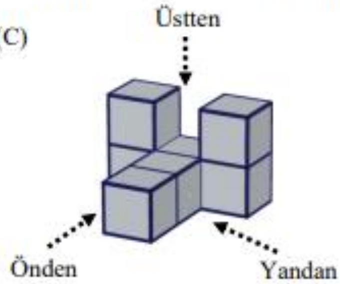
(A)



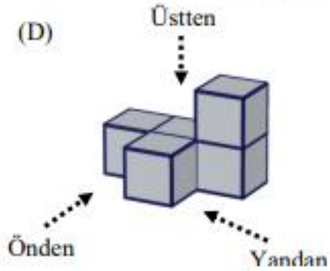
(B)



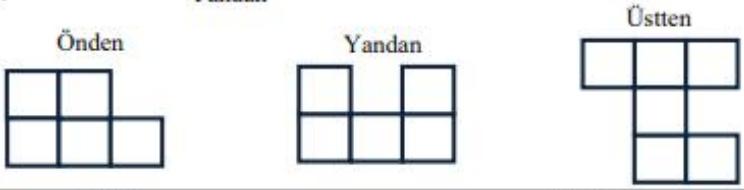
(C)



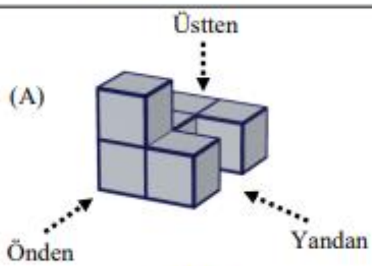
(D)



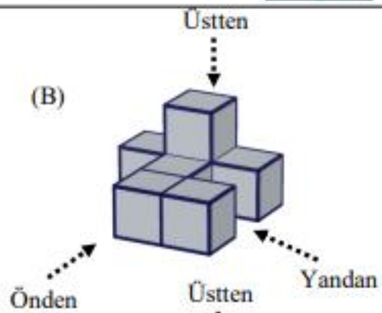
2.



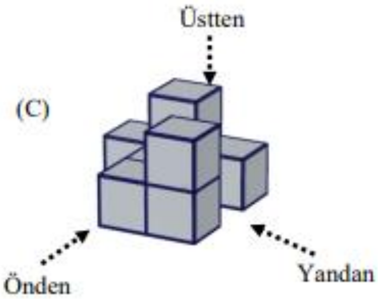
(A)



(B)

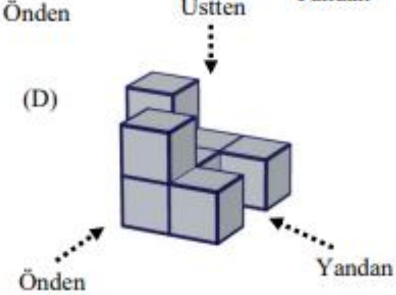


(C)

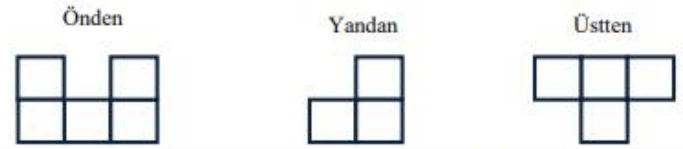


(D)

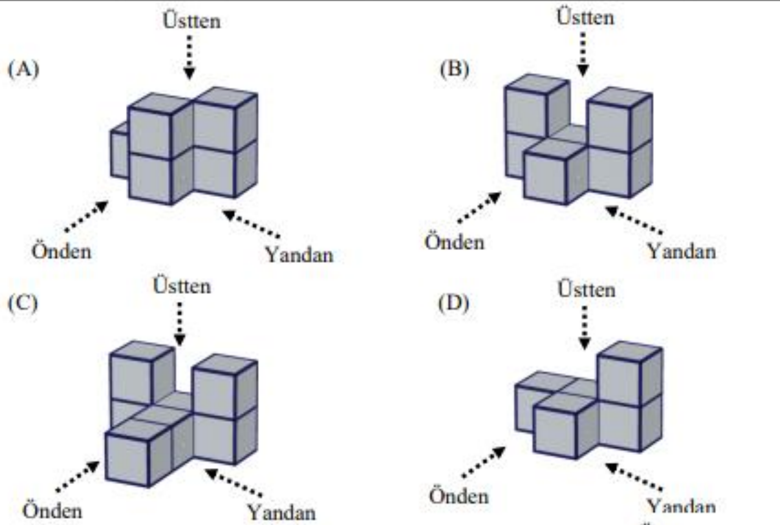
15



1.

