

Van Hiele Levels of Geometric Thinking, Spatial Anxiety, and Attitudes Toward Geometric Objects Among Prospective Primary School Teachers in Istanbul, Turkey

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Abstract

The aim of this study was to examine the Van Hiele geometric thinking levels, spatial anxiety, and attitudes toward geometric objects among 232 prospective classroom teachers studying at a public university in Turkey. The data were collected using the Van Hiele Geometry Test, the Spatial Anxiety Scale, the Attitude Scale on the Subject of Geometric Objects, and a Teacher Candidate Information Form developed by the researcher. This research employed a survey design. The findings revealed that the participants' geometric thinking levels ranged between Levels 1 and 4, with a concentration at Level 2-Descriptive Level. Participants exhibited low levels of spatial anxiety and medium attitudes toward geometric objects. No significant differences were found in these variables based on gender or preference for teaching geometry topics. However, third-year students were found to have higher levels of spatial anxiety compared to first- and second-year students. Additionally, those at Level 4 scored higher on the Van Hiele Geometry Test than those at other levels, while those at Level 1 had higher spatial anxiety and lower high school geometry grades. Finally, a low-level positive correlation was found between participants' scores on the Van Hiele Geometry Test and their high school geometry course grades, whereas a low-level negative correlation was observed between Van Hiele Geometry scores and spatial anxiety.

Key words: Attitude Scale on the Subject of Geometric Objects, geometry, prospective primary school teachers, spatial anxiety, Van Hiele Geometry

Introduction

Geometry is one of the branches of mathematics that many learners around the world struggle to master (Naufalet et al., 2021). It enters human life from the moment individuals begin to explore the physical world around them at birth and retains its significance throughout their lives (Gökbulut, Sidekli, & Yangın, 2010). Furthermore, it is recognized as one of the fundamental learning domains in both mathematics curricula and mathematics education (National Council of Teachers of Mathematics [NCTM], 2000). Geometry specifically addresses spatial sense and geometric reasoning. Students begin to comprehend geometric concepts through direct interaction with the physical environment. Because it involves the study of the physical properties of the surrounding space, geometry is relevant to every learner—turning the world itself into a vast classroom. As students observe, touch, and manipulate geometric shapes, they initiate and progressively develop their spatial reasoning skills (Howse & Howse, 2015). Geometry is taught across all educational levels, from primary through higher education, due to its foundational role in mathematical thinking (Pujawan, Suryawan, & Prabawati, 2020). Moreover, geometry is embedded in nearly every human creation—ranging from science to the arts—and is intertwined with daily life, further enhancing its significance (Sari, Machromah, & Purnomo, 2018; Van de Walle, 2001).

It is well recognized that geometry helps students develop a perspective that enables them to analyze and solve problems, as well as to establish meaningful connections between mathematics and real-life contexts (Duartepe, 2000a). Geometry instruction contributes not only to students' mathematical development but also to the enhancement of their cognitive skills (Clements & Sarama, 2011). Therefore, the teaching of geometry should not only aim to equip students with geometric knowledge and skills but also foster the development of geometric thinking (Baykul, 2014).

In order to foster geometric thinking, a critical component of mathematical thinking, and to enhance achievement in mathematics and geometry instruction, it is essential to first identify students' levels of geometric thinking (Akay & Kurtuluş, 2017; Cantürk Günhan, Altaylar, Dinçer Aksoy & Özdişçi, 2022; Osmanoglu, 2019). It is widely acknowledged that instruction tailored to students' respective levels can lead to greater success in geometry and, by extension, in mathematics overall (Choi Koh, 1999). Geometry education requires a sequential structure in which concepts are built upon one another, and smooth transitions between different thinking levels are ensured (Collier & Pateracki, 1998). However, students often struggle in geometry courses precisely because their geometric thinking levels are not adequately taken into account. Although geometry holds a significant place in mathematics education worldwide, Turkey included students' performance in geometry is generally low at the international level (Alex & Mammen, 2012; Gutiérrez, Jaime, & Fortuny, 1991; Halat, 2006, 2007; Mullis, Martin, Foy, & Arora, 2012). Research conducted in Turkey further supports this situation. According to the results of the Trends in International Mathematics and Science Study [TIMSS] (2007, 2011, 2015, 2019), Turkish students'

performance in geometry remains below the international average. Although the most recent TIMSS results indicate an improvement in geometry scores compared to previous years, the performance of Turkish students still lags behind the international mean (TIMSS 2019 Turkey Preliminary Report, 2020; Yıldırım, Özgürlük, Parlak, Gönen, & Polat, 2016). The persistent underperformance of Turkish students in international assessments such as TIMSS may, in part, be attributed to geometry instruction that does not sufficiently consider students' levels of geometric thinking (Asik Unal & Vezne, 2021).

The Van Hiele Model of Geometric Thinking has emerged as a prominent framework for identifying students' current levels in geometry and supporting their progression across these levels (Duatepe Paksu, 2016; Usiskin, 1982). The Van Hiele model explains how individuals perceive and conceptualize geometry. It outlines how students generally understand geometric concepts across distinct, hierarchical levels (Duatepe Paksu, 2016). From the perspective of the Van Hiele model of the development of geometric thought, the learner progresses from recognizing and identifying figures to understanding their properties, then to comprehending the interrelationships among these properties, and finally to appreciating the axiomatic systems in which these figures are embedded (Usiskin, 2003). Research examining students' levels of geometric thinking consistently indicates that students at various educational stages often fail to reach the expected level (Alex & Mammen, 2012; Fidan & Türnüklü 2010; Gökbulut, Sidekli, & Yangın 2010; Halat, 2006; Kurtuluş & Akay, 2017).

According to the model, students progress through five hierarchical levels while learning geometry: The Visual Level, the Descriptive Level, the Informal Deduction Level (also referred to as the Theoretical Level), the Deduction Level (Formal Logic), and the Rigor Level (The Nature of Logical Laws) (Burger, 1986; Clements, 2004; Crowley, 1987; Hoffer, 1981; Idris, 2003, 2009; Mason, 1998; Mayberry, 1983; Senk, 1989; Van Hiele, 1986). These levels differ in terms of students' modes of understanding and conceptualization. The sequential structure of the model moves from holistic visual perception to analytical decomposition of geometric figures, and ultimately to abstract mathematical reasoning and formal deduction (Duatepe Paksu, 2016). For students who cannot be classified into any of these five levels, Clements and Battista (1992) introduced an additional level known as the "pre-recognition" or "partial visualization" stage. At this preliminary stage-referred to as Level 0, students are only able to distinguish between geometric figures with and without corners, but are unable to identify or describe properties beyond such basic visual features. One of the fundamental characteristics of the Van Hiele levels is their sequential nature. According to the Van Hiele Model of Geometric Thinking, individuals progress through these levels in a specific order while learning geometry. In order for a person to operate at a given level, they must have successfully passed through the preceding levels (Jones, 2002). Advancement from one level to the next is not determined by age or general cognitive development, but rather by instruction and experiences with geometry (Van

Hiele, 1986). In other words, these levels of geometric thinking are influenced less by chronological age and more by the learner's exposure to geometric experiences, as well as the appropriateness of instruction and language used in relation to the student's current level of understanding (Van de Walle, Karp, & Bay-Williams, 2012). If the level of instruction does not include language and examples that align with the student's current level, meaningful learning may not occur. In such cases, students may appear to demonstrate characteristics of a higher level through memorized responses yet fail to reach that level when their understanding is probed in depth (Duatepe Paksu, 2016).

In interpreting, describing, and thinking critically about the objects that surround us, spatial ability plays as significant a role as geometry itself (Clements, 1998; National Council of Teachers of Mathematics [NCTM], 2000). Understanding the progression of geometric thinking is also essential for guiding efforts aimed at enhancing spatial reasoning. The development of spatial awareness and spatial thinking closely parallels the development of geometric thinking (Altun, 2009). Battista (2007) emphasized that geometric thinking is closely related to spatial thinking, which is defined as the ability to mentally visualize spatial objects, spatial relationships, and spatial transformations. Students who are proficient in identifying spatial relationships and possess a solid understanding of geometric concepts tend to exhibit higher levels of readiness for learning more advanced mathematical topics (Hoover, 1996). Spatial thinking is strongly associated with students' success in geometry and their levels of understanding geometric concepts (Erkek & Işıksal, 2012; Pujawan, Suryawan, & Prabawati, 2020; Schenck, 2023; Unal et al, 2009). Students' difficulties in learning geometry may be due to lack of spatial ability (Fitriyani et al., 2023; Pradika & Murwaningtyas, 2012).

One of the key topics in geometry-three-dimensional geometric solids requires the knowledge and skills associated with understanding, relating, and visualizing objects in space (Yıldız, 2009). The topic of geometric solids, which inherently involves spatial intelligence, has been identified as a challenging area for students not only in Turkey but also in other countries (Battista & Clements, 1996; Gutiérrez, 1992; Kösa & Ardiç, 2018). Numerous studies have also shown that both in-service teachers and prospective teachers often lack sufficient content knowledge and experience difficulties related to geometric solids (Akkaş & Gündoğdu Alaylı, 2022; Duatepe-Paksu, Musan, İymen, & Pakmak, 2012; Fujita, 2012; Gündoğdu Alaylı, 2023; Marchis, 2012; Mutlu, Deniz, & Polat, 2017; Ulusoy, 2019; Yıldızlı & Sarı, 2017). The insufficient level of knowledge that prospective and in-service teachers demonstrate regarding geometric solids may be attributed to their attitudes toward the subject (Gürefe & Kan, 2013). Therefore, it becomes essential to investigate prospective teachers' attitudes toward the topic of geometric solids.

Another factor that negatively affects spatial thinking is spatial anxiety (Dursun, 2010; Malanchini et al., 2017; Schenck, 2023; Wei, 2018). Spatial anxiety has been defined as "worry about getting lost" (Schmitz, 1997, p. 217) and as "the fear or apprehension experienced while engaging in spatial thinking" (Geer, 2019; Kremmyda et al.,

2016). Lawton (1994, p. 767) defined spatial anxiety as “anxiety about environmental navigation.” Similarly, spatial anxiety can be described as “fear and apprehension towards spatial processing which can prevent individuals from engaging in experiences and opportunities that might otherwise promote the development of spatial skills” (Lyons et al., 2018, p. 527). Lawton (1994) found that individuals with high levels of spatial anxiety tend to ignore environmental cues and are therefore more likely to become disoriented or lost. In contrast, individuals with lower spatial anxiety levels tend to use GPS devices less frequently and get lost less often (He & Hegarty, 2020), as they rely more on approximate spatial knowledge such as landmarks and familiar routes (Castelli, Corazzini, & Geminiani, 2008; Kremmyda et al., 2016; Nori, Mercuri et al., 2009; Nori et al., 2009; Nori, Zucchelli, Palmiero, & Piccardi, 2023). Spatial anxiety has been found to be negatively associated with navigation performance, leading to slower task completion and increased error rates (Walkowiak et al., 2015). It can adversely affect individuals’ ability to reach desired destinations and explore unfamiliar environments (Oliver et al., 2023). Moreover, spatial anxiety can be observed in children as young as 6 to 8 years old (Lauer et al., 2018; Ramirez et al., 2012). This type of anxiety may have long-term consequences. When elementary school teachers experience anxiety about spatial tasks, their students tend to show less development in spatial competence over the school year compared to peers whose teachers exhibit lower levels of spatial anxiety (Gunderson et al., 2013).

The challenges and deficiencies in geometry instruction constitute a global issue, and students’ low performance in geometry is a matter of serious concern among educators (Alex & Mammen, 2012). It is widely acknowledged that the key to improving geometry achievement lies in the quality of geometry instruction and its alignment with students’ developmental levels. The teaching process and the role of the teacher are critical in fostering the development of geometric thinking and enabling students to progress from one level to another (Türnüklü & Özcan, 2014). Clements and Sarama (2011) emphasize that improving teacher education is essential to addressing students’ underachievement in geometry. They also point out that teachers and prospective teachers often lack sufficient preparation for teaching geometry. Among the various mathematics topics, geometry is reported to be the least learned and, consequently, the least confidently taught area by pre-service teachers (Jones, Mooney, & Harries, 2002).

An expected and plausible outcome is that improvements in the Van Hiele levels of geometric thinking among prospective teachers, future educators will positively impact the effectiveness of instructional methods and techniques, thereby contributing to national performance averages in large-scale assessments such as PISA and TIMSS (Çaylan, Masal, Masal, Takunyacı, & Ergene, 2017). Lumbre et al. (2023) emphasized in their study that the use of Van Hiele geometric thinking levels by teachers is strongly associated with student achievement. The mathematical knowledge of primary school teachers, particularly their understanding of geometry is crucial for supporting student learning and academic success, especially given their role in providing the foundational

instruction necessary for students' future academic development (Osmanoğlu, 2019). Therefore, in order to deliver effective instruction aligned with geometry learning outcomes and to facilitate meaningful learning for their students, prospective primary school teachers must possess the expected level of content knowledge. In this context, it is essential to assess the geometric thinking levels of pre-service teachers before they enter the profession, so that potential learning deficiencies can be identified and addressed (Osmanoğlu, 2019). Additionally, the presence of spatial anxiety among prospective teachers may negatively affect their teaching performance and, in turn, diminish their students' academic achievement (Yurt & Çakmak Gürel, 2023). Considering that spatial anxiety can emerge at a very early age and potentially influence children's cognitive skills and performance (Erkek & Işıksal, 2012; Gunderson et al., 2013; Lawton & Kallai, 2002; Pilato, Peterson, & Anderson, 2023), it is crucial to identify the spatial anxiety levels of prospective primary school teachers who will be responsible for supporting children's development in the future.

