

# DETERMINANTS OF PRIMARY MATHEMATICS EDUCATION – A NATIONAL AND INTERNATIONAL CONTEXT

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**ABSTRACT.** The results of the international survey TIMSS indicate average or even below average performance of Slovak students in mathematics compared with the OECD countries and other partner countries. What are the factors that determine the mathematical education in primary school? During the last twenty years, teaching mathematics in Slovakia was affected by the two curricular modifications. A new curriculum for the year one of primary school was introduced in 1995 followed by the State Program Education for primary stage in 2008. They brought, on the one hand, a certain reduction in the scope of traditional mathematical curriculum in the first four years of primary school but, on the other hand, the mathematical instruction was enriched by some new topics. The teacher is an equally important factor, since he is responsible for implementation of mathematical education in school. Undergraduate training of prospective teachers - elementarists - builds on the mathematical training which they received in previous stages of education. In this view, it is important to consider the type of secondary school at which a teacher trainee had studied. Comparative analysis of the situation in Slovakia and abroad can yield new ideas to enhance the mathematical education.

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## Content of Mathematical Education in Primary Stage in Slovakia

There have been no significant changes in the content of primary mathematics over the years in Slovakia- it appears so at first sight. After closer analysis, however, a different conclusion is drawn. The range of mathematical knowledge that the pupil should acquire at the end of the fourth year of primary school has been since 1989 reduced but at the same time enriched with some new portions of knowledge. (More details in [8].)

The period since 1989 can be divided into three stages:

- before 1995;
- from 1995, when the new curriculum for the first year of primary school entered into force, to 2008;
- from 2008, when State Program of Education for primary stage was introduce, up to the present.

Mathematics has been in terms of the number of hours per week delivered as follows:

Number of moth closess non-model	Year						
Number of main classes per week	1.	2.	3.	4.			
before 1995	4	5	5	5			
before 2008	4	5	5	5			
after 2008	4	4	3	3			

(The weekly number of classes after 2008 refers to a minimum required by the state curriculum. It may differ depending on the school curriculum.)

The analysis of the last twenty years of mathematical education in primary school in the areas of arithmetic and algebra shows that these areas of mathematics were affected by some reductions in their content with respect to the first stage of education.

The pupil upon completion of year four of primary school in the period before 1995, had acquired the range of natural numbers to million and over million and he knew, within this range, how to add, subtract and multiply (both from memory and in written algorithm); he knew how to divide with a single-digit divisor using written algorithm; knew Roman numerals; could read and write fractions (notions as fraction bar, numerator and denominator).

After 1995 there was little change regarding the area of arithmetic and algebra. The content remained unchanged, except for fractions. The curriculum from 1995 [10] did not explicitly mentioned fractions; the tasks on propedeutics of fractions, however, appeared in the textbooks from this period. In the section of recommended expanded curriculum some new topics were offered as a possibility to enrich mathematical education, for example some exercises on multiplication with combinatorial motivation or calculations performed on the calculator.

But quite different situation occurred after 2008, when the state program of education for primary stage entered into force. A hypothetical situation may happen that a pupil who completes first fourth years of primary school under the new program would know the numeric range to only 10 000, would multiply and divide only within multiplication table, would not master written algorithms to neither multiply nor divide multi-digit numbers by a single-digit divisor and would not know Roman numerals nor concepts related to fractions. On the other hand, the thematic unit Solving Applied Tasks and Tasks which Develop Specific Mathematical Thinking offers in each grade additional topics for enriching instruction in mathematics.

From the above it is evident that the scope of primary stage arithmetic and algebra has been reduced and that the pupil progresses to the 2<sup>nd</sup> stage (lower secondary stage) of basic school with less knowledge to be able to build on in the following cycle of mathematical education. Reduction of the curriculum content, however, did not result from its difficulty for the junior school age pupil, but was the result of a reduction in the number of classes prescribed for primary stage mathematics.

Also, the body of knowledge from geometry prescribed for the first fourth years of primary school was reduced between 1995 and 2008 (see [10]). Compared with the previous period the student did not have to address the relative position of two lines in a plane, did not work with the concepts of intersecting lines, the intersection of two intersecting lines, parallel lines, parallelograms; angle (side, vertex, bisector). He might not have met with graphical sum, difference, multiple line segments, area of rectangles (only in the recommended expanded syllabus) or units of area.

