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Examining Pre-service Mathematics Teachers' Conceptual Structures About "Geometry"

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Abstract
The aim of this study is to examine pre-service mathematics teachers' conceptual structures about "geometry". Qualitative research methodology has been adopted in the study. The data of the study is obtained from mathematics teacher candidates who have been students at the faculties of education of an Anatolian university in the academic year of 2015-2016. The free word association test was used to collect the data. The "geometry" stimulus word is presented to participants by the word association test. A total of 65 response words obtained from the test have been arranged in frequency tables. The answer words were divided into 13 categories with the help of content analysis. Considering the frequencies and categories of answer words, a network of concepts has been developed that outlines the conceptual structures of pre-service mathematics teacher about "geometry". At the end of the research, the answer words with the highest frequency of the mathematics teacher candidates related to the "geometry" stimulus word are triangle, angle, area, polygon, etc. and the categories of answer words are triangle, quadrilateral/polygon, basic concepts of geometry, measurement, etc.
Keywords: Geometry, conceptual structures, free word association test, pre-service mathematics teachers.

1. Introduction

As a result of developments in information technology, the need for a person who understands mathematics, use his mathematics information and mathematical skills in daily life is increasing gradually. Mathematics is a language itself and has lots of basic concepts. Mathematics is an abstract science and mathematical concepts are obtained after an abstraction. It is so difficult to learn or understand a subject for the students, if the definitions of concepts in Mathematics are not fully comprehended. Therefore, the integration of a subject should be learned with definition, concept and interpreting of subject.

It is possible to divide mathematical knowledge into two; conceptual knowledge and procedural knowledge. Conceptual knowledge requires not only learning the concept, its definition and name, also it requires seeing the mutual transitions and relations of concepts. If the concepts are related to the groups which they mean, the meaning of the concept becomes understandable; they do not mean anything alone when separated from other concepts. Conceptual knowledge occurs as long as the concept is understood and internalized. When people learn new things, they build on their previous knowledge. Similarly, mathematical information is incorporated into existing information. When the new information can be appropriately related and reconciled with the old knowledge, then the understanding of the concept occurs (Baki and Kartal; 2004, Erdogan, 2007). By balancing the conceptual and procedural knowledge, it becomes easier for students to reveal high-order thinking skills necessary for understanding mathematics, to make assumptions, to make generalizations and to make inter-subject associations (Bekdemir, 2012; Birgin and Gürbüz, 2009). In this sense, both conceptual and procedural knowledge is needed to learn mathematics, and it is important to teach both types of knowledge (Olkun and Toluk, 2004; Rittle-Johnson Siegler and Alibali, 2001).

Teaching geometry, one of the most important branches of mathematics, emerges as a subcomponent of mathematics teaching. Geometry has played an important role in mathematics since ancient times. The fact that the beings around us have a geometric shape, the use in many disciplines, the creation of mathematical model and the use of problem solving make the geometry even more important. People compare an object or an entity they see in their surroundings with geometric shapes and objects in their daily lives, and they benefit from these shapes and objects in their professional lives. In this context, many studies have been carried out on the importance of teaching geometry (Aksu, 2005; Altun, 2002; Baki, 2006; Balcı-Şeker and Erdoğan, 2017; Çetin, Erdoğan, and Yazlık, 2015; Develi and Orbay, 2003; Erdoğan, Baloğlu, and Kesici, 2011; Kesici, Erdogan, and Özteke, 2011; Kurtulus et al., 2005). Nowadays we come across achievements related to teaching geometry at almost every grade level. In the mathematics curriculum of the Ministry of National Education, activities related to geometry should be mentioned as "Geometrical objects and shapes recognition, naming, building, drawing, comparison and grouping according to specific features. Thus, the students relate concepts and terms that are examined as abstractions with objects that they see in their surroundings." (MEB, 2005). Here, both the importance of geometric concepts is emphasized, it is also indicated that students are able to understand everyday life better through geometry.