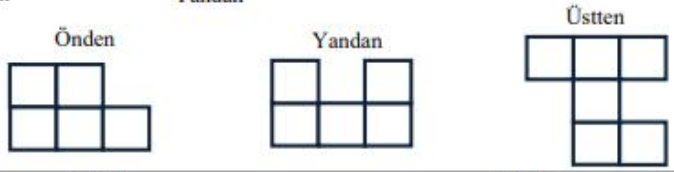


Önden
Yandan
Üstten

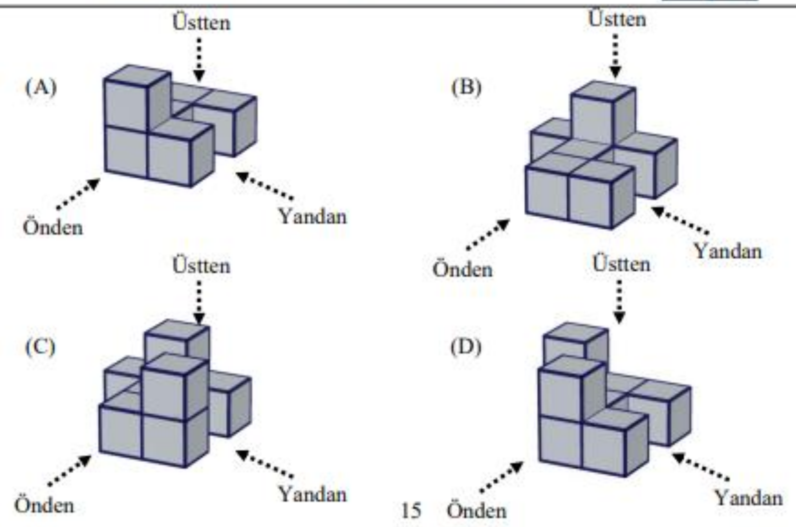


(A)
Üstten
Önden
Yandan
(B)
Üstten
Önden
Yandan
(C)
Üstten
Önden
Yandan
(D)
Üstten
Önden
Yandan

2.



Önden
Yandan
Üstten

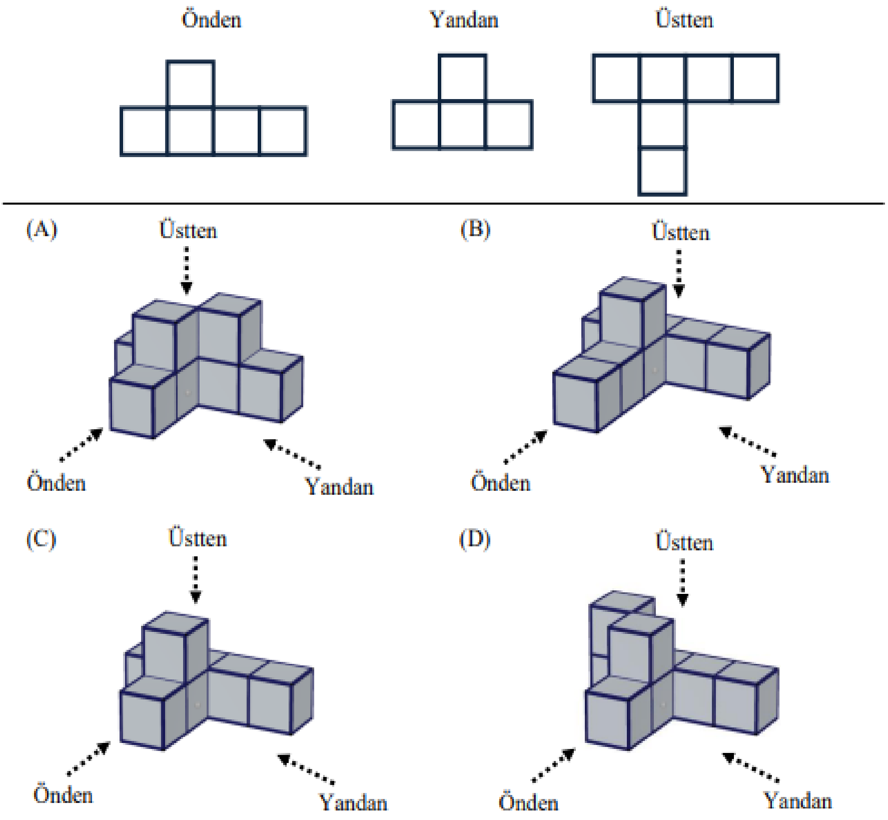


(A)
Üstten
Önden
Yandan
(B)
Üstten
Önden
Yandan
(C)
Üstten
Önden
Yandan
(D)
Üstten
15 Önden
Yandan

7. Bölüm

Bu bölümdeki sorularda çizginin üzerinde bir şeklin önden, yandan ve üstten görünümü ile çizginin altındaki seçeneklerden birinde şeklin kendisi verilmektedir. Üç farklı yönden görünümünü dikkate alarak şekli bulunuz.

Örnek: Aşağıdaki soruda önden, yandan ve üstten görünümleri verilen yapıyı bulunuz.



Önden, yandan ve üstten görünümü verilen şekil C seçeneğinde yer almaktadır.