Several studies have investigated the Van Hiele geometric thinking levels of prospective primary school teachers (Aktaş & Güler, 2011; Akkurt, 2010; Armah, Cofie, & Okpoti, 2018; Aşık Ünal & Vezne, 2021; Bal, 2011, 2012; Duatepe, 2000b; Duatepe-Paksu, 2013; Gökbulut, Sidekli, & Yangın, 2010; Halat, 2008; Robichaux-Davis & Guarino, 2016; Şahin, 2008; Toluk & Olkun, 2004). Although limited in number, there are also studies examining the spatial anxiety of prospective teachers (Ekici et al., 2018; Sarı, 2016; Yorulmaz & Çilingir Altınır, 2021), as well as studies investigating their attitudes toward the topic of geometric solids (Çağırğan, Yavuz, & Deringöl, 2017; Deringöl, 2018; Güreffe & Kan, 2013; Gündüz, Bulut, & Dündar, 2017). As can be seen, no study has yet been found in the literature that simultaneously examines these three interrelated variables. Based on this gap in the literature, the present study aims to investigate the Van Hiele geometric thinking levels, spatial anxiety, and attitudes toward the topic of geometric solids among prospective primary school teachers in Turkey. Specifically, the study seeks to answer the following research question: What are the Van Hiele geometric thinking levels, spatial anxiety levels, and attitudes toward geometric solids of prospective primary school teachers? The general hypothesis of this study is: "There is a relationship among prospective primary school teachers' Van Hiele geometric thinking levels, their spatial anxiety levels, their high school geometry grades, and their attitudes toward the topic of geometric solids." To achieve this goal, answers were sought for the following research questions:

What are the Van Hiele geometric thinking levels, spatial anxieties, and attitudes towards geometric shapes of prospective elementary school teachers?

Do the Van Hiele geometric thinking levels, spatial anxieties, and attitudes towards geometric shapes of prospective elementary school teachers vary based on various variables (gender, class, high school geometry course grade, whether they enjoy teaching geometry)?

Is there a significant relationship between the Van Hiele geometric thinking levels of prospective classroom teachers, their spatial anxiety, their high school geometry course grades, and their attitudes towards the subject of geometric objects?

Methodology

In terms of data, the study has a quantitative paradigm. Since the main purpose was to determine the prospective classroom teachers' Van Hiele geometric thinking levels, spatial concerns and attitudes towards the subject of geometric objects, the research was conducted in the relational scanning model. As stated by Karasar (2004), the survey model aims at "describing a situation existing in the past or recently as it is".

Sample

The sample consists of a total of 232 prospective elementary school teachers enrolled in a state university in Turkey, Istanbul, selected through simple random sampling method. The distribution of the teacher candidates in the study group is provided below.

Table 1
The distribution of teacher candidates

Grade	Total	
	n	%
First Grade	52	22.4
Second Grade	65	28.1
Third Grade	59	25.4
Fourth Grade	56	24.1
Total	232	100.0

The sample consists of a total of 232 prospective primary school teachers, with 52 (22.4 %) from the 1st grade, 65 (28.1 %) from the 2nd grade, 59 (25.4 %) from the 3rd grade, and 56 (24.1 %) from the 4th grade. Out of these prospective teachers, 183 (78.9 %) are female, and 49 (21.1 %) are male.

Participation in this study was entirely voluntary. The research was conducted in accordance with ethical principles, involving only those prospective classroom teachers who agreed to take part. Ethical considerations were upheld at every stage of the study, and strict confidentiality was maintained.

Data collection tools

In the study, the data were collected using the "Teacher Candidate Information Form," the "Van Hiele Geometry Test" the "Spatial Anxiety Scale" and the "Attitude Scale on the Subject of Geometric Objects."

Teacher Candidate Information Form: This form was developed by the researcher. It consists of questions related to the demographic characteristics of prospective classroom teachers, their high school geometry course grades, and whether they like or dislike teaching geometry topics.

The Van Hiele Geometry Test (VHGT): The Van Hiele Geometry Test (VHGT) was developed by Usiskin (1982) to assess the geometry domain knowledge of teacher candidates. The test consists of 25 multiple-choice geometry questions. The first five items correspond to Level 1, the next five to Level 2, the following five to Level 3, the subsequent five to Level 4, and the final five to Level 5 of geometric thinking. For example, the first group of five questions in the test is related to the visual level, which corresponds to the first level of geometric thinking, while the second group of five questions is associated with the descriptive level, corresponding to the second level (Osmanoğlu, 2019). The adaptation of the test into Turkish was conducted by Duatepe (2004), and it demonstrated sufficient reliability with a Cronbach's alpha coefficient. In Duatepe-Paksu's (2013) study, the reliability coefficient of the test was found to be 0.69. The reliability coefficient in this research is 0.64. The slightly lower value is thought to be due to the number of items in the test (Duatepe Paksu & Ubuz, 2009; Usiskin, 1982). Sample items are provided below.

Item 14:

What is a property that all rectangles have but some parallelograms do not?

- a) Opposite sides are equal.
- b) Diagonals are equal in length.
- c) Opposite sides are parallel.
- d) Opposite angles are equal.
- e) None of the above is correct.

Item 25:

Suppose that you have proven the following propositions I and II:

I. If p , then q .

II. If s , then not q .

Accordingly, which of the following can be inferred from propositions I and II?

- a) If s , then not p .
- b) If not p , then not q .
- c) If p or q , then s .
- d) If p , then s .
- e) If not s , then p .

The Spatial Anxiety Scale (SAS): The Spatial Anxiety Scale (SAS) developed by Lawton (1994), aims to measure the level of anxiety felt by individuals in situations that require spatial/navigational skills (Dursun, 2010). The scale consists of a single factor and a total of eight items. The Turkish adaptation of the scale resulted in a Cronbach's alpha value of 0.87 (Dursun, 2010). In this research, the alpha value for the scale was calculated as 0.84. The Spatial Anxiety Scale, comprising eight items, has a minimum possible score of eight and a maximum of 40. As the score increases, the individual's anxiety level is considered high, while a decreasing score indicates a lower anxiety level. Sample items are provided below.

Madde 4:

"When I realize that I am lost during a journey and then try to find my way."

Madde 7:

"When I try a new route that I think will be a shortcut without using a map."

The Attitude Scale on the Subject of Geometric Objects (ASSGO): The Attitude Scale on the Subject of Geometric Objects (ASSGO) was developed by Gürefe and Kan (2013) for prospective teachers. It comprises three subscales and a total of 20 items, including 'Negative Attitude Towards Learning and Teaching Geometric Objects,' 'Positive Attitude Towards Extracurricular Activities with Geometric Objects,' and 'Positive Attitude Towards Learning and Teaching Geometric Objects.' This scale was developed in accordance with Turkish culture by examining many international scales. Since the sample consisted of Turkish teacher candidates, no English adaptation was required. The reliability coefficient for this scale is 0.92 according to the original study by Gürefe and Kan (2013). In the present study, the reliability coefficient for the scale was found to be 0.87. Sample items are provided below.

Item 2:

"Since it requires abstract thinking, I find it difficult to learn the topic of geometric objects."

Item 6:

"I think I will have difficulty adjusting to students' level when explaining geometric objects."

Data collection

Data collection tools were applied to prospective classroom teachers in consecutive sessions. Missing forms were removed, and data entries were made for the remaining forms to be analysed.

Data analysis

In determining the geometric thinking levels of prospective teachers, the criteria outlined by Usiskin (1982) were utilized. This criterion involves correctly answering at least 3 out of 5 questions or at least 4 out of 5 questions. The choice of which criterion to use depends on the type of error that the study aims to control. If the study aims to prevent assigning an individual to a geometric thinking level above their actual level, the criterion should be to correctly answer at least 4 out of 5 questions. If the study aims to prevent assigning an individual to a geometric thinking level below their actual level, the criterion should be to correctly answer at least 3 out of 5 questions (Usiskin, 1982). The choice of which criteria to apply is left to the researchers' preferences (Knight, 2006). In this study, where the aim is to examine the geometric thinking levels of prospective primary school teachers in terms of various variables, the criterion of correctly answering at least 3 out of 5 questions was employed. In the

next stage, adherence to the rule that all previous levels must be successfully passed for prospective teachers to be assigned to any level was maintained due to the hierarchical structure of geometric thinking levels (Usiskin, 1982). According to this, the scoring is as follows (Usiskin, 1982, s.22):

- 1 point if the criteria are met in questions 1-5 (Level 1),
- 2 points if the criteria are met in questions 6-10 (Level 2),
- 4 points if the criteria are met in questions 11-15 (Level 3),
- 8 points if the criteria are met in questions 16-20 (Level 4),
- 16 points if the criteria are met in questions 21-25 (Level 5).

Based on this scoring system, the required scores for a teacher candidate to be at Level 1 is one point; for Level 2, it is three points; for Level 3, it is seven points; for Level 4, it is 15 points; and for Level 5, it is 31 points. Subsequently, descriptive statistical techniques were used to analyse the frequencies and percentages for each level. After determining the teacher candidates' levels of geometric thinking, spatial anxiety scores, and attitudes towards the topic of geometric objects, the relevant data were analysed using SPSS 21. Before commencing the analyses, a Kolmogorov-Smirnov test was conducted to assess the normality of the data distribution. Simultaneously, Skewness-Kurtosis values of the scores were examined. The level of significance was found to be lower than .05 based on the Kolmogorov-Smirnov test results. Additionally, considering the skewness coefficient between +2.0 and -2.0, as outlined by George and Mallery (2010), it was observed that the data exhibited a normal distribution. Consequently, parametric tests were employed for further analysis. The data analysis involved the application of Independent-Samples t-Test, One Way ANOVA, and Pearson Moment Correlation tests, and the subsequent calculation of results. Independent-Samples t-Test was used to look at whether there was a difference between the scores obtained from the scales in the variables, One Way ANOVA was used to look at the differences in situations with more than two variables (classes and levels), LSD and Tamhane were used in the post hoc tests to determine between which groups this difference occurred, and finally Pearson Moment Correlation was used to look at the relationship between the scores obtained from the scales and the high school geometry course grades of the classroom teacher candidates. In selecting the post hoc tests, it was checked whether the variances were homogeneous and for those with LSD, the Tamhane Test was performed for the groups without LSD and the results were interpreted. In the tests performed, significant differences were examined and since the magnitude of this difference did not provide complete information, the effect size was calculated in order to be able to interpret it. In the results where a significant difference was found, the eta-square (η^2) formula was used to determine the effect size in the One Way ANOVA Test. Accordingly, η^2 ($\text{Eta } 2 = \text{SS Between} / \text{SS Total}$) formula was used. While evaluating the effect values found, the values .010: Small; .059: Medium; .138: Large were taken into consideration (Cohen, 1988).

Results

The findings are presented in the order of research problems below. Accordingly, the results of the first sub-problem are provided in Tables 2 and 3. The analysis results for prospective primary school teachers' Van Hiele geometric thinking levels are presented in Table 2, based on the frequency and percentage values of 232 teacher candidates.

Table 2
Frequency and percentage values for Van Hiele Geometric Thinking Levels of prospective primary school teachers

Levels	1 st Grade		2 nd Grade		3 rd Grade		4 th Grade		Total	
	n	%	n	%	n	%	n	%	n	%
Level 1- Visual.	12	23.1	14	21.5	6	10.2	8	14.3	40	17.2
Level 2- Description	23	44.2	28	43.1	35	59.3	25	44.6	111	47.8
Level 3- Informal deduction	15	28.8	19	29.2	16	27.1	20	35.7	70	30.2
Level 4- Deduction	2	3.8	4	6.2	2	3.4	3	5.4	11	4.7

As a result of the analyses conducted within the scope of this research, as can be understood from the table above, it is observed that 17.2 % (n:40) of the candidates are at Level 1-Visualation; 47.8 % (n:111) at Level 2-Description; 30.2 % (n:70) at Level 3- Informal deduction; and 4.7 % (n:11) at Level 4-Deduction. It is noted that there is no candidate at Level 5-Rigor. In summary, it can be stated that prospective primary school teachers are predominantly clustered at Level 2-Description. When examined according to class level, it is observed that at each grade level, there is a predominant presence at Level 2-Description.

The findings related to the first sub-problem (spatial anxiety and attitudes towards geometric objects) are presented in Table 3.

Table 3
Mean scores obtained from the scales

Scale	N	Mean	Sd
SAS	232	1.96	.66
ASSGO	232	2.82	.42

The scores obtained from the "Spatial Anxiety Scale (SAS)" and "Attitude Scale on the Subject of Geometric Objects (ASSGO)" are as shown in Table 3. To determine the levels based on the scores obtained from the scales, the scale's range width was calculated using the formula "range width/number of groups to be created" ($4/5=0.80$) (Tekin, 1993). The arithmetic mean intervals of the scale are determined as follows: 1.00-1.79 'Very Low', 1.80-2.59 'Low', 2.60-3.39 'Medium', 3.40-4.19 'High', 4.20-5.00 'Very High'. Accordingly, prospective primary school teachers' spatial anxiety levels were found to be 'Low', and their attitudes towards geometric objects were at a 'Medium' level.

The findings related to the second problem are presented in Tables 4, 5, 6, 7, and 8.

Table 4
Independent Sample t-Test results for scores obtained from the scales by gender

Scale	Gender	N	Mean	S	t	p
VHGT	Female	183	5.71	4.87	-.131	.512
	Male	49	5.81	5.56		
SAS	Female	183	15.83	5.43	.764	.927
	Male	49	15.18	4.76		
ASSGO	Female	183	56.61	8.54	.501	.407
	Male	49	55.93	7.99		

To examine whether there is a significant difference in the scores obtained from the measurement tools based on the ‘gender’ variable, Independent Sample t-Tests were conducted. There is no significant difference in the mean scores of “Van Hiele Geometry Test (VHGT)” ($t=-.131, p>.05$), “Spatial Anxiety Scale (SAS)” ($t=.764, p>.05$), and “Attitude Scale on the Subject of Geometric Objects (ASSGO)” ($t=.501, p>.05$) based on the gender of the prospective primary school teachers. Many studies have addressed the perception and outcome that the majority of teachers providing instruction to younger age groups such as in preschool and primary education are women (Smedley, 2007). The same applies to Turkey, i.e. teaching is predominantly perceived as a female profession and chosen by females. As seen in the present study, the majority of the prospective classroom teachers participating in the research are also women.

