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Elementary Mathematics Teacher Candidates' Geometric Thinking Levels And Their Self-Efficacy in Geometry

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Abstract: The present study aimed to examine the geometric thinking levels of elementary mathematics teacher candidates and to reveal the relationship between the participants' geometric thinking levels and their self-efficacy beliefs towards geometry. The sample group of the study was comprised of 85 freshman students studying in the elementary mathematics teaching department. The study, in which the relational survey model was employed, the "Van Hiele Geometry Thinking Test" and the "Self-Efficacy Scale towards Geometry" were administered. The relationships were analyzed by means of the Pearson Correlation Coefficient Calculation Technique. Interestingly, the findings revealed that approximately 30% of the teacher candidates had not reached the 2nd level. Thus, it can be deduced that the candidates' geometric thinking levels were low. While the relationship between the participants' geometric thinking scores and their overall scores for self-efficacy towards geometry was expected to be high, the results yielded a significantly weak (r=.064), but positive correlation. The examination of the relationship between geometric thinking levels and the sub dimensions of the self-efficacy towards geometry test revealed a weak (r=.004) but positive correlation between geometric thinking levels and the scores for positive self-efficacy beliefs towards geometry. On the other hand, there was again a weak (r= -.047) but negative relationship between geometric thinking levels and self-efficacy towards being able to use geometry. Furthermore, the analyses yielded a weak (r= -.202) indirect, yet a more significant correlation between geometric thinking levels and self-efficacy beliefs towards geometry.

Key words: Geometric thinking levels, Self-efficacy beliefs towards geometry, Elementary mathematics teacher candidates

1. Introduction

Geometry emerged and developed from the practical needs of daily life, and it was given an axiomatic structure by Euclid during mid-4th century B.C. The fundamental characteristic of this axiomatic structure is that a low number of axioms, postulates and definitions can prove the remaining other propositions by means of deductive inferences. This characteristic turned geometry into a system which many disciplines, including philosophy and natural sciences, follow (Yıldırım, 2000). Moreover, the need to transfer the thinking structure inherent in geometry to other generations and the need for geometric figures and terms in architecture, works of art, measurements in daily life, mathematical modeling and problem solving has, over the years, made geometry an indispensable component of the mathematics curricula in schools.

From the beginning of the 20th century to the present time, studies aiming to enrich the learning and teaching processes of geometry have continued to be conducted. Of these studies, some aimed to reveal how individuals' geometrical thinking developed. Within this context, the most well-known theory in geometry education is the geometric thinking theory of the Van Hiele couple. This theory was developed in 1957 by two mathematics educators, Pierre M. a hierarchical manner and his wife Dina Van Hiele-Gelfold during their Ph.D. studies in Ultrehct University (Crowley, 1987). The same year, P.M. Van Hiele published a research article in France, explaining the main points of his study.

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This study and his Ph.D. research drew the attention of scholars in education in the Soviet Union, who conducted more comprehensive studies in this area and reformed the geometry teaching programs in their country in the 1960s (Fuys, Geddes & Tiskler,1988). With a paper presented in the annual meeting of NCTM in 1974, the educationalists in America were informed of the theory. In subsequent years, other countries also started to take this theory into consideration while developing their geometry curricula.

According to this theory, individuals' geometric thinking levels consist of five stages and develop in a hierarchical manner. Each level indicates how individuals think about these geometric concepts and these different types of thought processes; it does not indicate which geometric concepts and to what extent they are acquired. In order for an individual to be assigned to one level, all the levels need to be passed (Usiskin, 1982). Below is a description of how students in each level think.

1st Level (Visualization): At this level, the student is interested in the image of the given figure. The geometric features does not matter at this level. The student identifies, names and compares the figures based on their images.

2nd Level (Analysis): The student at this level can list the features of a geometric figure but cannot build a relationship among them. At this level, the features and rules of a figure can be discovered by making use of activities such as folding and measuring, and these can be proven via experimental methods.

3rd Level (Abstraction): At this level, the student starts to see the relationships among the features of geometric figures. Axioms become more meaningful to the student and based on these axioms, they can make simple inferences and categorizations like "every square is a rectangle." Students at this level can follow a proof, but cannot make their own proofs.

