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Preservice primary teachers' three dimensional thinking skills

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Abstract

This study investigates primary school preservice teachers' abilities in relation to figures, one of the basic concepts of geometry, and more specifically, to name figures; to draw solid figures from their given corresponding nets and the nets from the solids; and to sketch a three-dimensional structure on the plane from a given perspective. The sample consisted of 62 year 1 and 119 year 3 students registered in the Primary School Education programme at Selçuk University, Education Faculty, Department of Elementary Education in the 2007-2008 academic year. The study had a survey research design and a test consisting of open-ended items was administered for data collection. Descriptive statistics and t-tests were used in data analysis. The results indicated that preservice teachers encountered difficulties in naming rectangular prism-square prism and rectangular pyramid-rectangular prism as well as in drawing these three-dimensional solid figures from their corresponding nets. Moreover, first year students achieved a higher average success rate than third year students. In their undergraduate studies, preservice teachers were not provided with opportunities to take part in the process via a curriculum which involves activities, materials and projects that develop spatial skills.

Keywords: Geometry; figure; three-dimensional structure; prism; pyramid; spatial ability.

1. Introduction

Geometry is a part of mathematics concerned with recognising geometric objects such as points, lines, planes, planar figures, space and spatial figures both on the plane and in 3-dimensional space and finding relationships among these objects; with defining geometric coordination; with explaining and specifying transformations; with using visual-spatial skills; with proving geometric propositions and with measures of geometric shapes such as length, angle, area and volume (Baykul, 2002; Baki, 2006). Many objects of daily life are related to a geometric concept. This prioritises geometry and its teaching. Besides, the importance of geometry is increased by the fact that children of primary school ages in particular, due to the intellectual developmental stage they are in, need to learn mathematical concepts via concrete tools and their visual representations.

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Suydam (1985) stated one of the aims of geometry teaching to be to develop of logical thinking skills (cited in Grouws, 1992). Another such aim is to improve spatial inference. It is also possible to come across expressions such as spatial ability and spatial reasoning in relation to spatial inference. Spatial ability includes reasoning via thinking skills, comparison, calculation and mental transformations of images (Casey *et. al.*, 2008). However, spatial inference could be regarded as a product of spatial reasoning.

Three-dimensional thinking has special significance in spatial reasoning. Three-dimensional spatial skills involve the ability to interpret the figurative knowledge of three-dimensional objects and to visualise these objects (McClintock, Jiang and July, 2002). Despite its significance, students and even preservice teachers have been observed to struggle with three-dimensional thinking. Parillo (2007) noted that students had difficulties in relation to volume and surface area, which could be considered within three-dimensional thinking skills, and that they were unable to learn these concepts. Likewise, Olkun (2007), in his study with participants from 4, 5, 6 and 7th grades of primary education in Turkey, observed that even 7th grade students struggled to find the number of cubic units in a given prism.

One source of the difficulties learners encounter in geometry could be teachers' knowledge of the subject area. Teachers seek to teach the subject to the learners using relevant teaching approaches, techniques, materials and activities based on their own education and experience. Therefore, identifying preservice teachers' subject knowledge and taking relevant measures for any inadequacies, if there are any; and designing a separate course for geometry and its teaching as part of the curriculum of education faculties could be a solution to some of the learner difficulties. Lundsgaard (1998) reported the immediate need to alter the current insufficient education offered to several young teachers both in schools and in teacher education institutions (cited in Barrantes and Lorenzo, 2006).

In learning geometry, which has an important status in the primary, secondary, and undergraduate curricula and in our daily lives, the teaching that takes place in the initial stage of primary education, where the concept is introduced for the first time, has vital importance. In the process of teaching and learning, teachers, who seek to utilise various concrete-abstract materials, activities and teaching techniques, would initially be expected to have a good grasp of the area themselves and possess a wide range of information and experience on the subject area.

The present study aims to identify preservice primary teachers' knowledge of three-dimensional solid figures, which have substantial importance in geometry, and to suggest relevant recommendations.

2. Methodology

2.1. Research design

In scientific research that aims to achieve and investigate the truth (Burr, 1995), it is essential to identify a sound research design in to answer the research questions in the best possible way. The aims of the present study included the identification of preservice teachers' current levels of naming geometric solid figures; drawing the nets of solid figures and the solids from their corresponding nets; as well as drawing a given three-dimensional structure on a two-dimensional plane within a certain perspective. This study had a survey research design as it seeked to describe a situation as it is in its own circumstances.

