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Parallelogram Conceptions and Misconceptions of Students Who Study to Become Teachers in Pre-Primary and Primary Education

KEYWORDS: conception, parallelogram, preprimary and primary teacher training, rectangle, rhombus, quadrilaterals

Katarína Žilková

Associate Professor, Faculty of Education, Catholic University in Ružomberok, Slovakia

ABSTRACT *It is necessary to check the progress and assess the knowledge in the process of improving the quality of mathematical preparation of prospective students who study to become teachers. Foreign and domestic studies often point out a relatively low level of knowledge of geometry. The paper discusses some misconceptions about parallelograms and their visualizations, which were found in students who study to become primary education teachers.*

INTRODUCTION

The study of mathematical objects focussing on improving knowledge of plane geometric shapes and their properties is part of the mathematical education of students who study pre-primary and primary education.

Based on available scientific studies it can be concluded that assessing the level of geometric knowledge of pre-primary and primary future teachers in the education process and the related diagnosis of potential distortions in the cognitive process is an important research problem. Specifically, Marchis (2012) studied the diagnostics of cognitive deficiencies of convex quadrilaterals in Romania. She put together the most common problems associated with creating every quadrilateral group definition. Contay and Duatepe Paksu (2012) from Turkey had similar research objectives and they published a study, which focussed on the level of understanding in relations between deltoids and squares. In Scotland, Fujita and Jones (2006) analysed the level of knowledge in the same target group of respondents, focusing in particular in the detection of relations among the respective groups of quadrangles. All the studies mentioned above consistently note the relatively low level of knowledge on the properties of quadrilaterals in the pre-primary and primary education of future teachers.

Our subjective and objective long-term observations of students with insufficient knowledge of fundamental properties of convex polygons resulted in research of the level of geometric knowledge of future teachers in pre-primary and primary education. The diagnostic and identification of problems or more precisely, distortions in the knowledge of students were especially the aim of determining the level of geometric knowledge, which is essential for a successful re-education of potential misconceptions.

Objectives of the study

The main objective of the research was to determine the level of knowledge of students on the properties of convex quadrilaterals. Identifying and understanding the convex quadrilaterals and their properties was part of the research. This was the most problematic part for the students. This paper describes the research results of students understanding of parallelograms. The objective was to determine whether students know the basic properties of parallelograms and understand the relationship among different groups of parallelograms. Specifically, we investigated the conception and misconceptions of squares, rhombuses, rectangles and parallelograms.

Population of the study

The sample included first to third year students of the Bachelor study program majoring in pre-primary and primary education at a specific faculty of teaching at the Slovak University from 2011 to 2013. This means that these were at least successful secondary school graduates. Therefore these students should have mastered the geometry curriculum at secondary school. The sample included 159 respondents. In terms of gender distribution, we can conclude that the number of men involved in the research were negligible and in the context of the research focus it was not necessary to distinguish the gender. Given the sample, the research results will be interpreted and applicable only to the group observed in these years.

Research Method

The research methods to obtain the data were in the form of a test. The test was carried out using pen and paper. The respondents selected and chose the correct answers. Evaluation of the responses is implemented in the following way: for every correct answer the respondent received 1 point, for an incorrect answer they received 0 points. This was to trace the implication relationships among responses to every question and determine their difficulty level. The content of the test was conceived in such a way so that it covered the basics of quadrilaterals only at the level of an elementary school graduate. Mr. and Mrs. Van Hieles levels theory of geometric understanding was used as an initial theoretical framework. From this perspective, the test has been designed so it covered the first three Van Hiele levels, i.e., the level of visualization, the level of analysis (description) and the abstraction level (relationships).

Analysis and interpretations of data

The CHIC program statistical implication analysis was used for processing of the test results. We searched for relationships among the students' answers because we wanted to find out if they have fixed and stable knowledge about squares, rhombuses, parallelograms and rectangles.

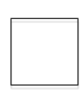
There were 8 questions in the test in which the student should explicitly express the basis properties of parallelograms. These were the questions P_3, P_5c, P_6, P_9, P_11b, P_12, P_13b, P_14c:

P_3: Is a rectangle always a parallelogram?

a. yes
b. no

P_5: Which words describe the shape?

a. rhombus
b. quadrilateral
c. parallelogram
d. rectangle



P_6: Parallelogram is ______ rectangle

a. always

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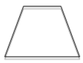
b. sometimes
c. never

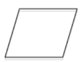
P_9: Square is ________a parallelogram
a. always
b. sometimes
c. never

P_11: Which words describe the shape?
a. rectangle
b. parallelogram
c. quadrilateral
d. trapezoid

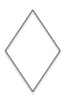


P_12: Is parallelogram always a rhombus?
a. yes
b. no

P_13: Which words describe the shape?
a. quadrilateral
b. parallelogram
c. square
d. rectangle



P_14: Which words describe the shape?
a. square
b. kite
c. parallelogram
d. rectangle



A significant implication relationship can be observed between student responses to items P_3 and P_9 (Fig.1). If a student knew the correct answer and chose that the rectangle is always a parallelogram then he also knew with a high significant implication intensity the correct answer that a square is always a parallelogram (Fig. 1). The fact that a square is always a parallelogram was mastered by 87% of students. A considerably smaller success rate is shown between the relation rectangle -> parallelogram in question P_3 (44%). Thus, we conclude that if a student knows that the rectangle group includes squares and rectangles, and he or she knows that these planar shapes are parallelograms then he or she can also understand the relationship between square -> rectangle.