4th Level (Deduction): At this level, students can sequence the relationships. They can use theorems, axioms, and definitions while making geometric proofs. They can prove other theorems deductively by making use of the already proven theorems and axioms.

5th Level (Rigor): Students at this level can interpret the axioms, theorems, and definions of Euclidian geometry in non-Euclidian geometry and do their applications.

Upon the review of the related literature, studies examining individuals' geometric thinking levels in accordance with the levels identified by Van Hiele were encountered. In a study by Fidan and Türnüklü (2010), it was found that 47.9% of grade 5 elementary students' geometric thinking level was at level 0 (none of the Van Hiele levels). It was also revealed that the geometric thinking levels of the same students varied with respect to the variables of gender, use of computer, the status of having or not having attended kindergarten, and level of parents' education. In a master's thesis by Coşkun (2009), the relationship between proof writing skill and Van Hiele Geometry thinking levels of secondary school students was examined; a positive interaction was identified. Bal (2011), investigated the impact of geometric education based on the constructionist approach upon elementary education teacher candidates' success levels in geometry and their Van Hiele geometric thinking levels. As an outcome of the study, no variation in the level of success in geometry was observed, while their geometric thinking levels were found to be effected positively. In another study by Bal (2011), teacher candidates' (students from the education departments of computer and educational technologies, elementary teacher education, science and technology teacher education) geometric thinking levels and their attitudes towards geometry were examined. The study revealed that the teacher candidates were at different thinking levels and had a high level of attitude. It also found that there was a low, but significant relationship between geometric thinking levels and attitudes in the dimension of "anxiety".

The studies on geometric thinking levels encountered in literature are mainly studies those conducted with elementary or secondary school students. However, there are few if any studies examining the thinking levels of elementary mathematics teacher candidates, who are to teach the geometric thinking skills to elementary students. Naturally, one of the most important factors impacting students' success in geometry and their development in geometric thinking levels is the mathematics teacher since Van Hiele states that each child sequentially passes through all the levels of geometric thinking. The transitions through these levels are not realized based on age, but rather on education (Aksu & Tığlı, 2007). The geometric thinking level of the teacher is highly influential on the geometric thinking level s/he will equip students with and their development in the thinking levels. The geometric thinking levels of teacher candidates who are in their pre-service period are important for both themselves and the thinking levels of the students whom they will be teaching.

When the recent results of international exams such as TIMSS (Trends in International Mathematics and Sciences Study) and PISA (Program for International Student Assessment) are examined, it can be observed that Turkish students received the lowest scores in the area of geometry (Hurma, 2011). The questions in these exams are based more on reasoning and geometric thinking levels. Thus, studies on examining and developing the geometric thinking levels of elementary mathematics teacher candidates, who will teach students entering these exams, will indirectly contribute to increasing the success rates of students taking these international exams.

Self-efficacy, which is defined as people's personal beliefs about their capabilities of planning and exercising actions necessary to achieve their self-designated goals (Bandura, 1997), implies that the teacher's knowledge and thinking level in the concept to be taught are influential, and that the teacher's self-efficacy in the course s/he teaches influences the educational activities (Caprara, Barbaranelli, Steca & Malone, 2006; Henson, Roberts, Tharp & Moreno, 2001; Palmer, 2006). In addition, Ashton (1984) stated that there was a consistent relationship between teachers' self-efficacy beliefs and students' success −that teachers with a high level of self-efficacy increased students' in-class performance. Accordingly, the present study is significant in predicting teacher candidates' capabilities in teaching geometry effectively when their teaching profession begins.

Among some of the studies in the related literature, studies examining the relationship between self-efficacy beliefs and some other variables were encountered. Özkan and Yıldırım (2013) investigated the relationship among success in geometry, self-efficacy in geometry, parents' level of education, and gender; they reported a significant relationship between self-efficacy and both individual's success and parents' level of education. On the other hand, in a study by Erkek and Işıksal Bostan (2015), the roles of spatial anxiety, self-efficacy perceptions in geometry and gender variables in predicting success in geometry were examined. They found that the variable of self-efficacy beliefs towards geometry was significantly predictive of success in geometry. In addition, Yenilmez and Uygan (2010) examined the impact of the creative drama method upon 7th grade students' self-efficacy beliefs towards geometry and found a significant impact.