2.2. Sample

The sampling technique used in this qualitative research was purposeful sampling subsumed under the nonprobability sampling techniques, where individuals or events are studied as they are (Patton, 1990). The sample consisted of 62 year 1 and 119 year 3 students registered in the Primary School Education programme at Selçuk University, Education Faculty, Department of Elementary Education in the 2007-2008 academic year. The decision to include year 1 and year 3 students to the sample was based on the opportunity to test whether year 3 students, who had taken a mathematics teaching course, differed from year 1 students, who had yet to take the course, in terms of their skills in relation to the research aims. Accordingly, this would allow researchers to put forth recommendations grounded in the current situation of teacher education institutions regarding geometry and its teaching.

2.3. Data collection materials

For data collection purposes a test was developed and run by the researchers which consisted of open-ended items that required learners to draw geometric solid figures and their nets and to sketch three-dimensional structures within a two-dimensional perspective. Expert opinions were obtained and the teaching programme was drawn on in the design of the test. In order to ensure content validity of the test 4 educators and preservice teachers were consulted. The test was conducted within a certain sufficient time in the spring term of 2007-2008 academic year and the results formed the data for the study. Before the administration of the test, necessary explanations about the test items were made.

2.4. Data analysis

The data obtained from the test was qualitative and classification and analysis were conducted in two phases. Initially correct answers to the test items were coded as ‘1’ and wrong answers as ‘0’. In order to determine preservice teachers’ success in naming given solids and in drawing given solids and nets, descriptive statistics such as frequency and percentages were emloyed. In order to compare preservice teachers’ success in drawing the corresponding nets of given solids and the solids from the given nets dependent samples t-test was administered. Independent samples t-test was then conducted to compare the average success of year 1 and year 3 students. Secondly, participants’ naming of geometric solid figures used in the test items was then categorically identified.

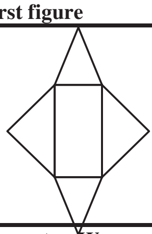
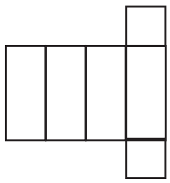
3. Results and Discussion

In this section statistical analyses based on the data obtained from the test items conducted with preservice teachers are presented and interpreted.

3.1. From the net to the solid figure

Correct answer percentages of 181 preservice teachers regarding the first figure which required drawing a rectangular pyramid from its given net and the second figure which required drawing a square prism from its given net are presented in Table 1.

Table 1: Correct answer percentages for the first item

		First figure			Second figure		
							
		Correct	Wrong	Total	Correct	Wrong	Total
Year 1	No	54	8	62	35	27	62
	%	87.1	12.9	100	56.5	43.5	100
Year 3	No	91	28	119	58	61	119
	%	76.5	23.5	100	48.7	51.3	100
Total	No	145	36	181	93	88	181
	%	80.1	19.9	100	51.4	48.6	100

As seen in Table 1, 87.1% of first year students were able to draw the rectangular pyramid correctly from its given net which is presented in the first figure. Correct response percentage of the third year students for the same figure was 76.5%. Correct response ratio in total was calculated as 80.1%. Thus, 19.9% of preservice teachers were not successful in drawing a rectangular pyramid, one of the basic concepts of geometry, from its corresponding net.

When the second figure is considered, 56.5% of first year preservice teachers could correctly draw a square prism from its given net, while 48.7% of third year students were successful in correctly drawing the solid. In total 51.4%

of students correctly drew the solid. Therefore, for this test item, preservice teachers' correct response percentage for square prism was lower than that of rectangular pyramid.

3.2. Naming the solid figures from their nets

The categories obtained from preservice teachers' naming of the nets of rectangular pyramid and square prism are provided in Table 2.

Table 2: Naming for the first item

First figure	Frequency	Percentage	Second figure	Frequenc	Percentage
Rectangle Pyramid	31	17.1	**Square Prism**	41	22.7
Pyramid	63	34.8	Rectangular Prism	89	49.2
No answer	39	21.5	No answer	33	18.2
Triangular Prism	25	13.8	Rectangle	4	2.2
Triangular Pyramid	6	3.3	Cube	3	1.7
Rectangular Prism	6	3.3	Prism	3	1.7
Prism	4	2.2	Cylinder	3	1.7
Cone	3	1.7	Vertical Prism	2	1.1
Rectangle	2	1.1	Square-Rectangular Prism	1	0.6
Rectangular area	1	0.6	Square	1	0.6
Vertical prism	1	0.6	Square-Rectangle	1	0.6

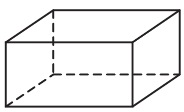
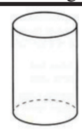
As presented in Table 2, 17.1% of preservice teachers correctly named the net presented as the first figure. Although 34.8% named the solid as a pyramid, they couldn't provide its particular name. On the other hand, a high percentage of 13.8 named it as a triangular prism.