Table 5
Independent Sample t-Test results for scores obtained from the scales according to the Attitude Toward Teaching Geometry

Scale	(Dis)Liking	N	Mean	S	t	p
VHGT	Liking	134	5.61	5.12	-.402	.796
	Disliking	98	5.88	4.88		
SAS	Liking	134	15.65	5.26	-.139	.854
	Disliking	98	15.75	5.38		
GSG	Liking	134	3.97	.88	5.117	.063
	Disliking	98	3.35	.94		
ASSGO	Liking	134	57.00	8.11	1.129	.222
	Disliking	98	55.74	8.79		

To investigate whether there is a significant difference in the scores obtained from the measurement tools based on the variable ‘or disliking teaching geometry,’ an Independent Samples t-Test was conducted. The average scores of the “Van Hiele Geometry Test (VHGT)” ($t=-.402, p>.05$), “Spatial Anxiety Scale (SAS)” ($t=-.139, p>.05$), high school geometry course grades (GSG) ($t=5.117, p>.05$), and “Attitude Scale on the Subject of Geometric Objects (ASSGO)” ($t=1.129, p>.05$) indicate that there is no significant difference among the teacher candidates in terms of their preference for teaching geometry. Although the geometry course grades in high school do not show

a significant difference, it means that the probability of this occurring in the sample is 94 %. This situation may be explained by the fact that the scores reflecting enjoyment and lack of enjoyment in teaching geometry topics are very close to each other.

Table 6
One-Way Analysis of Variance (ANOVA) results for scale scores by classes

Scales	Class	N	Mean	Std. Deviation	Sum of squares	Mean square	F	p
VHGT	1 st Class	52	.22	.21	.030	.010	.249	.862
	2 nd Class	65	.22	.20	9.258	.041		
	3 rd Class	59	.21	.19	9.289			
	4 th Class	56	.24	.19				
	Total	232	.22	.20				
SAS	1 st Class	52	1.87	.61	4.096	1.365	3.197	.024
	2 nd Class	65	1.83	.49	97.355	.427		
	3 rd Class	59	2.17	.81	101.451	1.365		
	4 th Class	56	1.96	.65				
	Total	232	1.96	.66				
GSG	1 st Class	52	3.59	.82	1.233	.411	.442	.723
	2 nd Class	65	3.70	1.08	211.991	.930		
	3 rd Class	59	3.74	.95	213.224			
	4 th Class	56	3.80	.94				
	Total	232	3.71	.96				
ASSGO	1 st Class	52	2.78	.44	.086	.029	.159	.923
	2 nd Class	65	2.84	.37	40.819	.179		
	3 rd Class	59	2.83	.43	40.905			
	4 th Class	56	2.82	.43				
	Total	232	2.82	.42				

One-Way Analysis of Variance (ANOVA) was performed to see whether the scores obtained from the measurement tools created a significant difference according to the 'class' variable. Accordingly, the difference in the mean scores of the "Spatial Anxiety Scale (SAS)" [$F_{(3-228)} = 3.197, \eta^2 = .040, p < .05$] according to the classes of the classroom teacher candidates is statistically significant (Table 6). When the effect size of the difference found in the Spatial Anxiety Scale (SAS) was examined, it was observed that this difference had a small effect ($\eta^2 = .040$). The LSD test was conducted among the post-hoc tests. According to this, it was found that 3rd grade ($M = 2.17$) prospective teachers had more spatial anxiety than 1st grade ($M = 1.87$) and 2nd grade ($M = 1.83$) prospective teachers. The differences in Van Hiele Geometry Test (VHGT) [$F_{(3-228)} = .249, p > .05$], high school geometry grades (GSG) [$F_{(3-228)} = .442, p > .05$] and "Attitude Scale on the Subject of Geometric Objects (ASSGO)" [$F_{(3-228)} = .159, p > .05$] according to their classes are not statistically significant.

Table 7
 One-Way Analysis of Variance (ANOVA) results for the levels of Van Hiele Geometry Test based on scale scores

Scales	Level	N	Mean	Std. Deviation	Sum of squares	Mean square	F	p
VHGT	Level 1	40	.04	.00	8.996	2.999	13.870	.000
	Level 2	111	.12	.00	.292	.001		
	Level 3	70	.41	.04	9.289			
	Level 4	11	.81	.12				
	Total	232	.22	.20				
SAS	Level 1	40	2.27	.91	6.036	2.012	4.808	.003
	Level 2	111	1.95	.59	95.415	.418		
	Level 3	70	1.84	.57	101.451			
	Level 4	11	1.65	.29				
	Total	232	1.96	.66				
GSG	Level 1	40	3.05	1.06	32.908	10.969	13.870	.000
	Level 2	111	3.74	.88	180.316	.791		
	Level 3	70	3.87	.83	213.224			
	Level 4	11	4.81	.40				
	Total	232	3.71	.96				
ASSGO	Level 1	40	2.86	.36	.096	.032	.178	.911
	Level 2	111	2.81	.45	40.809	179		
	Level 3	70	2.81	.39	40.905			
	Level 4	11	2.80	.38				
	Total	232	2.82	.42				

One-Way Analysis of Variance (ANOVA) was performed to see whether the scores obtained from the measurement tools create a significant difference according to the Van Hiele Geometry Test Levels. Accordingly, the differences in the mean scores of “Van Hiele Geometry Test (VHGT)” [$F_{(3-228)} = 13.870, \eta^2 = .968, p < .01$], “Spatial Anxiety Scale (SAS)” [$F_{(3-228)} = 4.808, \eta^2 = .059, p < .05$] and high school geometry grades (GSG) [$F_{(3-228)} = 13.870, \eta^2 = .154, p < .01$] according to the geometry levels of the classroom teacher candidates are statistically significant (Table 7). When the effect sizes of the differences were examined, it was observed that the difference in the “Van Hiele Geometry Test (VHGT)” was large ($\eta^2 = .968$), the difference in the “Spatial Anxiety Scale (SAS)” was medium ($\eta^2 = .059$) and the difference in high school geometry grades (GSG) was large ($\eta^2 = .154$). Tamhane post-hoc tests were performed and the results indicated that those at Level 4 ($M = .81$) had higher scores than prospective classroom teachers at Level 1 ($M = .04$), Level 2 ($M = .12$), and Level 3 ($M = .41$). When spatial anxiety was considered, those at Level 1 ($M = 2.27$) are more anxious than those at Level 4 ($M = 1.96$). According to the high school geometry grades (GSG) of the prospective classroom teachers, those at Level 4 ($M = 4.81$) were higher than those at Level 1 ($M = 3.05$), Level 2 ($M = 3.74$), and Level 3 ($M = 3.87$). The difference in the

“Attitude Scale on the Subject of Geometric Objects (ASSGO)” [$F_{(3-228)} = .178, p > .05$] scores of the prospective classroom teachers, according to their geometric levels, was not statistically significant.

The findings related to the third problem are presented in Table 8.

Table 8
Result of Pearson Correlation Test between Van Hiele Geometry Test scores and scale scores

Scales	N	r	p
GSG		.324	.000
SAS	232	-.202	.002
ASSGO		-.038	.568

As can be understood from Table 8, a low-level positive correlation was observed between the “Van Hiele Geometry Test (VHGT)” and the class teacher candidates’ geometry course grades in high school (GSG) ($r = .324; p < .01$), and a low-level negative correlation was found with the “Spatial Anxiety Scale (SAS)” ($r = -.202; p < .05$). No significant relationship was detected between the “Van Hiele Geometry Test (VHGT)” and the “Attitude Scale on the Subject of Geometric Objects (ASSGO).”

Discussion

In this study, which investigated the geometric thinking levels, spatial anxieties, and attitudes towards geometric objects of prospective classroom teachers, teacher candidates are at levels 1-4 in terms of geometric thinking. The study predominantly concludes that teacher candidates cluster at Level 2(Description). No teacher candidates were at Level 0 or the highest level, Level 5. Interestingly, some teacher candidates were at Level 1, which is typically expected to correspond to preschool and the early years of primary education. Given the age and readiness of university students, it is anticipated that they should demonstrate Level 3 thinking characteristics in terms of Van Hiele geometric thinking levels to be successful in geometry and calculus-related courses and to comprehend geometric proofs (Teppo, 1991). This research unfortunately reveals that, at worst, the geometric thinking levels of prospective classroom teachers are predominantly at Level 2, which is the simple deduction level, rather than the expected minimum of Level 3. It is observed that the geometric thinking levels of prospective classroom teachers, as per the Van Hiele model, are not at the anticipated level. Although the study is limited to classroom teachers and data collection tools used, the level of geometry knowledge of classroom teacher candidates is not sufficient for successful geometry teaching in the first stage of primary education. These results may have been obtained because the reliability of the Van Hiele Geometry Test is somewhat low. However, in many studies conducted in Turkey (Akin & Sezgin, 2022; Asik Unal & Vezne, 2021; Osmanoğlu, 2019; Şahin, 2008, 2012), measurements were made with this international test, and as in this study, the levels of prospective teachers

were not sufficient. Unfortunately, this research result highlights Turkey's failure in geometry. Therefore, despite the increasing results in international exams over the years, it is evident that the inadequacy of our prospective classroom teachers, who will be responsible for educating our primary school students, persists. According to Usiskin (1982), the assertion that "only 50 % of students study geometry in secondary education, and only one-third of them can understand it" unfortunately reflects the situation revealed by the research. Considering that prospective teachers will teach at the primary education level, their geometric proficiency should ideally surpass the expected level for this age group. Moreover, taking into account the education prospective teachers receive from primary to university levels, the low levels of geometric thinking raise suspicions about certain deficiencies in their understanding of geometry (Saraçoğlu & Ağılıoğlu, 2022).

Şahin's (2008) study revealed that 34.1 % of prospective classroom teachers were at Level 0, 37.8 % at Level 1, and 25.6 % at Level 2. None of the prospective classroom teachers in this study have reached Levels 3 and 4, as observed. In Erdoğan's (2006) study, 39.4 % of teacher candidates were found to be at Level 0 in terms of geometric thinking. In Şahin's (2012) study, the number of teacher candidates at Levels 4 and 5 of the Van Hiele geometric levels is quite low. While there are 10 teacher candidates at Level 4, there are only two teacher candidates at Level 5. Akkurt's (2010) study, which investigated the geometric conceptual knowledge of primary school mathematics and prospective elementary school teachers through concept maps, revealed in its sub-stage analysing the distribution of candidates according to their levels of geometric thinking that, predominantly, 43.5 % of the candidates clustered at Level 2, similar to the findings of this research. Gökbulut, Sidekli, & Yangın's (2010) study on 3rd grade students in the elementary teacher education program found that their Van Hiele Geometric Thinking Levels should ideally be at Level 3 or higher. However, the observed levels were at 0, 1, and 2, with no students reaching Levels 3 and 4. Additionally, nine students were unable to reach even Level 0. The study also revealed that university students, including prospective classroom teachers, concentrated their Van Hiele geometric thinking levels mostly at Levels 2 and 1 in the geometric thinking test (Akin & Sezgin, 2022). Akay and Kurtuluş's (2017) study with prospective teachers also indicated that participants mostly clustered at Level 2 in the Van Hiele geometric thinking test, with other department teacher candidates tending to be at Level 1. In the study by Asik Unal & Vezne (2021), approximately 89.3 % of 131 prospective classroom teachers were found to be below Level III, the Van Hiele thinking level. Bal's (2011) study, which examined the relationship between the geometric thinking levels and attitudes towards geometry of prospective classroom teachers, revealed that, in the initial stage of determining the geometric thinking levels, most candidates were at the third level. Only 2.2 % of the candidates were found to reach the fifth level, and even one-fifth of them could not be assigned to any level. According to Bal's (2012) research, 17.4 % of teacher candidates were categorized as "0: not assigned to

any level,” 26.6 % at Level 1 (Visualisation), 16.1 % at Level 2 (Description), 32.9 % at Level 3 (Informal deduction), 4.6 % at Level 4 (Deduction), and 2.3 % at Level 5 (Rigor). It was concluded that 4.6 % of teacher candidates were at “4: Derivation of results,” and 2.3 % at “5: Ability to see relationships.” Thus, approximately one-tenth of the teacher candidates participating in the study are found to be at the expected level. Osmanoglu’s (2019) research, which aimed to determine the geometric thinking levels and learning deficiencies of prospective primary school teachers, revealed that the participating teacher candidates were predominantly at the third level, which is the level of simple deduction. In the study by Sarama and Clements (2009), the majority of teacher candidates performed below Level 3, with many at Level 0 and close to one-third at Level 1 (Clements & Sarama, 2011).

As evident, the results of numerous studies indicate that the expected levels of geometric thinking in teacher candidates enrolled in education faculties are generally low (Çetin & Dane, 2004; Duatepe, 2000b; Halat, 2008; Knight, 2006). Considering that teacher candidates in Turkey undergo approximately 12 years of education from primary to higher education, the fact that their geometric thinking levels are low emerges as a crucial issue that deserves careful attention.

The initial results of the study indicate that the spatial anxieties of prospective teachers are ‘low,’ and their attitudes towards geometric objects are at a ‘Medium level. Therefore, prospective classroom teachers experience less anxiety in situations that require spatial function. This suggests that they may approach learning geometry and, especially when teaching, with a positive perspective. Sari’s (2016) research aimed to investigate the relationship between spatial skills and spatial anxiety levels of prospective classroom teachers. Although the study made comparisons based on gender, it is observed that anxiety scores were generally low. Similarly, in the research conducted by Ekici et al. (2018), which included prospective classroom teachers, spatial anxiety levels were found to be low, especially for prospective classroom teachers. Yorulma & Çilingir Altuner’s (2021) research with classroom teachers revealed that the spatial anxiety levels of teacher candidates were high, contrary to the findings of this research. In another study examining the relationship between spatial dimensions and spatial anxiety in China and Russia, it was observed that the Chinese participants had higher spatial anxiety compared to the Russians (Wei et al., 2018).

The conclusion that prospective classroom teachers’ attitudes toward the topic of geometric objects are at a ‘medium’ level unfortunately suggests that this group of teacher candidates, who will become teachers for elementary school students, might face difficulties in teaching the topic of geometric objects, which is a component of geometry. Gündüz’s (2017) research with teacher candidates also found that their attitudes toward geometric objects were at a medium level, similar to the findings of this study. In the research conducted by Gündüz & Bulut and Dündar (2017) with prospective classroom teachers, it was determined that teacher candidates had a medium level of attitude. In Deringöl’s (2018) research, which examined the attitudes

of teacher candidates who took mathematics teaching courses toward geometric objects, it was concluded that the attitudes of teacher candidates toward geometric objects were at a medium level.