When self-efficacy beliefs and the variables that display a relational interaction are taken into consideration, it is believed that there may be a relationship between teacher candidates' thinking levels and their self-efficacy beliefs. Thus, the present study aimed to examine the geometric thinking levels of elementary mathematics teacher candidates and to reveal the relationship between the participants' geometric thinking levels and their self-efficacy beliefs towards geometry. To this end, the research question of the study was as follows:

Is there a relationship between elementary mathematics teacher candidates' Van Hiele geometric levels and their self-efficacy beliefs towards geometry?

2. Materials and Methods

The relational survey model was employed to identify teacher candidates' geometric thinking levels and their self-efficacy beliefs towards geometry. This model assumes a research approach that aims to describe a condition that existed in the past or still continues to exist.

2. 1. The Sample of the Study

The sample of the study was comprised of 85 freshman students studying in the elementary mathematics teaching department of the education faculty in a university in the Black Sea Region of Turkey during the 2012-2013 academic year. Of these participants, 56 were female, while 29 were male.

2. 2. Data Collection Tools

In the present study, the data collection tools were the “Van Hiele Geometry Thinking Test” and the “Self-Efficacy towards Geometry Scale”. Further information regarding these data collection tools are presented under the sub headings below.

2.2.1. The Van Hiele Geometry Thinking Test (VHGTT)

The “Van Hiele Geometric Thinking Test- VHGTT” was utilized to identify the geometric thinking level of the students participating in the research study. Van Hiele’s geometric thinking test is composed of five hierarchical levels and each level should be passed in order to reach the subsequent level.

The Cronbach Alpha value for the overall test, the Turkish adaptation, the reliability and the validity of which were done by Duatepe (2000), was calculated to be .75. In this test, there is a total of 25 multiple-choice questions, five for each thinking level.

While the first five questions belong to the first level, every subsequent five question belongs to the 2^{nd}, 3^{rd}, 4^{th} and 5^{th} levels, respectively. To pass onto a new level, at least three of the five questions in one level need to be answered correctly. As for the scores, the first, second, third, fourth and fifth levels are 1 point, 3 points, 7 points, 15 points, and 31 points, respectively.

2.2.2. The Scale of Self-efficacy towards Geometry

The scale developed by Başer and Cantürk Gülhan (2007) was utilized in order to identify the teacher candidates’ self-efficacy beliefs towards geometry. This scale, which consisted of a total of 25 items, 18 of which were positive and 7 negative, was based on a five-point likert scale as follows:

“1. Never, 2. Sometimes, 3. Undecided, 4. Usually, 5. Always”

As for the items in the scale, they consist of three sub factors: (i) positive self-efficacy beliefs, (ii) being able to use geometry knowledge, and (iii) negative self-efficacy beliefs. Of the items, 12 were loaded onto the “Positive Self-efficacy Beliefs, while 7 were loaded onto “Negative Self-efficacy Beliefs”. The scale was administered to a total of 385 students in grades 6, 7 and 8 in a middle school in west of the Turkey. Başer and Cantürk Gülhan (2007) reported that the Cronbach Alpha Reliability Coefficient of the scale was .90.

The same scale was administered to 85 freshman students in the elementary mathematics teacher education department, who constituted the sample of the present study, and the reliability coefficients were examined once again. Table 1 presents the sub dimensions of the scale for self-efficacy towards geometry and the overall reliability anlaysis results for the scale.

Table 1. *The Sub Factors of the Scale and the Overall Cronbach Alpha Realibity Coefficient*

Sub Factors of Scale	Number of Items	Cronbach Alpha	Min-Max values
Positive Self-efficacy Beliefs	12	.79	3.25-4.27
Being able to use Geometry	6	.60	2.76-4.50
Negative Self-efficacy Beliefs	7	.74	3.36-4.50
Overall	25	.85	2.76-3.71

The analysis yielded a high degree of reliability (α=.85) for the scale, which was used to determine the elementary mathematics teacher candidates’ self-efficacy towards geometry.