For the second figure, 22.7% of the preservice teachers named the geometric solid correctly, 18.2% couldn't provide any answer at all, and a high percentage of 49.2 named it as rectangular prism.

3.3. From the Solid Figures to their Nets

Table 3 presents the percentages of correct answers given by 181 preservice teachers regarding the first figure which required drawing the net of a rectangular prism and the second figure which required drawing the net of a cylinder.

Table 3: Correct answer percentages for the second item

		First figure			Second figure		
							
		Correct	Wrong	Total	Correct	Wrong	Total
Year 1	No	51	11	62	51	11	62
	%	82.3	17.7	100	82.3	17.7	100
Year 3	No	94	25	119	100	19	119
	%	79	21	100	84	16	100
Total	No	145	36	181	151	30	181
	%	80.1	19.9	100	83.4	16.6	100

As shown in Table 3, regarding the first figure, 82.3% of first year students correctly drew the net for the given rectangular prism. However, 79% of third year students could draw the same solid correctly. In total 80.1% of students drew the solid figure correctly. For incorrect answers 20% in total could be considered to be a high ratio for rectangular prism which is a basic geometric solid figure. On the other hand, the higher success of first year students deserves attention.

As regards to the second figure, 82.3% of first year students correctly drew the net of the given cylinder while 84% of third year students correctly drew the net for the same solid. In total 83.4% of all students drew the net correctly. It is possible to argue that a 16% ratio of wrong answers in total is high for a cylinder which is again a basic solid figure in geometry.

Table 4 shows the categories regarding preservice teachers' naming of the given rectangular prism and cylinder.

Table 4: Namings for the second item

First figure	Frequency	Percentage	Second figure	Frequency	Percentage
Rectangular Prism	**135**	**74.6**	**Cylinder**	**147**	**81.2**
No answer	34	18.8	No answer	30	16.6
Rectangle	3	1.7	Cylinder prism	1	0.6
Cylinder	3	1.7	Cylinder Region	1	0.6
Cube	2	1.1	Elliptical Cylinder	1	0.6
Vertical Prism	2	1.1	Cone	1	0.6
Prism	1	0.6			
Square-prism	1	0.6			

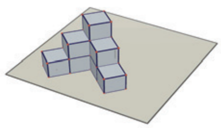
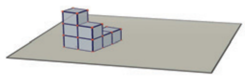
As the results presented in Table 4 with regards to the first figure shows, 74.6% of preservice teachers named the given geometric solid correctly, 18.8% couldn't provide an answer and 6.6% gave a variety of answers. Although the ratio of correct answers was high, given that the participants were preservice teachers the wrong answer ratio of 25% is something to be considered.

For the second figure, 81.2% of preservice teachers named the given geometric solid correctly, 16.6% couldn't provide an answer and 2.2% gave a variety of answers. Similar to the situation for the first figure, the wrong answer ratio of 19% is again something to be considered despite the high ratio of correct answers.

3.4. Transformation Between Dimensions

The distribution of correct and wrong answers to the third item in the test, which asked participants to draw two three-dimensional structures composed of cubic units onto a two-dimensional plane from a certain angle, are presented in Table 5.

Table 5: Correct answer percentage for the third item

		First figure			Second figure		
							
		Correct	Wrong	Total	Correct	Wrong	Total
Year 1	No	12	50	62	10	52	62
	%	19.4	80.6	100	16.1	83.9	100
Year 3	No	3	116	119	27	92	119
	%	2.5	97.5	100	22.7	77.3	100
Total	No	15	166	181	37	144	181
	%	8.3	91.7	100	20.4	79.6	100

Regarding the first figure, 19.4% of first year students, 2.5% of third year students, and 8.3% of students in total drew the given three-dimensional structure onto a two-dimensional plane correctly. As shown in Table 4, the percentages for the second figure were 16.1%, 27%, and 37% respectively.

3.5. Comparison of Preservice teachers' Averages in Terms of their Success in Drawing the Corresponding Net of the Given Geometric Solid Figures and the Solid Figures from their Nets

Dependent samples t-test was administered in order to compare preservice teachers' total scores of their test results in relation to the first item, which asked participants to draw geometric solid figures from their given nets, and to the second item, which asked participants to draw the nets of given geometric solid figures. T-test analysis results are presented in Table 6.

Table 6: Comparison of the firs and second items

	N	$\bar{x}$	Sx	t
Item 1	181	1.31	0,67	-5,384
Item 2	181	1.64	0.60	

The t value was statistically significant at .05 level as presented in Table 6 (t=-5,384, α=0,05). This suggested that preservice teachers were more successful in drawing the net of a given geometric solid figure than drawing the solid from its corresponding net.