In the study, the geometry levels, spatial anxieties, and attitudes toward geometric objects of prospective classroom teachers were examined based on the “gender” variable, and it was concluded that there was no significant difference according to this variable. In Şahin’s (2008) research investigating the Van Hiele Geometry levels of classroom teachers and prospective classroom teachers, no gender difference was found among classroom teachers, while a difference in favour of males was observed among prospective classroom teachers. In a study conducted by Nopriana et al. (2023), it was revealed that male mathematics teacher candidates reached the highest level of geometric thinking. In a research study that examined the Van Hiele Geometric Thinking Levels of 3rd grade students in primary school, once again, the geometric thinking levels of male students were higher than those of female students (Gökbulut, Sidekli, & Yangın, 2010). As observed, there is no consensus on gender in research studies. Similar to the findings of this research, there are also studies in the literature indicating that gender does not make a significant difference (Asik Unal & Vezne, 2021; Bal, 2012; Çakmak & Güler, 2014).

When spatial anxiety is examined based on the ‘gender’ variable, in Sarı’s (2016) study, which aimed to investigate the relationship between prospective classroom teachers’ spatial skills and spatial anxiety levels, it was observed that female teacher candidates had higher spatial anxiety compared to male teacher candidates. In another study examining the relationship between spatial anxiety and mathematics anxiety among prospective elementary mathematics teachers, it was also understood that female students were more anxious than male students in the sub-dimensions of spatial anxiety related to orientation (direction finding) (Yurt & Çakmak Gürel, 2023). Literature suggests that the reason for this difference, as found in the research conducted by Lawton (1994, 1996), is explained by the fact that women consider instructions in wayfinding (route strategy), while men understand their positions in relation to the reference points in their environment (orientation strategy). This claim is supported by many studies (Casey et al., 1997; Dursun, 2010; Erkek & Işıksal-Bostan, 2015; Ferguson, Maloney, Fugelsang, & Risko, 2015; Gibeau et al., 2023; Malanchini et al., 2017; Lauer, Esposito, & Bauer, 2018; Lawton, 1994, 1996; Lawton & Kallai, 2002; Lyons et al., 2018; Ramirez et al., 2012). In a study examining the relationship between spatial dimensions and spatial anxiety in China and Russia, it was found that women’s spatial anxiety is higher than men’s (Wei et al., 2018). As observed, although the literature often suggests that women have higher spatial anxiety than men, in this study, even though women’s scores are higher than men’s, indicating higher anxiety, this difference does not constitute a significant distinction. There are also studies, albeit few, where no significant difference is found, as in the results of this research (Hund & Minarik, 2006; Saucier et al., 2002).

In the research, the attitudes of prospective classroom teachers towards geometric shapes did not differ based on gender. Similarly, in Deringöl's (2018) study, no significant difference was found based on gender. In the research conducted by Çağırğan, Yavuz, & Deringöl (2017) with mathematics teacher candidates, there was also no significant difference based on gender.

In this study, there was no significant difference in the Van Hiele Geometric Thinking levels, spatial anxieties, high school geometry course grades, and attitudes towards geometric objects among prospective classroom teachers based on their 'liking or disliking teaching geometry' status. Although the scores were in favour of 'liking to teach geometry', the observed differences did not reach statistical significance. In Turkey, prospective classroom teachers take courses such as 'Basic Mathematics in Primary School' in the first year, 'Mathematics Teaching I-II' in the third year, and 'Teaching Practice I-II' in the fourth year. In the first year, they cover the theoretical part of mathematics in the 'Basic Mathematics in Primary School' course. In the third year, they learn various teaching methods/techniques through teaching courses. In the fourth year, they have the opportunity to apply what they have learned by doing a 6-hour internship in various primary schools every week with the 'Teaching Practice I-II' courses. They take their first steps into teaching by practicing what they have learned in these schools. Therefore, prospective teachers, especially in the last two years, prepare themselves for teaching by working with children and experiencing teaching geometry, which is a branch of mathematics. Within the scope of this research, the lack of a significant difference in the examinations based on whether prospective classroom teachers like or dislike teaching geometry is a subject open to discussion. The lack of content knowledge in geometry among teacher candidates, or their perception of not feeling adequately prepared or having enough teaching experience, may explain the non-significant findings in this regard.

In the examination based on the 'grade levels' of prospective classroom teachers, it was observed that there was a difference in spatial anxiety. Although this difference had a small effect in terms of effect size, it shows that third-year prospective teachers have more spatial anxiety than first- and second-year prospective teachers. In Turkey, Mathematics Teaching courses are offered in the third year. The reason for this anxiety may be higher because this is the class where they start applying their theoretical knowledge. In this research, no difference was found in the Van Hiele Geometric thinking levels of prospective classroom teachers based on their grades. In another study examining the arithmetic means of prospective elementary and secondary mathematics teacher candidates' geometric thinking levels, in contrast to this research, it is generally observed that the scores on the geometry thinking test increase as the grades progress (Oral & İlhan, 2012). Oflaz (2010) conducted a study with teacher candidates and found that there was no significant difference in the geometric thinking levels of teacher candidates in the first grade compared to those in the fourth grade, similar to the results of this research. Additionally, in this study,

the attitudes of prospective classroom teachers towards geometric objects did not differ based on the grades they were in.

When the scores of the classroom teacher candidates were examined according to their 'levels', the difference between Van Hiele Geometry Test scores and geometry grades in high school was found to be significant with a large effect and the difference between spatial anxiety scores was significant with a medium effect. Accordingly, those in Level 4 have higher Van Hiele Geometry scores compared to prospective classroom teachers in other levels. This is an expected result because as scores increase at higher levels, an inevitable increase in geometric thinking is anticipated. Looking at their spatial anxiety and high school geometry grades, those at Level 1 are more anxious and have lower high school geometry grades compared to those at other levels. The decrease in spatial anxiety as thinking levels increase and the increase in high school geometry grades are expected outcomes. The attitudes of prospective classroom teachers towards geometric objects do not show a significant difference based on their current levels.

Finally, the research determined that there is a low-level and inverse relationship between the Van Hiele Geometry Test and the high school geometry grades of prospective classroom teachers, and a low-level relationship with the "Spatial Anxiety Scale (SAS)." However, no significant relationship was found with the "Attitude Scale on the Subject of Geometric Objects (ASSGO)." As the geometric thinking of prospective classroom teachers increases, their high school geometry grades also increase, and conversely, their spatial anxieties decrease. Usiskin (1982) and Senk (1989) have reached similar conclusions in their studies, stating that as students' achievements increase, their levels of geometric thinking also increase, consistent with the findings of this research. In Şener-Akbay's (2012) study, a significant correlation was observed between Van Hiele geometry test scores and geometry achievement scores. The results of the research conducted by Duatepe Paksu (2013) with classroom teachers are consistent with this research. In contrast to the findings of this study, there are also studies indicating that the weighted grade point average or geometry achievement does not predict spatial anxiety (Bal, 2012; Erkek & Işıksal-Bostan, 2015; Yurt &Çakmak Gürel, 2023).

Conclusion and recommendations

In this research conducted at a state university in Turkey, a detailed examination was made of the geometric thinking levels, spatial anxieties, and attitudes towards geometric objects of 232 prospective elementary school teachers. The results indicate that the candidates do not possess the required thinking levels, exhibit low levels of spatial anxiety, and maintain a medium attitude towards geometric objects. Moreover, the noteworthy finding of a relationship between the Van Hiele Geometry Test scores of teacher candidates and their high school geometry grades and spatial anxiety adds significance to the study. It is evident that the knowledge in the field of geometry acquired from preschool to higher education can influence their spatial anxieties. As

members of the group that will become teachers for primary school students, their sufficient subject knowledge, and their sense of readiness affect their students' current and future geometry success. Therefore, these findings can form a valuable basis for understanding the competence of teacher candidates in geometry teaching and for developing educational programs. In this context, it is important to review and update teacher education programs. Revising teaching methods and curricula to enhance the competencies of future teachers in geometry may contribute to addressing the deficiencies in this area. The development of advanced training modules for geometry teaching could further enhance the competencies of teacher candidates in this regard. Experimental and longitudinal studies could be conducted to assess the effects of different pedagogical approaches in geometry teaching.

Moreover, the geometry-related content in teacher education programs should be restructured to include practice-based instructional environments enriched with modules that are aligned with the individual thinking levels of prospective teachers. To address spatial anxiety, the curriculum should incorporate reflective practices that foster cognitive awareness, alongside learning strategies that support affective development. Rather than approaching geometry instruction solely as knowledge transmission, the curriculum must be designed to promote the integrated development of key competencies such as problem-solving, visualization, and intuitive reasoning. Therefore, a comprehensive revision of teacher education curricula-strengthening both content knowledge and pedagogical competencies-may significantly enhance the confidence and instructional efficacy of future teachers in the domain of geometry education.

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Razine geometrijskoga mišljenja prema Van Hieleovu modelu, prostorna anksioznost i stavovi prema geometrijskim tijelima među budućim učiteljima razredne nastave u Istanbulu, Turska

Sažetak

Cilj ovoga istraživanja bio je ispitati razine geometrijskoga mišljenja prema Van Hieleovu modelu, prostornu anksioznost i stavove prema geometrijskim tijelima među 232 buduća učitelja razredne nastave koji studiraju na javnom sveučilištu u Turskoj. Podatci su prikupljeni pomoću Van Hieleova testa geometrije, ljestvice prostorne anksioznosti, ljestvice stavova o geometrijskim tijelima te obrasca za podatke o učiteljskim kandidatima koji su osmislili istraživači. Ovo istraživanje provedeno je prema anketnom (survey) istraživačkom nacrtu. Rezultati su pokazali da su razine geometrijskoga mišljenja sudionika varirale između 1. i 4. razine, s naglaskom na 2. – opisnu razinu. Sudionici su pokazali nisku razinu prostorne anksioznosti i umjerene stavove prema geometrijskim tijelima. Nisu pronađene značajne razlike u tim varijablama s obzirom na spol ili preferenciju poučavanja geometrijskih sadržaja. Međutim, studenti treće godine imali su višu razinu prostorne anksioznosti u usporedbi s onima s prve i druge godine. Također, studenti na 4. razini postigli su više rezultate na Van Hieleovu testu geometrije od onih na nižim razinama, dok su studenti na 1. razini imali veću prostornu anksioznost i niže ocjene iz geometrije u srednjoj školi. Na kraju, utvrđena je niska pozitivna korelacija između rezultata sudionika na Van Hieleovu testu geometrije i njihovih ocjena iz geometrije u srednjoj školi, dok je između rezultata testa i prostorne anksioznosti pronađena niska negativna korelacija.

Ključne riječi: budući učitelji razredne nastave; ljestvica stavova o geometrijskim tijelima; geometrija; prostorna anksioznost; Van Hieleova geometrija

Uvod

Geometrija je jedna od grana matematike s kojom se mnogi učenici diljem svijeta teško nose (Naufalet i sur., 2021). Ulazi u ljudski život od samoga rođenja, kada pojedinci počinju istraživati fizički svijet oko sebe te zadržava svoju važnost tijekom cijeloga života (Gökbulut, Sidekli i Yangin, 2010). Nadalje, geometrija se prepoznaje kao jedno od temeljnih područja učenja u matematičkom kurikulumu i obrazovanju iz matematike (National Council of Teachers of Mathematics [NCTM], 2000). Geometrija se posebno bavi prostornim osjećajem i geometrijskim zaključivanjem. Učenici počinju razumijevati geometrijske pojmove u izravnoj interakciji s fizičkim okruženjem. Budući da uključuje proučavanje fizičkih svojstava prostora oko nas, geometrija je relevantna za svakog učenika - čineći sam svijet ogromnom učionicom. Kako učenici promatraju, dodiruju i oblikuju geometrijske oblike, oni pokreću i postupno razvijaju svoje prostorne sposobnosti rezoniranja (Howse i Howse, 2015). Geometrija se poučava na svim razinama obrazovanja, od osnovnoga do visokoga, zbog svoje temeljne uloge u matematičkom mišljenju (Pujawan, Suryawan i Prabawati, 2020). Štoviše, geometrija je utkana u gotovo svaki ljudski stvaralački pothvat - od znanosti do umjetnosti - i isprepliće se sa svakodnevnim životom, što dodatno povećava njezinu važnost (Sari, Machromah i Purnomo, 2018; de Walle, 2001).

Opće je prihvaćeno da geometrija pomaže učenicima razviti perspektivu koja im omogućuje analiziranje i rješavanje problema, kao i uspostavljanje značajnih poveznica između matematike i stvarnih životnih situacija (Duartepe, 2000a). Nastava geometrije doprinosi ne samo matematičkom razvoju učenika, nego i unapređenju njihovih kognitivnih sposobnosti (Clements i Sarama, 2011). Stoga poučavanje geometrije ne bi trebalo imati za cilj samo opremiti učenike geometrijskim znanjem i vještinama, već i potaknuti razvoj geometrijskoga mišljenja (Baykul, 2014).

Kako bi se potaknuo razvoj geometrijskoga mišljenja - ključnoga sastavnog dijela matematičkoga mišljenja - i unaprijedila postignuća u nastavi matematike i geometrije, nužno je prvo identificirati razine geometrijskoga mišljenja učenika (Akay i Kurtuluş, 2017; Cantürk Günhan, Altaylar, Dinçer Aksoy i Özdişçi, 2022; Osmanoğlu, 2019). Široko je prihvaćeno da nastava prilagođena odgovarajućim razinama učenika može dovesti do većega uspjeha u geometriji, a posljedično i u matematici općenito (Choi Koh, 1999). Obrazovanje iz geometrije zahtijeva sekvencijalnu strukturu u kojoj se pojmovi nadograđuju jedan na drugi, te se osiguravaju glatki prijelazi između različitih razina mišljenja (Collier i Pateracki, 1998). Međutim, učenici se često susreću s poteškoćama na tečajevima geometrije upravo zato što se njihove razine geometrijskoga mišljenja ne uzimaju dovoljno u obzir. Iako geometrija zauzima značajno mjesto u matematičkom obrazovanju širom svijeta, uključujući i Tursku, postignuća učenika u geometriji općenito su niska na međunarodnoj razini (Alex i Mammen, 2012; Gutiérrez, Jaime i Fortuny, 1991; Halat, 2006, 2007; Mullis, Martin, Foy i Arora, 2012). Istraživanja provedena u Turskoj dodatno potvrđuju ovu situaciju. Prema rezultatima studije Trends

in International Mathematics and Science Study [TIMSS] (2007., 2011., 2015. i 2019.), postignuća turskih učenika u geometriji ostaju ispod međunarodnoga prosjeka. Iako najnoviji rezultati TIMSS-a ukazuju na poboljšanje rezultata iz geometrije u odnosu na prethodne godine, postignuća turskih učenika i dalje zaostaju za međunarodnim prosjekom (TIMSS 2019 Turkey Preliminary Report, 2020; Yıldırım, Özgürlük, Parlak, Gönen i Polat, 2016). Stalna niska postignuća turskih učenika na međunarodnim ispitivanjima poput TIMSS-a mogu se dijelom pripisati nastavi geometrije koja ne uzima u dovoljnoj mjeri u obzir razine geometrijskoga mišljenja učenika (Asik Unal i Vezne, 2021).