2. 2. Data Analysis

The SPSS 16.0 software package program was utilized to analyse the data obtained in the study. The relationship between teacher candidates’ attitudes towards geometry and the Van Hiele geometric thinking test were analyzed by means of the Pearson Correlation Coefficient Calculation Technique.

Prior to this correlational analysis, the Q-Q test was employed to analyze the distribution of the teacher candidates' geometric thinking scores and the scores they received from the scale for self-efficacy towards geometry (also addressing the scores from the self-efficacy sub factors). The Pearson Product-Moment Correlation was utilized to analyze these variables, which were observed to have a normal and a continuous distribution, indicating that they possessed the required traits. Descriptive statistics were utilized to identify teacher candidates' average scores regarding self-efficacy towards geometry and its sub dimensions and those regarding their geometric thinking levels. A significance level of 0.05 was used for the correlations.

3. Findings

The frequency distribution of the geometric thinking levels of the teacher candidates participating in the study is presented in Table 2 below.

Table 2. *The Frequency Distribution of Teacher Candidates' Geometric Thinking Levels*

Geometric Thinking Levels	N	%
0*	8	9.4
1	16	18.8
2	13	15.3
3	24	28.2
4	17	20.0
5	7	8.2
Total	85	100

Level 0* : It is regarded as the condition where teacher candidates do not meet any of the criteria of belonging to any one level.

When Table 2 is examined, it can be observed that highest percentage of teacher candidates (28.2%) are mostly at level 3: *Abstraction*, and the lowest percentage (8.2%) are at level 5: *Rigor*. Furthermore, 9.4% of the teacher candidates are observed to be at level "0", indicating that they do not belong to any level, while accummulation – after level 3 – is observed in levels 4 and 1. The mean socres and standard deviations regarding the teacher candidates' self-efficacy towards geometry and its sub dimensions are presented in Table 3.

Table 3. *The Distribution of Teacher Candidates' Self-Efficacy towards Geometry*

Sub Factors of Scale	N	$\bar{X}$	S
Positive Self-effiacy	85	44.75	5.26
Negative Self-effiacy	85	15.24	3.96
Being able to use	85	19.63	3.46
Self-efficacy Total	85	91.14	10.26

As presented in Table 3, the descriptive statistical analyses yieled rather high mean scores (x=91.14) for teacher candidates' overall self-efficacy towards geometry, while the highest mean score (x=44.75) observed among the sub dimensions belongs to the participants' positive self-efficacy beliefs.

3. 1. The Relationship between Teacher Candidates' Self-efficacy towards Geometry and their Geometric Thinking Scores

The relationship between teacher candidates' geometric thinking scores and the scores they received in the scale of self-efficacy towards geometry, which was analyzed via the Pearson Product-Moment Correlation, and the scores are presented in Table 5.

Table 5. *The Correlation between Self-efficacy towards Geometry and Geometric Thinking Scores*

Self-efficacy towards Geometry	Geometric Thinking Score
Self-efficacy	.064
Positive Self-effiacy	.004
Negative Self-effiacy	-.202
Being able to use	-.047

When the data in Table 5 are examined, it can be observed that the correlations between individuals' geometric thinking levels and (i) their overall score for self-efficacy towards geometry (r=.064) and (ii) their positive self-efficacy towards geometry score (r=.004) were quite weak, but positive as the correlation coefficients fell between the range of 0.0 and 0.3. However, despite being weak, a negative correlation (r= -.047) between geometric thinking scores and the self-efficacy to being able to use geometry was observed. In addition, despite being weak and negative, a more significant correlation (r= -.202), was found between geometric thinking scores and negative self-efficacy towards geometry.

4. Conclusion, Discussion and Recommendations

The findings of the present study, which aimed to determine teacher candidates' geometric thinking levels, their self-efficacy, and the relationship between these variables were examined, revealed that (i) there were teachers across all geometric thinking levels at different ratios, (ii) the candidates had a high level of self-efficacy towards geometry, and (iii) there was a very low relationship between geometric thinking scores and their self-efficacy.