The term geometry derives from the Greek word "geometrien" and consists of the combination of the words "geo" meaning "place" and "metric" meaning "measure". Geometry was first described as a field of science studying the size and smallness of objects (Altun, 2008; Yavuz, Kepceoglu, and Kerpic, 2016). However, today;

it is described as the branch of mathematics which examines point, line, plane, planar shapes, space, spatial shapes and relations among them, as well as measuring such as length, angle, area and volume of geometric shapes (Baykul, 2002). In this context, geometric bodies and shapes, their features, and their relation to each other form the subject of geometry. Geometry is based on four basic elements: undefined terms, defined terms, axioms and theorems. Point, line, plane and space are undefined terms. Definitions of these terms cannot be made using other concepts. The defined terms are terms defined within the language and logic rules, depending on the undefined terms and the terms previously defined. Line segment, the half line, the angle and the triangle can be shown as examples. Then, the basic purpose of the geometry can be expressed as recognizing the properties of geometric objects in plane and space, finding relationships between them, and proving geometric propositions. Until the children begin to school, they acquire informal knowledge and experience on geometric concepts that are most related to space geometry. The task of the school is to organize them according to the level of mental development of the children and formalize them, to acquire new geometric concepts and relationships among them by taking the knowledge and skills they have learned.

An increase in effect of constructivist learning approach in educational environments revealed different techniques and strategies in order to make up a shortage in conceptual understanding of traditional assessment and evaluation and also measurement of change. In this context, the techniques which determine the students' cognitive structures, the relations between concepts in this structure, revealing the relations and evaluating whether these relations are enough or not, became important. It is presented by the researchers that Free Word Association Test (FWAT), which is one of these techniques, is an effective one in revealing cognitive structures, determining conceptual changes and confirming misconceptions.

In Free Word Association Test (FWAT) students are expected to response association of a concept or concepts verbally or in written. The responses given are analyzed. A frequency table of the response in words is created. Associations of the concepts obtained are used to determine the conceptual structure of students. Free word association test has been used in many studies (Ay, 2011; Bahar, Johnstone, and Sutcliffe, 1999; Bahar and Özatlı, 2003; Dikmenli, 2010a; Dikmenli, 2010b; Kurt and Ekici, 2013a; Kurt and Ekici, 2013b). It is seen in literature that students have many alternative concepts about geometry. In this context, it is possible to determine the cognitive structure of pre-service mathematics teachers and reveal the alternative concepts using free word association. When the related literature is studied, it is seen that there are some studies searching the pre-service mathematics teachers' conceptual structures about mathematics concepts through word association test (Benibil and Erdoğan, 2016; Benibil and Erdoğan, 2016b; Gökbaş and Erdoğan, 2016; Turan and Erdoğan, 2016; Turan and Erdoğan, 2017), but there is no study searching the conceptual structures of pre-service mathematics teachers about "geometry" concept. Hence, it is thought that the study results will contribute a lot to the literature. The aim of this study is to determine the conceptual structures of mathematics teacher candidates about "geometry" which is one of the most important learning domains of mathematics.

2. Method

In this study, phenomenological approach that is one of the qualitative research approaches is used. Phenomenological approach is used to research the phenomenon that we are aware but have difficulty in comprehending.

2.1. Participants

The study group consists of 60 teacher candidates in the field of mathematics having education at a university in Anatolia during 2015-2016 Academic Year. 30 of them are mathematics teacher candidates studying at 4th and 5th grades, and 30 of them are having education at pedagogical formation program. 44 (73%) of the participants of this study are female and 16 (26%) are male. The average age of the participants was 22,6 years (range 21–35).

2.2. Data Collection

Free Word Association Test is used as data collection tool. The candidate teachers are given the concept "Geometry". The "Geometry" concept was written top to bottom 10 times.