Van Hieleov model geometrijskoga mišljenja istaknuo se kao važan okvir za prepoznavanje trenutačnih razina učenika u geometriji i podršku njihovom napretku kroz te razine (Duatete Paksu, 2016; Usiskin, 1982). Van Hieleov model objašnjava kako pojedinci percipiraju i konceptualiziraju geometriju. On opisuje način na koji učenici općenito razumiju geometrijske pojmove kroz različite, hijerarhijske razine (Duatete Paksu, 2016). S aspekta Van Hieleova modela razvoja geometrijskoga mišljenja, učenik napreduje od prepoznavanja i identificiranja likova, preko razumijevanja njihovih svojstava, zatim do shvaćanja međuodnosa među tim svojstvima, te na kraju do uvažavanja aksiomatskih sustava u kojima su ti likovi ugrađeni (Usiskin, 2003). Istraživanja koja ispituju razine geometrijskoga mišljenja učenika dosljedno pokazuju da učenici na različitim razinama obrazovanja često ne dosežu očekivanu razinu (Alex i Mammen, 2012; Fidan i Türnüklü 2010; Gökbulut, Sidekli i Yangın 2010; Halat, 2006; Kurtuluş i Akay, 2017).

Prema modelu, učenici prolaze kroz pet hijerarhijskih razina tijekom učenja geometrije: vizualna razina, opisna razina, razina neformalne dedukcije (također poznata kao teorijska razina), razina dedukcije (formalna logika) i razina rigoroznosti (priroda logičkih zakona) (Burger, 1986; Clements, 2004; Crowley, 1987; Hoffer, 1981; Idris, 2003, 2009; Mason, 1998; Mayberry, 1983; Senk, 1989; Van Hiele, 1986). Ove razine razlikuju se prema načinima na koje učenici razumiju i konceptualiziraju geometriju. Sekvencijalna struktura modela kreće se od cjelovitoga vizualnog opažanja preko analitičke dekompozicije geometrijskih likova, a na kraju do apstraktnoga matematičkog rasuđivanja i formalne dedukcije (Duatete Paksu, 2016). Za učenike koje nije moguće svrstati u bilo koju od ovih pet razina, Clements i Battista (1992) uveli su dodatnu razinu poznatu kao „predprepoznavanje” ili faza „djelomične vizualizacije”. U ovoj početnoj fazi, nazvanoj Razina 0, učenici mogu samo razlikovati geometrijske likove s kutovima i bez kutova, ali nisu u stanju identificirati ili opisati svojstva izvan tih osnovnih vizualnih karakteristika. Jedna od temeljnih značajki Van Hieleovih razina jest njihova sekvencijalna priroda. Prema Van Hieleovu modelu geometrijskog mišljenja, pojedinci napreduju kroz ove razine određenim redoslijedom tijekom učenja geometrije. Kako bi osoba mogla djelovati na određenoj razini, mora prethodno uspješno proći kroz sve prethodne razine (Jones, 2002). Napredak s jedne razine na drugu nije određen dobi ili općim kognitivnim razvojem, već nastavom i iskustvima s geometrijom

(Van Hiele, 1986). Drugim riječima, ove razine geometrijskoga mišljenja manje su pod utjecajem kronološke dobi, a više izlaganja učenika geometrijskim iskustvima, kao i primjerenosti nastave i jezika koji se koristi u skladu s trenutačnom razinom razumijevanja učenika (Van de Walle, Karp i Bay-Williams, 2012). Ako razina nastave ne uključuje jezik i primjere usklađene s trenutačnom razinom učenika, smisleno učenje možda neće nastupiti. U takvim slučajevima učenici mogu djelovati kao da pokazuju karakteristike više razine kroz naučene odgovore, no ne uspijevaju doseći tu razinu kada se njihovo razumijevanje detaljnije ispituje (Duatepe Paksu, 2016).

U tumačenju, opisivanju i kritičkom promišljanju o predmetima koji nas okružuju, prostorne sposobnosti igraju jednako važnu ulogu kao i sama geometrija (Clements, 1998; National Council of Teachers of Mathematics [NCTM], 2000). Razumijevanje razvoja geometrijskoga mišljenja također je ključno za usmjeravanje napora usmjerenih na unaprjeđenje prostornoga rezoniranja. Razvoj prostorne svijesti i prostornoga mišljenja usko prati razvoj geometrijskoga mišljenja (Altun, 2009). Battista (2007) istaknuo je da je geometrijsko mišljenje usko povezano s prostornim mišljenjem, koje se definira kao sposobnost mentalnoga vizualiziranja prostornih objekata, prostornih odnosa i prostornih transformacija. Učenici koji su vješti u prepoznavanju prostornih odnosa i posjeduju solidno razumijevanje geometrijskih pojmova obično pokazuju višu razinu spremnosti za učenje naprednijih matematičkih tema (Hoover, 1996). Prostorno mišljenje snažno je povezano s uspjehom učenika u geometriji i njihovim razinama razumijevanja geometrijskih pojmova (Erkek i Işıksal, 2012; Unal i sur., 2009; Pujawan, Suryawan i Prabawati, 2020; Schenck, 2023). Teškoće učenika u učenju geometrije mogu biti uzrokovane nedostatkom prostorne sposobnosti (Fitriyani i sur., 2023; Pradika i Murwaningtyas, 2012).

Jedna od ključnih tema u geometriji - trodimenzionalna geometrijska tijela - zahtijeva znanje i vještine povezane s razumijevanjem, povezivanjem i vizualizacijom objekata u prostoru (Yıldız, 2009). Tema geometrijskih tijela, koja u svojoj biti uključuje prostornu inteligenciju, prepoznata je kao izazovno područje za učenike ne samo u Turskoj nego i u drugim zemljama (Gutiérrez, 1992; Battista i Clements, 1996; Kösa i Ardiç, 2018). Brojne studije također su pokazale da i nastavnici u službi i budući nastavnici često nemaju dovoljno sadržajnoga znanja te imaju poteškoće povezane s geometrijskim tijelima (Akkaş i Gündoğdu Alaylı, 2022; Duatepe-Paksu, Musan, İymen i Pakmak, 2012; Fujita, 2012; Gündoğdu Alaylı, 2023; Marchis, 2012; Mutlu, Deniz i Polat, 2017; Ulusoy, 2019; Yıldızlı i Sari, 2017). Nedostatna razina znanja koju budući i trenutačni nastavnici pokazuju o geometrijskim tijelima može se pripisati njihovim stavovima prema toj temi (Gürefe i Kan, 2013). Stoga postaje nužno istražiti stavove budućih nastavnika o temi geometrijskih tijela.

Još jedan čimbenik koji negativno utječe na prostorno mišljenje jest prostorna anksioznost (Dursun, 2010; Malanchini i sur., 2017; Schenck, 2023; Wei, 2018). Prostorna anksioznost definirana je kao „strah od gubljenja” (Schmitz, 1997, str. 217) te kao „strah ili nelagoda koja se doživljava tijekom prostornoga mišljenja”

(Geer, 2019; Kremmyda i sur., 2016). Lawton (1994, str. 767) definirao je prostornu anksioznost kao „anksioznost vezanu uz snalaženje u okolišu”. Slično tome, prostorna anksioznost može se opisati kao „strah i nelagoda prema prostornom procesiranju, što može spriječiti pojedince da se uključe u iskustva i prilike koje bi inače mogle potaknuti razvoj prostornih sposobnosti” (Lyons i sur., 2018, str. 527). Lawton (1994) otkrio je da osobe s visokim razinama prostorne anksioznosti imaju tendenciju ignorirati znakove iz okoline i su stoga podložnije dezorijentaciji ili gubljenju. Suprotno tome, osobe s nižim razinama prostorne anksioznosti rjeđe koriste GPS uređaje i rjeđe se gube (He i Hegarty, 2020) jer se više oslanjaju na približno prostorno znanje poput orijentira i poznatih ruta (Castelli, Corazzini i Geminiani, 2008; Kremmyda i sur., 2016; Nori, Mercuri i sur., 2009; Nori i sur., 2009; Nori, Zucchelli, Palmiero i Piccardi, 2023). Utvrdilo se da je prostorna anksioznost negativno povezana s izvedbom pri snalaženju, što dovodi do sporijega izvršavanja zadataka i povećane stope pogrešaka (Walkowiak i sur., 2015). Ona može nepovoljno utjecati na sposobnost pojedinaca da dosegnu željene destinacije i istraže nepoznata okružja (Oliver i sur., 2023). Nadalje, prostorna anksioznost može se uočiti kod djece već u dobi od 6 do 8 godina (Lauer i sur., 2018; Ramirez i sur., 2012). Ova vrsta anksioznosti može imati dugoročne posljedice. Kada učitelji razredne nastave iskuse anksioznost u vezi s prostornim zadacima, njihovi učenici tijekom školske godine pokazuju manji razvoj prostorne kompetencije u usporedbi s vršnjacima čiji učitelji imaju niže razine prostorne anksioznosti (Gunderson i sur., 2013).

Izazovi i nedostaci u nastavi geometrije predstavljaju globalni problem, a niski rezultati učenika u geometriji predstavljaju ozbiljnu zabrinutost među odgojno-obrazovnim djelatnicima (Alex i Mammen, 2012). Opće je prihvaćeno da ključ za poboljšanje postignuća u geometriji leži u kvaliteti nastave geometrije i njezinoj usklađenosti s razvojnim razinama učenika. Proces poučavanja i uloga učitelja ključni su za poticanje razvoja geometrijskoga mišljenja i omogućavanje učenicima napredovanja s jedne razine na drugu (Türnüklü i Özcan, 2014). Clements i Sarama (2011) naglašavaju kako je unapređenje obrazovanja učitelja neophodno za rješavanje problema slabih postignuća učenika u geometriji. Također ističu da nastavnici i budući nastavnici često nemaju dovoljno pripreme za poučavanje geometrije. Među različitim područjima matematike, geometrija je navedena kao područje koje se najmanje uči, a posljedično i područje koje budući nastavnici najmanje samouvjereno poučavaju (Jones, Mooney i Harries, 2002).

Očekivani i vjerojatni rezultat je da će poboljšanja razina geometrijskoga mišljenja prema Van Hieleovu modelu među budućim nastavnicima, budućim edukatorima, pozitivno utjecati na učinkovitost nastavnih metoda i tehnika, čime će pridonijeti nacionalnim prosjecima postignuća u velikim međunarodnim procjenama poput PISA-e i TIMSS-a (Çaylan, Masal, Masal, Takunyacı i Ergene, 2017). Lumbre i sur. (2023) istaknuli su u svojoj studiji da je upotreba razina geometrijskoga mišljenja prema Van Hieleu od strane nastavnika snažno povezana s postignućima učenika. Matematičko znanje učitelja razredne nastave, osobito njihovo razumijevanje geometrije, ključno

je za potporu učenju i akademskom uspjehu učenika, posebno imajući u vidu njihovu ulogu u pružanju temeljne nastave potrebne za budući akademski razvoj učenika (Osmanoğlu, 2019). Stoga, kako bi pružili učinkovitu nastavu usklađenu s ishodima učenja geometrije i omogućili smisleno učenje svojim učenicima, budući učitelji razredne nastave moraju posjedovati očekivanu razinu sadržajnoga znanja. U tom kontekstu, nužno je procijeniti razine geometrijskoga mišljenja studenata prije njihova ulaska u struku, kako bi se eventualni nedostaci u učenju mogli prepoznati i otkloniti (Osmanoğlu, 2019). Osim toga, prisutnost prostorne anksioznosti među budućim učiteljima može negativno utjecati na njihovu nastavnu izvedbu, a posljedično i smanjiti akademska postignuća njihovih učenika (Yurt i Çakmak Gürel, 2023). Imajući u vidu da se prostorna anksioznost može pojaviti u vrlo ranoj dobi i potencijalno utjecati na kognitivne sposobnosti i postignuća djece (Erkek i Işıksal, 2012; Gunderson i sur., 2013; Lawton i Kallai, 2002; Pilato, Peterson i Anderson, 2023), ključno je utvrditi razine prostorne anksioznosti budućih učitelja razredne nastave koji će u budućnosti biti odgovorni za potporu dječjem razvoju.

U nekoliko studija prikazana su istraživanja Van Hieleove razine geometrijskoga mišljenja budućih učitelja razredne nastave (Aktaş i Güler, 2011; Akkurt, 2010; Armah, Cofie i Okpoti, 2018; Aşık Ünal i Vezne, 2021; Bal, 2011, 2012; Duatepe, 2000b; Duatepe-Paksu, 2013; Gökbulut, Sidekli i Yangın, 2010; Halat, 2008; Robichaux-Davis i Guarino, 2016; Şahin, 2008; Toluk i Olkun, 2004). Iako ograničenoga opsega, postoje i studije koje ispituju prostornu anksioznost budućih učitelja (Ekici i sur., 2018; Sarı, 2016; Yorulmaz i Çilingir Altınar, 2021), kao i studije koje istražuju njihove stavove prema temi geometrijskih tijela (Çağırğan, Yavuz i Deringöl, 2017; Deringöl, 2018; Güreffe i Kan, 2013; Gündüz, Bulut i Dündar, 2017). Kao što je vidljivo, u literaturi još nije pronađena studija koja istovremeno ispituje ove tri povezane varijable. Temeljem ovih praznina u literaturi, cilj ovoga istraživanja jest ispitati Van Hieleove razine geometrijskoga mišljenja, prostornu anksioznost i stavove prema temi geometrijskih tijela među budućim učiteljima razredne nastave u Turskoj. Konkretno, studija nastoji odgovoriti na sljedeće istraživačko pitanje: Koje su Van Hieleove razine geometrijskoga mišljenja, razine prostorne anksioznosti i stavovi prema geometrijskim tijelima budućih učitelja razredne nastave? Opća hipoteza ovoga istraživanja glasi: „Postoji povezanost između Van Hieleovih razina geometrijskoga mišljenja budućih učitelja razredne nastave, njihovih razina prostorne anksioznosti, ocjena iz geometrije u srednjoj školi te njihovih stavova prema temi geometrijskih tijela.” Za ostvarenje ovoga cilja traženi su odgovori na sljedeća istraživačka pitanja:

Koje su Van Hieleove razine geometrijskoga mišljenja, prostorne anksioznosti i stavovi prema geometrijskim tijelima budućih učitelja razredne nastave?