Figure 1: Hierarchical implication graph - the concept of a parallelogram (questions are ordered from left to right 3, 9, 6, 11b, 12, 14c, 13b)

There is another implication relationship (although not a significant one) between the responses to the questions P_14c and P_13b. We expected the significance of this relationship, because these are essentially identical questions. The only difference is that in the question P_14c the image of a parallelogram is positioned in an unusual way. The results of the test have confirmed that the position of this shape affects its recognition. More difficult question (P_14c in comparison with P_13b) is the one in which a planar shape is positioned in an unusual position. Success rate for P_14c was 77% and for P_13b was 87%. The success rate is considered to be very low and the difference between them points out to the fact that according to Van Hiele the levels of understanding of geometric figures, i.e., 77% of students are only at the first level of analysis - the description.

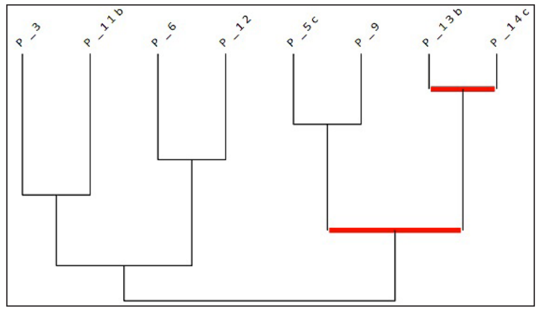


Figure 2: Graph, which show similarity in responses - the concept of a parallelogram (questions ordered from the left 3, 11b, 6, 12, 5c, 9, 13b, 14c)

The graph of similar responses (Fig. 2) shows a significant similarity between the responses to the question P_13b and P_14c, which we mentioned above. Lines in-between the questions in the graph (Fig. 2) determine similarities that can be found among the answers. The higher the line is placed in the chart, the more similarities there are in the answers. Similarities highlighted in red are significant.

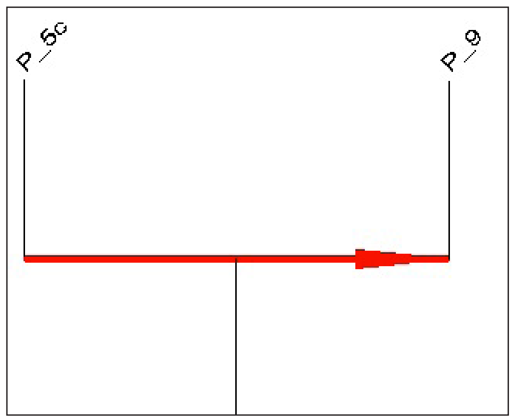


Figure 3: Implication graph - the concept of a parallelogram (question 5c, 9)

More similar responses can be found between items P_5c and P_9. These are the same question from a content point of view, but one question is asked through pictorial demonstrations and the other is ask verbally. The success rate for these questions suggests that it was much easier for the students to answer the one without a picture. Therefore we decided to determine whether there is an implication relationship between the answers to these questions. The implication hierarchical graph (Fig. 3) confirms the relationship between implication between P_5c and P_9.

We assume that students have formed a mental image of parallelogram in such a way that parallelograms are usually presented in textbooks of mathematics - in general position and shape. Therefore, the image of a square would not induce in students a connection with parallelograms. Figural mental imagination may therefore affect the accuracy of the answers. However, we can not induce the general conclusion in this case, because similarities among the different properties in square -> parallelogram relationship are not substantial.

If we look at the graph of similarities (Fig. 2) as a whole, we find that students responded in a similar ways to all the questions related to the concept of a parallelogram. Significant similarity in the responses, and thus understanding the concept of a parallelogram showed responses to the questions P_5c, P_9, P_13b and P_14c.

In the further analysis of responses to parallelograms we compared the answers to the questions in which an image of a par-

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allelogram occurred and we asked for its categorisation into other categories. We selected questions P_4, P_13, P_14 and we graphed them in the following implicative graph (Fig. 4).