Stimulus Concept: GEOMETRY
GEOMETRY:……
GEOMETRY:……
GEOMETRY:……
GEOMETRY:……
GEOMETRY:……
GEOMETRY:……
GEOMETRY:……
GEOMETRY:……
GEOMETRY:……
GEOMETRY:……

The aim of writing the concept top to bottom is to prevent the teacher write down the words that the concept reminds in other words to eliminate the risk of getting chain answers. Thus, this will prevent going beyond the scope of test. The studies conducted using Free Word Association Test are examined and the appropriate response time for the stimulus concept is determined as 30 seconds. The responses given for the stimulus concept (geometry) by candidate teachers are examined. Main categories are organized in line with the responses for stimulus concept and response words are put appropriate categories. The same procedure is applied again one week later and some response words are placed to other categories. After this second procedure, the categories and the words in responses were approved by an expert.

2.3. Data Analysis

The responses of mathematics teacher candidates to the stimulus concept given in order to analyze Free Word Association Test are investigated using content analysis method. After the content analysis, a frequency table for the words given as a response to stimulus concept was created. According to frequency table, a conceptual network is drawn which reveals the conceptual structures of teacher candidates considering the responses to the stimulus concept "geometry."

3. Results

In this part, first of all, the responses of mathematics teacher candidates' to the stimulus concept "geometry" in Free Word Association Test and the categories obtained from the response words are given. Afterwards, the conceptual network including frequencies and categories is presented.

3.1. Findings Related to The Response Words Given to Stimulus Concept "Geometry" and Created Categories

65 response words are obtained from the Free Word Association Test applied to teacher candidates about "geometry" stimulus concept. These 65 words are organized in 13 categories and these categories are shown in Table 1. The categories are created considering the high school syllabus in our country.

Table 1. The Categories Organized Using the Responses for "Geometry" Stimulus Concept

Categories	Frequency (f)	%
1. Triangle	104	20
2. Quadrilateral/Polygon	78	15
3. Basic Concepts of Geometry	72	13,8
4. Measurement	70	13,5
5. Angle	47	9
6. Circle/Disk	42	8,1
7. General Structure of Geometry	40	7,7
8. Types of Geometry	20	3,8
9. Solid Geometry	19	3,7
10. Field of Application	14	2,7
11. Capability	8	1,5
12. Conics	4	0,8
13. Transformations	2	0,4
TOTAL	520	100

As a result of the analysis of the obtained data, the answers given by the participants in the first category about the concept of geometry were most concentrated under the category of "Triangle" and this emerged as the dominant category (f = 104). The most focused concept in this category is the concept of "triangle", which gives the name in the category, followed respectively by the concepts; Pythagoras, Trigonometry, Bisector, Median, Hypotenuse, Euclid, Equilateral Triangle, Altitude, Leg, Isosceles Triangle and Special Triangle. The response words for "Triangle" category are as in Table 2.

Table 2. Response Words in “Triangle” Category

Category	Associations	Frequency (f)	%
1. Triangle	Triangle	48	46
	Pythagoras	14	13
	Trigonometry	8	8
	Bisector	5	5
	Median	5	5
	Hypotenuse	5	5
	Euclid	5	5
	Equilateral Triangle	4	4
	Altitude	4	4
	Leg	2	2
	Isosceles Triangle	2	2
	Special Triangle	2	2
	TOTAL	104	100

The second category contains concepts related to the geometry concept "Quadrilateral / Polygon" (f = 78). In this category, while the associations specified by the participants are mostly Polygon, Square, Rectangle concepts, these concepts are followed by quadrilateral, trapezoid, and parallelogram concepts, respectively. It is remarkable that “rhombus” and “deltoid” which can be placed in this category are not among the responses teacher candidates given. The response words for “Quadrilateral/Polygon” category are as in Table 3.