Variraju li Van Hieleove razine geometrijskoga mišljenja, prostorne anksioznosti i stavovi prema geometrijskim tijelima budućih učitelja razredne nastave ovisno o različitim varijablama (spol, godina studija, ocjena iz geometrije u srednjoj školi, uživaju li u poučavanju geometrije)?

Postoji li značajna povezanost između Van Hieleovih razina geometrijskoga mišljenja budućih učitelja razredne nastave, njihove prostorne anksioznosti, ocjena iz geometrije u srednjoj školi i njihovih stavova prema temi geometrijskih tijela?

Metodologija

Što se tiče podataka, istraživanje se temelji na kvantitativnom paradigmatu. Budući da je glavni cilj bio utvrditi Van Hieleove razine geometrijskoga mišljenja budućih učitelja razredne nastave, prostorne zabrinutosti i stavove prema temi geometrijskih tijela, istraživanje je provedeno u okviru korelacijsko-istraživačkoga modela. Kao što navodi Karasar (2004), anketni model ima za cilj „opisati situaciju koja postoji u prošlosti ili nedavno, onakvu kakva jest”.

Uzorak

Uzorak se sastoji od ukupno 232 buduća učitelja razredne nastave upisanih na državnom sveučilištu u Istanbulu, Turska, odabranih jednostavnim slučajnom metodom uzorkovanja. Raspodjela budućih nastavnika u istraživačkoj skupini prikazana je u nastavku.

Tablica 1

Uzorak se sastoji od ukupno 232 buduća učitelja razredne nastave, od kojih je 52 (22,4 %) iz prve godine, 65 (28,1 %) iz druge godine, 59 (25,4 %) iz treće godine i 56 (24,1 %) iz četvrte godine. Među tim budućim učiteljima, 183 (78,9 %) su žene, a 49 (21,1 %) su muškarci. Sudjelovanje u ovom istraživanju bilo je u potpunosti dobrovoljno. Istraživanje je provedeno u skladu s etičkim načelima, uključujući samo one buduće učitelje razredne nastave koji su pristali sudjelovati. Etička načela poštivana su tijekom svih faza istraživanja, a stroga povjerljivost je održavana.

Alati za prikupljanje podataka

U istraživanju su podatci prikupljeni pomoću Obrasca za informacije o budućim učiteljima, Van Hiele testa geometrije, Skale prostorne anksioznosti i Skale stavova prema temi geometrijskih tijela.

Obrazac za informacije o budućim učiteljima: Ovaj obrazac razvio je istraživač. Sastoji se od pitanja vezanih uz demografske karakteristike budućih učitelja razredne nastave, njihove ocjene iz geometrije u srednjoj školi te informacije o tome vole li ili ne vole poučavati teme iz geometrije.

Van Hieleov test geometrije (VHTG): Van Hieleov test geometrije (VHTG) razvio je Usiskin (1982) za procjenu znanja budućih nastavnika iz područja geometrije. Test se sastoji od 25 pitanja s višestrukim izborom vezanih uz geometriju. Prvih pet pitanja odnosi se na Razinu 1, sljedećih pet na Razinu 2, narednih pet na Razinu 3, potom pet na Razinu 4, a zadnjih pet na Razinu 5 geometrijskoga mišljenja. Na primjer, prva skupina od pet pitanja u testu povezana je s vizualnom razinom, koja odgovara

prvoj razini geometrijskoga mišljenja, dok je druga skupina od pet pitanja povezana s deskriptivnom razinom, koja odgovara drugoj razini (Osmanoğlu, 2019). Adaptaciju testa na turski jezik provela je Duatepe (2004), a test je pokazao zadovoljavajuću pouzdanost mjerenjem Cronbachova alfa koeficijenta. U istraživanju Duatepe-Paksua (2013) koeficijent pouzdanosti testa iznosio je 0,69. Koeficijent pouzdanosti u ovom istraživanju je 0,64. Manje vrijednosti se pripisuju broju stavki u testu (Duatepe Paksu i Ubuz, 2009; Usiskin, 1982). Primjeri stavki prikazani su u nastavku.

Stavka 14:

Koja je svojina koju svi pravokutnici imaju, a neki paralelogrami nemaju?

- a) Suprotne stranice su jednake duljine.
- b) Dijagonale su jednake duljine.
- c) Suprotne stranice su paralelne.
- d) Suprotni kutovi su jednaki.
- e) Nijedna od navedenih tvrdnji nije točna.

Stavka 25:

Pretpostavimo da ste dokazali sljedeće tvrdnje I i II:

- I. Ako je p, onda je q.
- II. Ako je s, onda nije q.

Koje od sljedećega se može zaključiti iz tvrdnji I i II?

- a) Ako je s, onda nije p.
- b) Ako nije p, onda nije q.
- c) Ako je p ili q, onda je s.
- d) Ako je p, onda je s.
- e) Ako nije s, onda je p.

Skala prostorne anksioznosti (SPA): Skala prostorne anksioznosti (SPA), koju je razvio Lawton (1994), ima za cilj mjeriti razinu anksioznosti koju pojedinci osjećaju u situacijama koje zahtijevaju prostorne/navigacijske vještine (Dursun, 2010). Skala se sastoji od jednoga faktora i ukupno osam stavki. Turska adaptacija skale pokazala je vrijednost Cronbachova alfa koeficijenta od 0,87 (Dursun, 2010). U ovom istraživanju, alfa koeficijent skale iznosio je 0,84. Skala prostorne anksioznosti, koja se sastoji od osam stavki, ima minimalni mogući rezultat osam i maksimalni 40. Kako rezultat raste, smatra se da je razina anksioznosti pojedinca visoka, dok niži rezultat ukazuje na nižu razinu anksioznosti. Primjeri stavki dani su u nastavku.

Stavka 4:

„Kada shvatim da sam se izgubio/la tijekom putovanja i potom pokušavam pronaći put.”

Stavka 7:

„Kada pokušavam novi put za koji mislim da je prečac, a da pritom ne koristim kartu.”

Skala stavova prema predmetu geometrijskih tijela (SSPPGT): Skalu stavova prema predmetu geometrijskih tijela (SSPPGT) razvili su Güreffe i Kan (2013) za

buduće nastavnike. Sastoji se od tri podskale i ukupno 20 stavki, koje uključuju: „Negativan stav prema učenju i poučavanju geometrijskih tijela,” „Pozitivan stav prema izvannastavnim aktivnostima s geometrijskim tijelima” i „Pozitivan stav prema učenju i poučavanju geometrijskih tijela.” Ova skala razvijena je u skladu s turskom kulturom proučavanjem brojnih međunarodnih skala. Budući da je uzorak sačinjen od turskih budućih nastavnika, nije bila potrebna adaptacija na engleski jezik. Koeficijent pouzdanosti ove skale iznosi 0,92 prema izvornom istraživanju Gürefea i Kana (2013). U ovom istraživanju, koeficijent pouzdanosti skale iznosio je 0,87. Primjeri stavki dane su u nastavku.

Stavka 2:

„Budući da zahtijeva apstraktno razmišljanje, smatram da mi je teško naučiti temu geometrijskih tijela.”

Stavka 6:

„Mislim da ću imati poteškoća u prilagodbi razini učenika prilikom objašnjavanja geometrijskih tijela.”

Prikupljanje podataka

Alati za prikupljanje podataka primijenjeni su na buduće učitelje razredne nastave tijekom uzastopnih sesija. Nedostajući obrasci su uklonjeni, a podatci iz preostalih obrazaca su uneseni i pripremljeni za analizu

Analiza podataka

Prilikom određivanja razina geometrijskoga mišljenja budućih učitelja korišteni su kriteriji koje je postavio Usiskin (1982). Ovaj kriterij podrazumijeva točno odgovaranje na najmanje 3 od 5 pitanja ili najmanje 4 od 5 pitanja. Odabir kriterija ovisi o vrsti pogreške koju istraživanje želi kontrolirati. Ako je cilj spriječiti dodjeljivanje pojedinca razini geometrijskoga mišljenja višoj od njegove stvarne razine, kriterij treba biti točno odgovaranje na najmanje 4 od 5 pitanja. Ako je cilj spriječiti dodjeljivanje pojedinca razini nižoj od stvarne, kriterij treba biti točno odgovaranje na najmanje 3 od 5 pitanja (Usiskin, 1982). Odabir kriterija prepušten je preferencijama istraživača (Knight, 2006). U ovom istraživanju, kojemu je cilj ispitati razine geometrijskoga mišljenja budućih učitelja razredne nastave prema različitim varijablama, korišten je kriterij točnih odgovora na najmanje 3 od 5 pitanja. U sljedećoj fazi zadržano je pravilo da se za dodjelu bilo koje razine budućim učiteljima mora uspješno proći sve prethodne razine, zbog hijerarhijske strukture razina geometrijskoga mišljenja (Usiskin, 1982). Prema tome, bodovanje je kako slijedi (Usiskin, 1982, s.22):

- 1 bod ako su kriteriji ispunjeni za pitanja 1 – 5 (Razina 1),
- 2 boda ako su kriteriji ispunjeni za pitanja 6 – 10 (Razina 2),
- 4 boda ako su kriteriji ispunjeni za pitanja 11 – 15 (Razina 3),
- 8 bodova ako su kriteriji ispunjeni za pitanja 16 – 20 (Razina 4),
- 16 bodova ako su kriteriji ispunjeni za pitanja 21 – 25 (Razina 5).

Na temelju ovoga sustava bodovanja, potrebni rezultati za budućega nastavnika da bude na razini 1 iznose jedan bod; za razinu 2 tri boda; za razinu 3 sedam bodova; za razinu 4 petnaest bodova; a za razinu 5 trideset i jedan bod. Nakon toga, za analizu učestalosti i postotaka za svaku razinu korištene su deskriptivne statističke tehnike. Nakon određivanja razina geometrijskoga mišljenja budućih nastavnika, rezultati prostorne anksioznosti i stavovi prema predmetu geometrijskih tijela analizirani su pomoću programa SPSS 21. Prije početka analiza provedeni su Kolmogorov-Smirnov test za procjenu normalnosti distribucije podataka. Istovremeno su ispitivane vrijednosti Asimetrije (Skewness) i Kurtoze (Kurtosis). Razina značajnosti na temelju Kolmogorov-Smirnova testa bila je manja od ,05. Također, uzimajući u obzir koeficijent asimetrije između +2,0 i -2,0, prema Georgeu i Malleryju (2010), uočeno je da podatci pokazuju normalnu distribuciju. Posljedično, za daljnju analizu korišteni su parametrijski testovi. Analiza podataka uključivala je primjenu t-testa za neovisne uzorke (Independent-Samples t-Test), jednostruke analize varijance (One Way ANOVA) te Pearsonove korelacijske analize (Pearson Moment Correlation), kao i izračun dobivenih rezultata.

T-test za neovisne uzorke korišten je za ispitivanje postoji li razlika između rezultata dobivenih na skalama unutar varijabli, One Way ANOVA korišten je za ispitivanje razlika u situacijama s više od dvije varijable (razredi i razine), dok su u post hoc testovima korišteni LSD i Tamhane testovi za određivanje između kojih se grupa razlike pojavljuju. Pearsonova korelacijska analiza korištena je za ispitivanje odnosa između rezultata dobivenih na skalama i ocjena iz geometrije u srednjoj školi budućih učitelja razredne nastave. Prilikom odabira post hoc testova provjeravana je homogenost varijanci, a za skupine koje nisu zadovoljavale LSD test provedena je Tamhaneova analiza, te su rezultati interpretirani.

U provedenim testovima ispitivane su značajne razlike, a budući da veličina te razlike nije pružala potpune informacije, izračunata je veličina učinka radi bolje interpretacije. Za rezultate u kojima je pronađena značajna razlika, korištena je eta-kvadrat (η^2) formula za određivanje veličine učinka u One Way ANOVA testu. Prema tome, korištena je formula η^2 ($Eta^2 = SS \text{ Between} / SS \text{ Total}$). Prilikom vrednovanja pronađenih vrijednosti učinka, uzimani su u obzir sljedeći pragovi: 0,010 – mali učinak; 0,059 – srednji učinak; 0,138 – veliki učinak (Cohen, 1988).

Rezultati

Rezultati su predstavljeni prema redoslijedu istraživačkih problema. Sukladno tome, rezultati prvoga podproblema prikazani su u tablicama 2 i 3. Rezultati analize razina geometrijskoga mišljenja budućih učitelja razredne nastave prema Van Hieleovu modelu predstavljeni su u Tablici 2, temeljeni na frekvencijama i postotcima za 232 buduća učitelja.

Tablica 2

Kao rezultat analiza provedenih u okviru ovoga istraživanja, što je vidljivo iz gornje tablice, uočava se da je 17,2 % ($n = 40$) kandidata na razini 1 – vizualizacija; 47,8 %

(n = 111) na razini 2 – opis; 30,2 % (n = 70) na razini 3 – neformalna dedukcija te 4,7 % (n = 11) na razini 4 – dedukcija. Napominje se da nema kandidata na razini 5 – strogoća. Ukratko, može se reći da se budući učitelji razredne nastave uglavnom nalaze na razini 2 – opis. Proučavajući prema razredima, uočava se da je na svakom razrednom stupnju prisutna pretežna koncentracija na razini 2 – opis.

Rezultati povezani s prvim podproblemom (prostorna anksioznost i stavovi prema geometrijskim tijelima) prikazani su u Tablici 3.

Tablica 3

Rezultati dobiveni na Skali prostorne anksioznosti (SPA) i Skali stavova o geometrijskim tijelima (SSPPGT) prikazani su u Tablici 3. Kako bi se odredile razine na temelju rezultata dobivenih na skalama, širina raspona skale izračunata je pomoću formule *raspon skale / broj grupa koje se formiraju* ($4/5 = 0,80$) (Tekin, 1993). Intervali aritmetičke sredine skale određeni su kako slijedi: 1,00 – 1,79 „vrlo nisko”; 1,80 – 2,59 „nisko”; 2,60 – 3,39 „srednje”; 3,40 – 4,19 „visoko” i 4,20 – 5,00 „vrlo visoko”. Sukladno tome, razina prostorne anksioznosti budućih učitelja razredne nastave ocijenjena je kao „niska”, dok su njihovi stavovi prema geometrijskim tijelima bili na „srednjoj” razini.