In order to compare the average success of first and third year students, independent groups t-test was administered using total scores. T-test results are presented in Table 7.

Table 7: Comparison of first and third years

	N	$\bar{x}$	Sx	t
Year 1	62	3.44	1.12	1.67
Year 3	119	3.13	1.15	

T value, as presented in Table 7, was not significant at .05 level (t=1.67, α=0,05). It is possible to conclude that the average success levels of first and third year students were not significantly different.

4. Discussion and Conclusions

Mathematics is a symbolic language of patterns, relationships, and structural models which include abstraction and generalisation; and involves skills such as calculation, reading tables and graphs, reasoning, problem solving and visualisation (Polya, 1945). Hence mathematics is a crucial element of the updated primary curriculum.

Learning approaches which have changed in the recent years assign various roles to teachers and students in the classroom. Learners require teacher guidance in their active participation to the learning process with activities, materials, and projects. In this context, teachers should be able to internalise the acquisition and practice of their subject area knowledge.

Geometry is one of the most important topics learners are expected to acquire in primary and other levels of education. Within geometry, the abilities to see basic geometric figures and two/three-dimensional figures from different perspectives and to produce and discover figurative patterns require learners to possess certain skills and teachers to ensure that their learners acquire these skills.

One of the factors that affect success in geometry and geometric problem solving is spatial ability (Battista, 1990). Spatial ability which is also known as the ability to use spatial images is a prerequisite for a variety of topics in mathematics and geometry. Due to strong connections between geometry and spatial ability, spatial ability was included into the geometry programme (Clements and Battista, 1992). For instance, American National Mathematics Teacher Council (NCTM, 2000), as part of the standards it identified for geometry programmes, emphasised the necessity for learners to be able to recognise spatial relationships and use spatial reasoning in problem solving from pre-school education until year twelve.

Two discrete sub-dimensions of spatial ability are the abilities of spatial visualisation and mental transformation (Clements, 1998). While spatial visualisation is defined as the ability to mentally transform and use the image of an object or part of an object, mental transformation is defined as the ability to understand the relationship among the elements of a structure and the new structure produced as a result of changes in elements or of personal perspective.

The findings of the present study indicated a substantial ratio of wrong drawings in obtaining the figures from their given nets and the nets of given figures of basic geometric concepts. Specifically when the two conditions were compared, learners were observed to struggle more in drawing solid figures from their nets than the nets of given solids. Possible reasons to this could include the absence of a specific course dedicated to geometry in the undergraduate education of preservice teachers; when studying geometric figures in previous education, being primarily introduced to solid figures before their corresponding nets; and having less practice in drawing the solid figure from its corresponding net.

Preservice teachers demonstrated a low performance in drawing rectangular prism-square prism and rectangular pyramid-rectangular prism from their given nets and naming these figures. This could signify an insufficient development of learners' spatial visualisation and mental transformation skills. The visualisation skill, which is a kind of reasoning based on mental images (Kosslyn, 1994), is an objective that preservice teachers should improve as it is a phenomenon teachers convey to their students. Preservice teachers' low performance was not only observed in drawing geometric figures but also in naming them. This could be the result of an incompatibility between geometric concepts, spatial visualisation, mental transformation and the names given to these as well as an inability to establish a logical relationship between the figure and its name. Another possible reason could be inadequate practice provided via activities and exercises where similarities and differences among figures could be observed. The highest success rate was achieved in naming the cylinder perhaps due to its distinctness from the other figures used in the present study in terms of the existing similarities among these figures. The lowest success rate was, thus, obtained in naming square prism.

Preservice teachers obtained a considerably low success rate in representing three-dimensional structures on a two-dimensional plane. This finding suggests that their three-dimensional thinking skills were relatively insufficient. This could be due to preservice teachers' previous education based on the former curriculum and also to not having practice using activities that develop three-dimensional thinking such as cubic units.

In total first year students had a higher average than third year students on the test items. Despite not being statistically significant, the different still deserves an explanation. Plausible explanations of the insignificant difference include an absence of a separate course on geometry and its teaching as well as the general tendency to exclude concepts of geometry in mathematics courses. Moreover higher average success rates of first year students than that of third year students, even if not statistically significant, could be due to the probable recency of first year students' knowledge of the concepts of geometry who had just graduated from secondary school and registered to their undergraduate degree.

In conclusion, the low level of knowledge, even in the basic concepts of geometry, of preservice teachers, who constituted the sample of the present study and who were the products of traditional teaching practices, emphasises the necessity to include courses on geometry and its teaching into the curriculum in teacher education institutions.

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