Table 3. Response Words in “Quadrilateral/Polygon” Category

Category	Associations	Frequency (f)	%
2. Quadrilateral/ Polygon	Polygon	24	31
	Square	17	22
	Rectangle	15	19
	Quadrilateral	9	12
	Trapezoid	9	12
	Parallelogram	4	5
	TOTAL	78	100

The third category is "Basic Concepts of Geometry" (f = 72). Participants' association for this category is Line, Space, Side, Ray, Plane, Similarity / Congruence, Point, Vertex, and Surface. It is remarkable that “vector” and “line segment” which can be placed in this category are not among the responses teacher candidates given. The response words for “Basic Concepts of Geometry” category are as in Table 4.

Table 4. Response Words “Basic Concepts of Geometry” Category

Category	Associations	Frequency (f)	%
3. Tools of Geometry	Line	19	26
	Space	15	21
	Side	13	18
	Ray	7	10
	Plane	6	8
	Similarity/Congruence	4	6
	Point	3	4
	Vertex	3	4
	Surface	2	3
	TOTAL	72	100

In the fourth category, participants associated geometry key words with the words in the "Measurement" category (f = 70). In this category it is seen that teacher candidates responded stimulus concept “geometry” giving Area, Degree, Volume, Length, Circumference, Measure, and Radian words. The response words for “Measurement” category are as in Table 5.

Table 5. Response Words in "Measurement" Category

Category	Associations	Frequency (f)	%
4. Measurement	Area	27	39
	Degree	11	16
	Volume	10	14
	Length	9	13
	Circumference	6	9
	Measure	4	6
	Radian	3	4
	TOTAL	70	100

The fifth category was formed as "Angle" (f = 47). The majority of participants have associated geometry key word with Angle word in this category. Other associations in this category are Right Angle, Interior Angle and Exterior Angle, respectively, and these associations are seen as angle variants. The response words for "Angle" category are as in Table 6.

Table 6. Response Words in "Angle" Category

Category	Associations	Frequency (f)	%
5. Angle	Angle	40	85
	Right Angle	3	7
	Interior Angle	2	4
	Exterior Angle	2	4
	TOTAL	47	100

Participants in the sixth category associated the geometry stimulus word with Circle / Disc-related words (f = 42). In this category it is seen that teacher candidates responded stimulus concept "geometry" giving Circle, Disk, Tangent/Chord, Radius, Arc, and Pi number words. It is remarkable that the frequency is low for the word Radius and Diameter word is not mentioned. The response words for "Circle/Disk" category are as in Table 7.

Table 7. Response Words in "Circle/Disk" Category

Category	Associations	Frequency (f)	%
6. Circle/Disk	Circle	19	45
	Disk	11	26
	Tangent/chord	6	14
	Radius	2	5
	Arc	2	5
	Pi number	2	5
	TOTAL	42	100

In the seventh category, participants associated the geometry stimulus word with the words related to "General Structure of Geometry" (f = 40). In this category, the most focused answer is the word, Figure, which is followed by the words Mathematics, Relation, Lesson, Connection, and Science respectively. The response words for "General Structure of Geometry" category are as in Table 8.

Table 8. Response Words in "General Structure of Geometry" category

Category	Associations	Frequency (f)	%
7. General Structure of Geometry	Figure	22	55
	Mathematics	8	20
	Relation	3	8
	Lesson	3	8
	Connection	2	5
	Science	2	5
	TOTAL	40	100

In the eighth category, participants associated geometry stimulus word with words related to "Types of Geometry" (f = 20). In this category it is seen that teacher candidates responded stimulus concept "geometry" giving Analytical Geometry, 3D Geometry, 2D geometry, and "Differential Geometry" words. It is thought that giving these words as response is because the geometry lessons they had during university education were in the defined types. The response words for "Types of Geometry" category are as in Table 9.