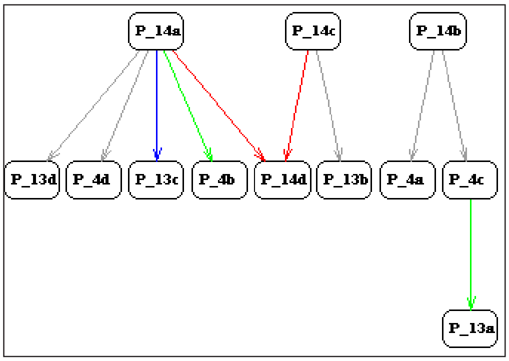

Figure 4:The implicative graph - the concept of a parallelogram (97, 90, 80, 70)

Looking at the implied relationship, it is clear that the easiest question P_13a relates to the most general category or more precisely it relates to an inclusive relationship parallelogram -> quadrangle. The hardest questions P_14a, P_14c and P_14b are all part of the task in which the image is displayed in an unusual way. This fact also suggests that figural mental imagination in students about quadrilaterals are normally associated with quadrilaterals being displayed in standard positions.

Major findings of the study

There were also additional data analysed which related to sub-groups of parallelograms. Particularly, we analysed the students' conceptions and misconceptions of squares and rectangles. The most important outcomes of the research include:

- Imagining the concept of a parallelogram and its characteristics are similar in all the answers to the questions concerning the parallelogram. Thus, the understanding of this concept is relatively well understood by students. The fact that ideas are firm does not mean they are correct. The correct understanding of the questions correlates with parallelograms being shown in the standard orientation. It has been shown that images, which show a parallelogram in a non-standard position are more difficult for students to understand. There is a similar situation with understanding of a square. The inclusive relationship between the category of squares and parallelograms is not usually problematic for students.
- Despite the fact that the students' responses in the understanding of rectangles are similar, the success rate in solving rectangle exercises was not as high as we expected. It has been shown that it is not such a big problem for students to categorise squares as rectangles, but it is a problem to categorise rectangles as parallelograms. The relationship square -> parallelogram is simpler than the relationship rectangle -> parallelogram. Based on this we conclude that rectangle is a problematic term and some respondents imagined more shapes than rectangles and squares. This fact has been also documented by other partial testings of students. It often happens that students consider right triangles and rectangular trapeziums as a rectangles (Fig. 5).

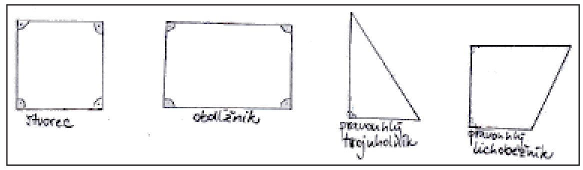

Figure 5: Misconception of rectangles

- Students do not see the correlation between rhombuses and squares. We assume that the problem is related to an inconsistent theoretical definitions of these terms in various Slovak textbooks. Squares and rhombuses are sometimes defined as disjoint classes and according to some definitions squares are viewed as a special case of rhombuses.
- Comparing the success rate and interconnections among responses to questions without pictures and questions with pictures we can conclude that it was easier for students to answer questions with pictures than without pictures, in which they had to create figural imagination by themselves.

Due to the design of the test, which included questions only on Van Hiele visualization level of analysis and abstraction, we can conclude that future primary and pre-primary teachers who are current students, had problems to solve exercises on an analytic level, or more precisely on a descriptive level (the object was rotated in a non-standard way) and also students had a problem with the exercises at the abstraction level or more precisely making connections among each category (categorising each object into a category based on its characteristics). A significant lack of knowledge does not allow students to actively create definitions, not even for a relatively simple plane geometric objects (commonly used in elementary school geometry).

Comparisons and Conclusions

The obtained research data uncovers the level of knowledge in the group of future pre-primary and primary education teachers in the area of convex quadrilaterals or parallelograms and their properties. As we have mentioned above, this research group was not a representative sample and therefore we can not reliably draw conclusions from this research and we can not generalise. The data was processed and collected over a period of three years at a faculty of the Slovak University. The aim was to contribute to the debate about the level of future teachers' knowledge and the data is to some extent an indicator of a students´ knowledge level.

In comparison with results from foreign studies, we can conclude that the majority of Slovak students studying at the faculty is on the first analysis and description level of Van Hiele theory and an insignificant part of them is on the second levels of abstraction and relationships. In many cases, students fail to recognize a geometric shape (particularly in a non-standard orientation), and also do not know very well the properties of a convex quadrilateral. The knowledge of these properties is a prerequisite to the correct categorization. For these and other reasons, it is appropriate to recommend to use such activities in the preparation of future primary education and pre-primary teachers which would purposefully and actively correct mental understanding of geometric concepts and objects in these students. The knowledge acquired from the research activities and subjective observations shows a need for greatly enriching content and didactic points of view in geometry in the preparation of future pre-primary and primary education teachers.

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