Nalazi povezani s drugim istraživačkim pitanjem prikazani su u tablicama 4, 5, 6, 7 i 8.

Tablica 4

Kako bi se ispitalo postoji li značajna razlika u rezultatima dobivenim na mjernim alatima temeljem varijable spola, provedeni su t-testovi za nezavisne uzorke. Nema značajne razlike u srednjim vrijednostima za Van Hieleov test geometrije (VHTG) ($t = -0,131, p > ,05$), Skalu prostorne anksioznosti (SPA) ($t = 0,764, p > ,05$) i Skalu stavova o geometrijskim tijelima (SSPPGT) ($t = 0,501, p > ,05$) prema spolu budućih učitelja razredne nastave. Mnoge studije ističu percepciju i činjenicu da većinu nastavnika koji poučavaju mlađe dobne skupine, poput predškolskoga i osnovnoškolskoga obrazovanja, čine žene (Smedley, 2007). I u Turskoj je nastava u velikoj mjeri percipirana i birana kao ženski poziv. Kao što se vidi u ovom istraživanju, većina budućih učitelja razredne nastave koji sudjeluju u studiji također su žene.

Tablica 5

Kako bi se istražilo postoji li značajna razlika u rezultatima dobivenim na mjernim alatima temeljem varijable sviđanja ili nesviđanja poučavanju geometrije, proveden je t-test za nezavisne uzorke. Prosječne vrijednosti za Van Hieleov test geometrije (VHTG) ($t = -0,402, p > ,05$), Skalu prostorne anksioznosti (SPA) ($t = -0,139, p > ,05$), ocjene iz geometrije u srednjoj školi (OGSS) ($t = 5,117, p > ,05$) i Skalu stavova o geometrijskim tijelima (SSPPGT) ($t = 1,129, p > ,05$) ukazuju na to da nema značajne razlike među kandidatima za učitelje u pogledu njihove sklonosti poučavanju geometrije. Iako ocjene iz geometrije u srednjoj školi ne pokazuju značajnu razliku, vjerojatnost pojave ovoga rezultata u uzorku iznosi 94 %. Ovu situaciju može se objasniti činjenicom da su rezultati koji odražavaju zadovoljstvo i nezadovoljstvo poučavanjem geometrijskih tema vrlo bliski jedan drugome.

Tablica 6

Provedena je jednosmjerna analiza varijance (ANOVA) kako bi se utvrdilo postoji li značajna razlika u rezultatima dobivenim na mjernim alatima prema varijabli razreda. Sukladno tome, razlika u srednjim vrijednostima na Skali prostorne anksioznosti (SPA) [$F_{(3-228)} = 3,197, \eta^2 = 0,040, p < ,05$] prema razredima budućih učitelja razredne nastave je statistički značajna (Tablica 6). Kada se ispita veličina učinka razlike na Skali prostorne anksioznosti (SPA), vidi se da ta razlika ima mali učinak ($\eta^2 = 0,040$). Kao post-hoc test korišten je LSD test. Prema njemu, utvrđeno je da budući učitelji 3. razreda ($M = 2,17$) imaju veću prostornu anksioznost od budućih učitelja 1. razreda ($M = 1,87$) i 2. razreda ($M = 1,83$). Razlike u rezultatima Van Hieleova testa geometrije (VHTG) [$F_{(3-228)} = 0,249, p > ,05$], ocjenama iz geometrije u srednjoj školi (OGSS) [$F_{(3-228)} = 0,442, p > ,05$] i na Skali stavova o geometrijskim tijelima (SSPPGT) [$F_{(3-228)} = 0,159, p > ,05$] prema razredima nisu statistički značajne.

Tablica 7

Provedena je jednosmjerna analiza varijance (ANOVA) kako bi se utvrdilo stvaraju li rezultati dobiveni na mjernim alatima značajne razlike prema razinama Van Hieleova testa geometrije. Sukladno tome, razlike u srednjim vrijednostima za Van Hieleov test geometrije (VHTG) [$F_{(3-228)} = 13,870, \eta^2 = 0,968, p < ,01$], Skalu prostorne anksioznosti (SPA) [$F_{(3-228)} = 4,808, \eta^2 = 0,059, p < ,05$] i ocjene iz geometrije u srednjoj školi (OGSS) [$F_{(3-228)} = 13,870, \eta^2 = 0,154, p < ,01$] prema razinama geometrije budućih učitelja razredne nastave su statistički značajne (Tablica 7). Kod ispitivanja veličina učinka razlikovanja, uočava se da je razlika u Van Hieleovu testu geometrije (VHTG) velika ($\eta^2 = 0,968$), razlika na Skali prostorne anksioznosti (SPA) srednja ($\eta^2 = 0,059$), dok je razlika u ocjenama iz geometrije u srednjoj školi (OGSS) velika ($\eta^2 = 0,154$). Kao post-hoc test korišten je Tamhane test. Prema njemu, ispitanici koji su na razini 4 ($M = 0,81$) ostvaruju veće rezultate od budućih učitelja razredne nastave na razini 1 ($M = 0,04$), razini 2 ($M = 0,12$) i razini 3 ($M = 0,41$). Što se tiče prostorne anksioznosti, ispitanici na razini 1 ($M = 2,27$) pokazuju veću anksioznost od onih na razini 4 ($M = 1,96$). Prema ocjenama iz geometrije u srednjoj školi, ispitanici na razini 4 ($M = 4,81$) imaju značajno veće ocjene od onih na razini 1 ($M = 3,05$), razini 2 ($M = 3,74$) i razini 3 ($M = 3,87$). Razlika u rezultatima na Skali stavova o geometrijskim tijelima (SSPPGT) [$F_{(3-228)} = 0,178, p > ,05$] budućih učitelja razredne nastave prema njihovim razinama geometrije nije statistički značajna. Nalazi vezani uz treći problem prikazani su u Tablici 8.

Tablica 8

Kao što je prikazano u Tablici 8, uočen je pozitivan korelacijski odnos niske razine između Van Hieleova testa geometrije (VHTG) i ocjena iz geometrije budućih učitelja razredne nastave u srednjoj školi (GSG) ($r = 0,324; p < ,01$), dok je za Skalu prostorne anksioznosti (SPA) utvrđena negativna korelacija niske razine ($r = -0,202; p < ,05$).

Nije uočena značajna povezanost između Van Hieleova testa geometrije (VHTG) i Skale stavova o geometrijskim tijelima (SSPPGT).

Rasprava

U ovoj studiji koja ispituje razine geometrijskoga mišljenja, prostornu anksioznost i stavove prema geometrijskim tijelima budućih učitelja razredne nastave, utvrđeno je da se ispitanici nalaze na razinama od 1 do 4 u pogledu geometrijskoga mišljenja. Glavni zaključak istraživanja jest da se budući učitelji najviše grupiraju na razini 2 - opis. Nisu pronađeni ispitanici na razini 0 niti na najvišoj, razini 5. Postoje ispitanici na razini 1, što je zanimljivo s obzirom na to da je to očekivana razina djece u predškolskom i ranom osnovnoškolskom obrazovanju. Zbog dobi i spremnosti studenata na fakultetu, očekuje se da bi trebali pokazivati karakteristike mišljenja na razini 3 prema Van Hieleovim razinama geometrijskoga mišljenja kako bi bili uspješni u predmetima vezanim uz geometriju i račun, te za razumijevanje geometrijskih dokaza (Teppo, 1991). Nažalost, ova istraživanja otkrivaju da su geometrijske razine mišljenja budućih učitelja razredne nastave najčešće na razini 2, koja predstavlja razinu jednostavnih zaključaka, umjesto očekivane minimalne razine 3. Uočava se da razine geometrijskoga mišljenja budućih učitelja prema Van Hieleovu modelu nisu na očekivanoj razini. Iako je ovo istraživanje ograničeno na učitelje razredne nastave, razina znanja iz geometrije budućih učitelja razredne nastave nije dovoljna za uspješno poučavanje geometrije u prvoj fazi osnovnoga obrazovanja. Ovi rezultati mogli su biti dobiveni zbog nešto niže pouzdanosti Van Hieleova testa geometrije. Međutim, u mnogim istraživanjima provedenim u Turskoj (Akin i Sezgin, 2022; Asik Unal i Vezne, 2021; Osmanoğlu, 2019; Şahin, 2008, 2012) mjerenja su rađena upravo ovim međunarodnim testom, te kao i u ovoj studiji, razine budućih učitelja nisu bile zadovoljavajuće. Nažalost, ovaj rezultat ističe neuspjeh Turske u području geometrije. Stoga, unatoč poboljšanjima ostvarenim na međunarodnim ispitima tijekom godina, očito je da nedostatak u području geometrije budućih učitelja razredne nastave, koji će predavati učenicima osnovnih škola, i dalje postoji. Prema Usiskinu (1982), tvrdnja da „samo 50 % učenika proučava geometriju u srednjem obrazovanju, a samo jedna trećina njih je razumije” nažalost odražava situaciju koju ovo istraživanje otkriva. S obzirom na to da će budući učitelji poučavati na razini osnovnoga obrazovanja, njihova geometrijska kompetencija trebala bi idealno biti viša od očekivane razine za ovu dobnu skupinu. Štoviše, uzimajući u obzir obrazovanje koje budući učitelji dobivaju od osnovne škole do sveučilišta, niske razine geometrijskoga mišljenja izazivaju sumnju u postojanje određenih nedostataka u njihovom razumijevanju geometrije (Saraçoğlu i Ağıloğlu, 2022).

Studija Şahin (2008) otkriva da je 34,1 % budućih učitelja razredne nastave na razini 0, 37,8 % na razini 1, a 25,6 % na razini 2. Kao što je uočeno, nijedan budući učitelj u ovoj studiji nije dosegnuo razine 3 i 4. U istraživanju Erdoğan (2006) 39,4 % kandidata za učitelje bilo je na razini 0 u pogledu geometrijskoga mišljenja. U studiji Şahin (2012) broj kandidata za učitelje na razinama 4 i 5 Van Hieleovih

geometrijskih razina bio je vrlo nizak. Dok ih je 10 bilo na razini 4, na razini 5 bila su samo 2 kandidata. Istraživanje Akkurt (2010), u kojem se putem konceptualnih mapa istraživalo geometrijsko konceptualno znanje nastavnika matematike u osnovnoj školi i budućih učitelja, u dijelu analize distribucije kandidata prema razinama geometrijskoga mišljenja pokazalo je da se većina kandidata (43,5 %) grupira na razini 2, što je slično nalazima ove studije. Studija Gökbulut, Sidekli i Yangin (2010) provedena na učenicima 3. razreda programa za obrazovanje učitelja osnovne škole otkrila je da njihova Van Hieleova razina geometrijskoga mišljenja idealno treba biti razina 3 ili više. Međutim, uočene razine bile su 0, 1 i 2, bez učenika koji su dostigli razine 3 i 4. Osim toga, devet učenika nije uspjelo doseći ni razinu 0. Studija je također pokazala da su studenti sveučilišta, uključujući buduće učitelje razredne nastave, koncentrirali svoje Van Hieleove razine geometrijskoga mišljenja uglavnom na razine 2 i 1 u testu geometrijskoga mišljenja (Akin i Sezgin, 2022). Istraživanje Akaya i Kurtuluşa (2017) s budućim učiteljima također je pokazalo da su sudionici uglavnom bili na razini 2 Van Hieleova testa geometrijskoga mišljenja, dok su kandidati iz drugih odjela bili skloniji razini 1. U studiji Asik Unal i Veznea (2021) otkriveno je da je približno 89,3 % od 131 budućeg učitelja razredne nastave bilo ispod razine 3 Van Hieleovih razina mišljenja. Studija Bala (2011), koja je istraživala odnos između razina geometrijskoga mišljenja i stavova prema geometriji budućih učitelja razredne nastave, pokazala je da je u početnoj fazi određivanja razina geometrijskoga mišljenja većina kandidata bila na trećoj razini. Samo je 2,2 % kandidata doseglo petu razinu, dok se čak jedna petina njih nije mogla svrstati ni u jednu razinu. Prema istraživanju Bala (2012), 17,4 % kandidata za učitelje kategorizirano je kao „0: nije svrstano ni u jednu razinu”, 26,6 % na razini 1 (vizualizacija), 16,1 % na razini 2 (opis), 32,9 % na razini 3 (neformalno zaključivanje), 4,6 % na razini 4 (izvođenje zaključaka) i 2,3 % na razini 5 (strogoća). Zaključeno je da je 4,6 % kandidata bilo na „4: Izvođenje zaključaka”, a 2,3 % na „5: Sposobnost uočavanja odnosa”. Tako se približno jedna desetina sudionika studije nalazi na očekivanoj razini. Istraživanje Osmanoglu (2019), koje je imalo za cilj utvrditi razine geometrijskoga mišljenja i nedostatke u učenju budućih učitelja osnovnih škola, pokazalo je da su sudionici, budući učitelji, pretežno na trećoj razini, odnosno razini jednostavnoga zaključivanja. U studiji Sarame i Clements (2009) uočen je podatak da je većina kandidata za učitelje bila ispod razine 3, pri čemu se mnogi nalaze na razini 0, a gotovo jedna trećina na razini 1 (Clements i Sarama, 2011).

Kao što je vidljivo, rezultati brojnih istraživanja ukazuju da su očekivane razine geometrijskoga mišljenja kandidata za učitelje koji su upisani na fakultete za obrazovanje uglavnom niske (Çetin i Dane, 2004; Duatepe, 2000b; Halat, 2008; Knight, 2006). Uzimajući u obzir da kandidati za učitelje u Turskoj prolaze kroz otprilike 12 godina obrazovanja, od osnovne do visoke škole, činjenica da su njihove razine geometrijskoga mišljenja niske predstavlja ključan problem kojem treba posvetiti posebnu pozornost.