Table 9. Response Words in "Types of Geometry" category

Category	Associations	Frequency (f)	%
8. Types of Geometry	Analytical Geometry	12	60
	3D Geometry	4	20
	2D Geometry	2	10
	Differential Geometry	2	10
	TOTAL	20	100

The ninth category is formed as "Solid Geometry" (f = 19). In this category it is seen that teacher candidates responded stimulus concept "geometry" with Prism, Cylinder, Cone, and Cube words. It is remarkable that teacher candidates didn't give pyramid and sphere responses that can be evaluated in this category. The response words for "Solid Geometry" category are as in Table 10.

Table 10. Response Words in "Solid Geometry" category

Category	Associations	Frequency (f)	%
9. Solid Geometry	Prism	9	47
	Cylinder	5	26
	Cone	3	16
	Cube	2	11
	TOTAL	19	100

In the tenth category, participants associated geometry stimulus word with concepts related to "Field of Application" (f = 14). In this category it is seen that teacher candidates responded stimulus concept "geometry" with architectural works, engineering, sketch, and map words. The response words for "Field of Application" category are as in Table 11.

Table 11. Response Words in "Field of Application" category

Category	Associations	Frequency (f)	%
10. Field of Application	Architectural works-Engineering	9	64
	Sketch-map	5	36
	TOTAL	14	100

In the eleventh category, participants have associated geometry stimulus with concepts related to "Capability" (f = 8). In this category it is seen that teacher candidates responded stimulus concept "geometry" with vision and perspective words. It is thought that teacher candidates think geometry classes require a different ability. The response words for "Capability" category are as in Table 12.

Table 12. Response words in "Capability" category

Category	Associations	Frequency (f)	%
11. Capability	Vision	6	75
	Perspective	2	25
	TOTAL	8	100

The twelfth category was formed as "Conics" (f = 4). In this category it is seen that teacher candidates responded stimulus concept "geometry" with ellipse, hyperbole, and parabola words. The response words for "Conics" category are as in Table 13.

Table 13. Response Words in "Conics" category

Category	Associations	Frequency (f)	%
12. Conics	Ellipse	2	50
	Parabola-hyperbola	2	50
	TOTAL	4	100

The thirteenth category was formed as "Transformations" (f = 2). In this category it is seen that teacher candidates responded stimulus concept "geometry" only with symmetry words. It is remarkable that teacher candidates didn't give response words reflection, translation, and rotation which can be placed in this category. The response words for "Transformations" category are as in Table 14.

Table 14. Response Words in "*Transformations*" category

Category	Associations	Frequency (f)	%
13. Transformations	Symmetry	2	100
	TOTAL	2	100

3.2. The Conceptual Network Related to The Conceptual Structure of Mathematics Teacher Candidates Concerning "Geometry"

In Figure 1, the conceptual network related to the conceptual structure of mathematics teacher candidates

concerning "geometry" is given.