The study was expected to yield findings indicating that the majority of the elementary mathematics teacher candidates' geometric thinking levels would be at levels 4 or 5. The reason is that according to NCTM (2000), secondary students should be at least at 4th level, and Van Hiele (1986) stated that primary school students are desired to reach the 2nd level of geometric thinking level. However, the findings of the present study that 9.4% (n=8) of the teacher candidates could not be assigned to any level and, in total, only 28.2% (n=24) were at 4th or 5th level are quite striking. Thus, the conclusion that elementary mathematics teacher candidates' geometric thinking levels are low can be drawn. Similar studies reported that the geometric thinking levels expected of teacher candidates in faculties of education were low (Bal, 2012; Duatepe, 2000; Durmuş, Toluk & Olkun, 2002; Erdoğan, 2006; Halat, 2008; Knight, 2006; Olkun, Toluk, & Durmus, 2002; Şahin, 2006; Toluk, Olkun & Durmuş, 2002). In a study conducted with elementary and secondary school mathematics teacher candidates (Oral & İlhan, 2012), it was reported that 5.3% (n=16) of the participants was not assigned to any level and that only 7% (n=21) were at level 4 or 5. Based on the results of these studies, conducted at different universities within close time periods, it is believed that there are serious problems regarding geometry teaching at secondary and undergraduate levels. In geometry teaching, geometry teachers should have sufficient knowledge to be at least one or two levels ahead of the students so that they can reach the defined objectives by integrating the topic to be taught within the entirety of mathematics. In addition, they should be able to present to the students the link between mathematics and daily life (Baki, 2006). Thus, it is recommended that qualitative studies, rather than quantitative ones, be conducted in order to arrive at a more in-depth and detailed understanding of the problems regarding elementary mathematics teacher candidates' geometric thinking levels and to generate more effective recommendations for solutions.

That the mathematics teacher candidates in the present study were at a sufficient level in geometric thinking even though they had some geometry knowledge can be attributed to the fact that geometric thinking levels are not taken into consideration in primary and secondary mathematics curricula. Hence, in mathematics curricula, teaching objectives regarding geometry should be reconsidered; it is recommended that they be modified based on Van Hiele's geometric thinking levels. In addition, that the present study was conducted with teacher candidates who were freshman students and that they had not received the geometry course at the time the study was conducted could be other factors impacting the this outcome. The reason is that undergraduate education can also be influential in enabling individuals to reach an advanced level of geometric thinking performance. In order to examine the development in these individuals' thinking levels, which are mostly low, it is recommended that the test be read ministered after the geometry course is offered and the change be examined by comparing their prior and subsequent geometric thinking levels.

While a high level of relationship between individuals' self-efficacy beliefs and geometric thinking levels was expected, the study yielded a very weak relationship. The correlation between individuals' geometric thinking scores and their scores for self-efficacy towards geometry was found to be highly weak (r=.064), but in the positive direction. In other words, the higher the individuals' geometric thinking levels are, the more increase there is, though low, in their scores for self-efficacy towards geometry.

The examination of the relationship between geometric levels and the sub dimensions of the self-efficacy towards geometry test yielded a weak (r=.004), but a positive correlation between geometric level and positive self-efficacy towards geometry, while the correlation between geometric level and the self-efficacy to use geometry was found to be again weak (r= -.047) , but in the negative direction. The negative correlation here is striking. This finding is different from the findings reported by Özkan and Yıldırım (2013), who conducted a study with grade 8 primary school students. It is believed that this may have derived from the grade level. It is recommended that a similar study be conducted to include secondary school and high school teacher candidates as well.

In the geometry course that teacher candidates take in their freshman year, they study logical inferences that required them to be at a certain geometric thinking level. However, based on the findings of the present study, it is observed that approximately 70% of the elementary mathematics teacher candidates are at a thinking level (3rd level) that is below the level of logical inferrencing. Thus, it can be concluded that elementary mathematics teacher education candidates do not have the sufficient thinking readiness required by the geometry course. Hence, it can be maintained that the insufficient readiness in thinking in the geometry course can impact individuals' both self-efficacy towards using geometry and academic success. Accordingly, to reach the intended objectives in undergraduate geometry courses, it is recommended that individuals' geometric thinking levels be identified prior to the geometry course and a learning environment conducive to the identified thinking level of the class be established.

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