Početni rezultati istraživanja ukazuju da je prostorna anksioznost budućih učitelja „niska”, a njihov stav prema geometrijskim tijelima na „srednjoj” razini. Stoga budući

učitelji razredne nastave iskazuju manju anksioznost u situacijama koje zahtijevaju prostornu funkciju. Ovo upućuje na to da bi mogli pristupati učenju geometrije, a posebno njenom poučavanju, s pozitivnim stavom. Istraživanje Sarı (2016) imalo je za cilj ispitati povezanost između prostornih sposobnosti i razina prostorne anksioznosti budućih učitelja razredne nastave. Iako je studija uspoređivala rezultate prema spolu, uočen je općenito nizak stupanj anksioznosti. Slično tome, u istraživanju Ekicija i sur. (2018), koje je uključivalo buduće učitelje razredne nastave, razine prostorne anksioznosti također su bile niske, osobito kod budućih učitelja razredne nastave. Istraživanje Yorulma i Çilingir Altiner (2021) provedeno s učiteljima razredne nastave otkrilo je da su razine prostorne anksioznosti kandidata za učitelje bile visoke, što je u suprotnosti s nalazima ovoga istraživanja. U drugoj studiji koja je ispitivala povezanost između prostornih dimenzija i prostorne anksioznosti u Kini i Rusiji, uočen je veći stupanj prostorne anksioznosti kod kineskih sudionika u usporedbi s ruskim (Wei i sur., 2018).

Kada se zaključi da su stavovi budućih učitelja razredne nastave prema temi geometrijskih tijela na „srednjoj” razini, nažalost to upućuje na mogućnost da će ova skupina budućih učitelja, koji će predavati učenicima osnovnih škola, imati poteškoće u poučavanju teme geometrijskih tijela, koja je sastavni dio geometrije. Istraživanje Gündüz (2017) provedeno s kandidatima za učitelje također je pokazalo da su njihovi stavovi prema geometrijskim tijelima na srednjoj razini, što je slično nalazima ove studije. U istraživanju koje su proveli Gündüz i Bulut Dündar (2017) s budućim učiteljima razredne nastave utvrđeno je da kandidati imaju srednju razinu stava. U istraživanju Deringöl (2018), koje je ispitivalo stavove kandidata za učitelje koji su pohađali nastavu matematike prema geometrijskim tijelima, zaključeno je da su stavovi kandidata prema geometrijskim tijelima na srednjoj razini.

U ovoj su studiji razine geometrije, prostorna anksioznost i stavovi prema geometrijskim tijelima budućih učitelja razredne nastave ispitivani u odnosu na varijablu „spol”, pri čemu je zaključeno da prema toj varijabli nema značajnih razlika. U istraživanju Şahin (2008), koje je proučavalo Van Hieleove razine geometrije među učiteljima i budućim učiteljima razredne nastave, nije uočena razlika između spolova među učiteljima, dok je kod budućih učitelja zabilježena razlika u korist muških ispitanika. Studija Nopriana i suradnika (2023) pokazala je da su muški kandidati za učitelje matematike postigli najvišu razinu geometrijskoga mišljenja. U istraživanju koje je ispitivalo Van Hieleove razine geometrijskoga mišljenja učenika 3. razreda osnovne škole ponovno je utvrđeno da su razine geometrijskoga mišljenja učenika bile više od razina učenica (Gökbulut, Sidekli i Yangın, 2010). Kao što se vidi, u istraživanjima ne postoji konsenzus o utjecaju spola. Slično nalazima ove studije, postoje i istraživanja u literaturi koja pokazuju da spol ne uzrokuje značajne razlike (Asik Unal i Vezne, 2021; Bal, 2012; Çakmak i Güler, 2014).

Kada se prostorna anksioznost ispituje prema varijabli „spol”, u studiji Sarija (2016), koja je imala za cilj istražiti povezanost između prostornih sposobnosti i razina prostorne

anksioznosti budućih učitelja razredne nastave, uočeno je da su kandidatkinje pokazale veću prostornu anksioznost u usporedbi s kandidatima. U drugom istraživanju koje je ispitivalo povezanost između prostorne i matematičke anksioznosti među budućim učiteljima matematike u osnovnoj školi također je utvrđeno da su studentice bile anksioznije od studenata u poddimenzijama prostorne anksioznosti vezane uz orijentaciju (pronalaženje smjera) (Yurt i Çakmak Gürel, 2023). Literatura sugerira da je razlog za ovu razliku, kako je utvrđeno u istraživanjima Lawton (1994, 1996), u tome što žene prilikom snalaženja u prostoru koriste upute (strategiju rute), dok muškarci razumiju svoje položaje u odnosu na referentne točke u okolini (strategiju orijentacije). Ova tvrdnja podržana je brojnim studijama (Casey i sur., 1997; Dursun, 2010; Erkek i Işıksal-Bostan, 2015; Ferguson, Maloney, Fugelsang i Risko, 2015; Gibeau i sur., 2023; Malanchini i sur., 2017; Lauer, Esposito i Bauer, 2018; Lawton, 1994, 1996; Lawton i Kallai, 2002; Lyons i sur., 2018; Ramirez i sur., 2012). U studiji u kojoj je ispitana povezanost između prostornih dimenzija i prostorne anksioznosti u Kini i Rusiji, utvrđeno je da je prostorna anksioznost žena viša nego kod muškaraca (Wei i sur., 2018). Kao što je uočeno, iako literatura često sugerira da žene imaju veću prostornu anksioznost od muškaraca, u ovoj studiji, iako su rezultati žena viši od muškaraca, što ukazuje na veću anksioznost, ta razlika ne predstavlja značajnu razliku. Postoje i studije, premda rijetke, u kojima se ne nalazi značajna razlika, kao što je slučaj i s rezultatima ovoga istraživanja (Hund i Minarik, 2006; Saucier i sur., 2002).

U istraživanju stavovi budućih učitelja razredne nastave prema geometrijskim likovima nisu se razlikovali prema spolu. Slično tome, u istraživanju Deringöl (2018) nije utvrđena značajna razlika prema spolu. Također, u istraživanju koje su proveli Çağırğan, Yavuz i Deringöl (2017) s kandidatima za učitelje matematike nije pronađena značajna razlika prema spolu.

U ovoj studiji nije utvrđena značajna razlika u Van Hieleovim razinama geometrijskoga mišljenja, prostornoj anksioznosti, ocjenama iz geometrije u srednjoj školi te stavovima prema geometrijskim tijelima među budućim učiteljima razredne nastave, temeljem njihove sklonosti ili nesklonosti prema poučavanju geometrije. Iako su rezultati bili u korist onih koji „vole poučavati geometriju”, zapažene razlike nisu dosegnule statističku značajnost. U Turskoj budući učitelji razredne nastave pohađaju predmete poput Osnovne matematike u osnovnoj školi, u prvoj godini, zatim Poučavanje matematike I-II u trećoj godini te Nastavne prakse I-II u četvrtoj godini. U prvoj godini obrađuju teorijski dio matematike kroz predmet Osnovna matematika u osnovnoj školi. U trećoj godini usvajaju različite metode i tehnike poučavanja kroz nastavne predmete. U četvrtoj godini imaju priliku primijeniti naučeno kroz šestosatnu praksu u različitim osnovnim školama svaki tjedan, u okviru predmeta Nastavna praksa I-II. Prve korake u poučavanju čine primjenom naučenoga u tim školama. Stoga se budući učitelji, osobito u posljednje dvije godine, pripremaju za poučavanje radeći s djecom i stječući iskustvo u poučavanju geometrije kao grane matematike. U okviru ovoga istraživanja, izostanak značajne razlike u rezultatima temeljenoj na tome vole

li budući učitelji razredne nastave poučavati geometriju ili ne, ostaje tema za daljnju raspravu. Nedostatak sadržajnoga znanja iz geometrije među kandidatima za učitelje ili njihova percepcija nedostatka pripremljenosti i iskustva u poučavanju može objasniti ove nedostatke nalaze.

U pregledu temeljenom na „razrednim razinama” budućih učitelja razredne nastave uočena je razlika u prostornoj anksioznosti. Iako je ta razlika imala mali učinak u smislu veličine efekta, pokazuje da budući učitelji treće godine imaju veću prostornu anksioznost u odnosu na one prve i druge godine. U Turskoj se nastavni predmeti iz područja poučavanja matematike nude u trećoj godini. Razlog za ovu anksioznost može biti veći jer je to godina u kojoj počinju primjenjivati svoje teorijsko znanje. U ovom istraživanju nije pronađena razlika u Van Hieleovim razinama geometrijskoga mišljenja budućih učitelja razredne nastave temeljem njihove godine studija. U drugoj studiji koja je ispitivala aritmetičke sredine razina geometrijskoga mišljenja budućih učitelja matematike na razinama osnovne i srednje škole, za razliku od ovoga istraživanja, općenito se uočava povećanje rezultata na testu geometrijskoga mišljenja kako napreduju razredi (Oral i İlhan, 2012). Oflaz (2010) proveo je istraživanje s kandidatima za učitelje i utvrdio da nema značajne razlike u razinama geometrijskoga mišljenja kandidata prve godine u usporedbi s onima četvrte godine, slično kao i u rezultatima ovoga istraživanja. Također, u ovoj studiji stavovi budućih učitelja razredne nastave prema geometrijskim tijelima nisu se razlikovali ovisno o razredu u kojem se nalaze.

Kada se rezultati kandidata za učitelje razredne nastave analiziraju prema njihovim „razinama”, utvrđeno je da je razlika između rezultata Van Hieleova geometrijskoga testa i ocjena iz geometrije u srednjoj školi statistički značajna s velikim učinkom, dok je razlika u rezultatima prostorne anksioznosti značajna s umjerenim učinkom. Sukladno tome, ispitanici na razini 4 imaju više rezultate na Van Hieleovu geometrijskom testu u usporedbi s kandidatima na ostalim razinama. Ovo je očekivani rezultat jer se s povećanjem rezultata na višim razinama očekuje i neizbježan porast geometrijskoga mišljenja. Promatrajući njihovu prostornu anksioznost i ocjene iz geometrije u srednjoj školi, oni na razini 1 pokazuju veću anksioznost i niže ocjene u odnosu na ostale razine. Smanjenje prostorne anksioznosti s porastom razina mišljenja te povećanje ocjena iz geometrije u srednjoj školi su očekivani ishodi. Stavovi budućih učitelja razredne nastave prema geometrijskim tijelima ne pokazuju značajne razlike temeljem njihovih trenutačnih razina.

U istraživanju je na kraju utvrđeno da postoji niska i obrnuta povezanost između Van Hieleova geometrijskoga testa i ocjena iz geometrije u srednjoj školi budućih učitelja razredne nastave, kao i niska povezanost sa Skalom prostorne anksioznosti. Međutim, nije pronađena značajna povezanost sa Skalom stavova prema geometrijskim tijelima. Kako se geometrijsko mišljenje budućih učitelja razredne nastave povećava, njihove ocjene iz geometrije u srednjoj školi također rastu, dok se njihova prostorna anksioznost smanjuje. Usiskin (1982) i Senk (1989) došli su do sličnih zaključaka u svojim istraživanjima, navodeći da se s povećanjem postignuća učenika povećavaju i

njihove razine geometrijskoga mišljenja, što je u skladu s nalazima ovoga istraživanja. U studiji Şener-Akbay (2012) uočena je značajna korelacija između rezultata Van Hieleova geometrijskoga testa i ocjena iz geometrije. Rezultati istraživanja koje je provela Duatepe Paksu (2013) s učiteljima razredne nastave također su u skladu s ovim istraživanjem. Suprotno nalazima ove studije, postoje i istraživanja koja ukazuju da ponderirani prosjek ocjena ili postignuće iz geometrije ne predviđaju prostornu anksioznost (Bal, 2012; Erkek i Işksal-Bostan, 2015; Yurt i Çakmak Gürel, 2023).

Zaključak i preporuke

U ovom istraživanju provedenom na državnom sveučilištu u Turskoj detaljno su ispitivane razine geometrijskoga mišljenja, prostorna anksioznost i stavovi prema geometrijskim tijelima među 232 buduća učitelja osnovne škole. Rezultati upućuju na to da kandidati nemaju potrebne razine mišljenja, pokazuju niske razine prostorne anksioznosti te imaju umjeren stav prema geometrijskim tijelima. Nadalje, značajan nalaz povezanosti između rezultata Van Hieleova geometrijskoga testa kandidata za učitelje i njihovih ocjena iz geometrije u srednjoj školi te prostorne anksioznosti dodatno doprinosi važnosti ovoga istraživanja. Jasno je da znanje iz područja geometrije stečeno od vrtičke do visokoškolske razine može utjecati na njihovu prostornu anksioznost. Kao pripadnici skupine koja će postati učitelji osnovnoškolskih učenika, njihovo dovoljno sadržajno znanje i osjećaj spremnosti utječu na trenutačni i budući uspjeh njihovih učenika u geometriji. Stoga ovi nalazi mogu predstavljati vrijednu osnovu za razumijevanje kompetencija kandidata za učitelje u poučavanju geometrije te za razvoj obrazovnih programa. U tom kontekstu, važno je pregledati i ažurirati programe obrazovanja učitelja. Revizija nastavnih metoda i kurikula s ciljem unapjređenja kompetencija budućih učitelja u geometriji može pridonijeti prevladavanju nedostataka u ovom području. Razvoj naprednih modula za osposobljavanje u poučavanju geometrije dodatno bi mogao unaprijediti kompetencije kandidata za učitelje u tom pogledu. Eksperimentalne i longitudinalne studije mogle bi se provesti za procjenu učinaka različitih pedagoških pristupa u poučavanju geometrije.

Nadalje, sadržaj vezan uz geometriju u programima obrazovanja učitelja trebao bi se restrukturirati kako bi uključivao obrazovne okoline temeljene na praktičnim aktivnostima, obogaćene modulima usklađenim s individualnim razinama mišljenja budućih učitelja. Za rješavanje prostorne anksioznosti, kurikulum bi trebao uključivati refleksivne prakse koje potiču kognitivnu osviještenost, uz strategije učenja koje podržavaju afektivni razvoj. Umjesto da se poučavanje geometrije promatra isključivo kao prijenos znanja, kurikulum mora biti osmišljen tako da potiče integrirani razvoj ključnih kompetencija poput rješavanja problema, vizualizacije i intuitivnoga rezoniranja. Stoga, sveobuhvatna revizija kurikula obrazovanja učitelja, jačajući kako sadržajno znanje tako i pedagoške kompetencije, može značajno unaprijediti samopouzdanje i učinkovitost budućih učitelja u području obrazovanja iz geometrije.