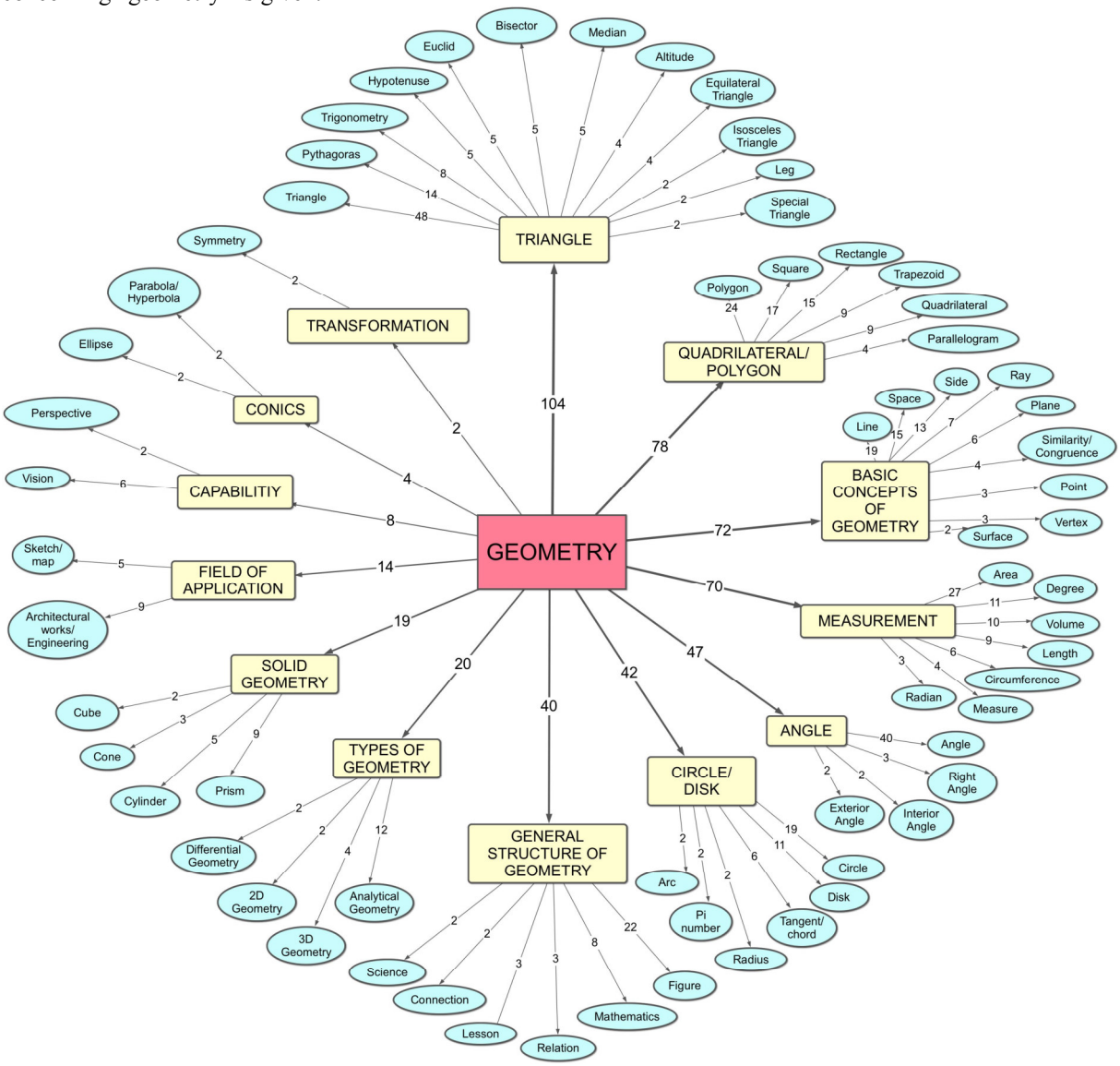

Figure 1. The Conceptual Networks of Mathematics Teacher Candidates with regard to "Geometry"

As it is seen in Figure 1 conceptual network, the mathematics teacher candidates mostly associates the "geometry" stimulus concept with the concepts in Triangle, Quadrilateral/Polygon, Basic Concepts of Geometry, and Measurement categories. It is thought that these concepts are associated more because they are basic for other subjects of geometry and they are mostly mentioned in syllabuses. It is seen that the mathematics teacher candidates associates the "geometry" stimulus concept with the concepts in Solid Geometry, Conics, and Transformation Geometry categories less. It is thought that this is because these category subjects are thought in advanced levels.

4. Conclusions and Recommendations

A rich data acquired at the end of this study which aims to determine the conceptual structures of pre-service mathematics teachers about the concept of "geometry" by using the free word association test. The data obtained by the free word association test are collected under 13 categories (Triangle, Quadrilateral/Polygon, Basic Concepts of Geometry, Measurement, Angle, Circle/Disk, General Structure of Geometry, Types of Geometry, Solid Geometry, Field of Application, Capability, Conics, Transformations). When these categories are examined, it can be seen that the answer words in the categories mainly include the basic geometry topics in the school curriculum.

At the end of the research, the dominant categories obtained by free word association test are Triangle, Quadrilateral/Polygon, Basic Concepts of Geometry and Measurement. When the answer words in these categories are examined, it is seen that these words include topics that are mainly included in the geometry curriculum from primary to university level. So the words in these categories are generally expected answers and

they are concepts that are commonly used in geometry subjects.

On the other hand, it is seen that the pre-service teachers do not associate the concepts related to the topics that were added to the curriculum later or exists at the end of curriculum. In our country, new sub-learning areas such as transformation geometry, trajectory, pattern and ornaments have been added to the field of geometry learning in the mathematics curriculum developed after 2005 based on constructivist philosophy. New concepts in this sub-learning field are translation, reflection, rotation, pattern, ornamentation and perspectives (MEB, 2005). The fact that pre-service teachers do not address these new concepts suggests that they have not yet internalized the new curriculum and that they are not at the expected level of competence in this respect. As a matter of fact, in their studies Gürbüz and Durmuş (2009), has determined that a significant proportion of the teachers who are newly mentioning about these subjects are not in the expected competence. With geometry stimulus word, a single answer word, symmetry, is associated in the category of transformation geometry, and this concept is often seen to be used instead of reflection transformation.

In the new curriculum, acquirements which require to do activities using dynamic geometry software as well as ruler, compass, angle marker, dotted paper, isometric paper, pattern blocks, tangram, etc. take part in geometry subjects. Nevertheless, the fact that teacher candidates have not associated the geometry stimulus word with these materials and dynamic geometry software suggests that the teacher candidates have not adopted activity-based instruction. This is a significant effect of the fact that questions asked in the university placement test applied in our country are not in an efficacy style.

There are also "rhombus", "deltoid", "regular polygon", which can be included in the "Quadrilateral/Polygon" category; "diameter" which may be included in the "Circle/Disk" category; "vector", "line segment", which may be included in the "Basic concepts of Geometry" category; It is a striking finding that the important concepts such as "pyramid" and "sphere" which may be included in the "Solid Geometry" category are not given as answer words.

At the end of the research, it is seen that the candidate teachers' conceptual structures of the geometric concept are not academically sufficient, and they focus on the basic concepts when they associated geometry. In the literature reviewed, it is seen that when the level of knowledge, skill and thinking about the geometry of the students in all the educational stages from primary education to universities are examined, it is seen that the students do not have sufficient conceptual knowledge about the subjects in geometry (Cansız-Aktas and Aktas, 2011; Cansız-Aktas and Aktas 2012; Ergun, 2010; Toluk, Olkun, and Durmuş, 2002; Türnüklü, Gündoğdu-Alaylı, and Akkaş, 2013). The memorization of the features of the shapes, the inadequate presentation of the examples, and especially giving the typical image, cause them to construct limited constructions about the geometric concepts and therefore they do not understand the concept.

Hiebert and Levefre (1986) pointed out that the most basic feature of conceptual information is the richness of content in terms of correctness and relational. Having the correct information in terms of content requires knowing the basic knowledge and essential features of a mathematical concept. However, understanding of conceptual knowledge with only these dimensions is not sufficient. Because in mathematics, a single concept does not make sense on its own. When a concept is associated with other mathematical concepts then the concept becomes meaningful and the conceptual learning in the mind of the individual takes place.

As a result, the findings point out that the conceptual structures of the teacher candidates for geometry should be developed more consciously and purposefully.

The following recommendations can be given as a result of this study:

- Free Word Association Test that is used in different fields is not mostly used in mathematics field that has abstract concepts. For that reason, it is recommended that defining some different concepts in order to reveal the associations that students create in their mind about mathematical concepts, researches can be conducted.
- After lecturing, Free Word Association Test can be conducted with students in order to measure to see whether meaningful learning actualized or not and also whether the concepts associated to subject created in mind or not.
- It can be recommended to use write and draw technique besides free word association test in order to determine concept illusions and alternative concepts as well as determining the conceptual structures of students.

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