Further reduction of the geometric syllabus in the primary stage since 2008 has been brought by the *State Program of Education, Mathematics (Learning Area: Mathematics and Work with Information), Annex ISCED 1* ([9]). The pupil who completes first fourth years of elementary school after 2008 is expected to know only the following notions from geometry: point, line segment, circle (centre, radius), circle, square, rectangle and quadrilateral. He will not necessarily know the terms as perpendicular, right angle and will not draw perpendicular lines or rectangles using a drafting triangle. Constructing formations from blocks according to a pattern, picture or plan and drawing plans for constructions is a new topic introduced by the curriculum. (The above topic, however, appeared in the primary mathematics textbooks in the period between 1995 - 2008 even though it was not explicitly mentioned in the curriculum [10]).

The analysis of the portions of geometry included in mathematical education in primary school in the previous twenty years shows that the given area of mathematics was affected by a significant limitation of its content.

From the given analysis it is evident that the scope of geometry is significantly reduced in the curriculum and that the pupil possesses rather limited range of knowledge to build on in geometry at the outset of the 2<sup>nd</sup> stage of basic school. Reduction of the geometric content of the curriculum, however, did not result from its difficulty for the junior school age pupil, but analogously to the fields of arithmetic and algebra, it was due to a reduction in number of mathematical classes prescribed for primary stage.

Before 1995, the mathematical education in primary school focused on topics from arithmetic, algebra and geometry. No additional or expanded curriculum was explicitly mentioned in the educational materials. Thus, topics (or individual tasks) from other areas of mathematics did not occur, in most cases, in teaching mathematics in the 1<sup>st</sup> stage of basic school.

The curriculum of 1995 [10] divided the content of mathematics into basic and advanced categories. The number of classes designated for basic content did not take up the full capacity of classes intended for the given year. Surplus classes could then be used to reinforce the thematic units of the basic curriculum, which was the case in majority cases of the teaching practice. Alternatively, they could be used to cover the topics from the expanded curriculum. In such case, the following topics from the recommended expanded curriculum were included into the teaching process: introduction to the syllabus of logic, equations, number line - representation of numbers, indirectly formulated verbal tasks, unknown in the expression, sorting geometric shapes according to their characteristics, developing functional thinking, the unit of length in the past, notation of the expansion of the natural numbers in decimal system, more difficult inequations, verbal tasks with non-empty intersection, constructing a triangle given the sides, determining the points on the square grid, converting the mixed units, numeric performances on calculator, approximate counting with rounding numbers, sorting by two properties, the area of triangle (square, rectangle) in square grid, drawing a square (rectangle) using drafting triangle.

A single topic from the other areas of mathematics, included in the recommended expanded curriculum, was solving tasks on multiplication with combinatorial motivation. The mathematical textbooks for the first to fourth year of basic school contained various combinatorial problems and elementary tasks from graph theory (connected line graphs, mazes, colouring maps). [7]

Different approach to the content of mathematical education was chosen in 2008 (according to [9]). There is a thematic unit Solving Applied Tasks and Problems Developing Specific Mathematical Thinking for each year of primary stage. It is not included as an extra or optional part of the curriculum (as a recommended expanding curriculum in the previous period). It is an integral part of mathematical curriculum in the first fourth years of basic school and is listed in recommended content and performance standards.

The range of mathematical education in the first stage of basic school has been extended by some new topics (even from the fields other than arithmetic, algebra and geometry) which were absent in the previous period: propedeutics of probability (probabilistic games, experiments and observations and the types of events), collecting and grouping data, creating tables and bar charts, propedeutics of arithmetic mean and combinatorial problems (in greater extent). This enrichment of mathematical instruction by new topics (as early as in the primary stage) has brought a greater dimension for applied mathematics and was probably a reaction to the content of mathematics that occurs in international surveys of mathematical abilities.

# **Prospective Teachers for Primary Education**

In an environment of tertiary education facilities (teacher training faculties) which prepare teachers for primary education, several surveys were conducted in the last twenty years in which the mathematical abilities of students –trainees were surveyed from different perspectives. Each of the survey's results were analysed with regard to the type of secondary school completed by the trainee.

Academic year 1997/1998, Faculty of Education University of Prešov, breakdown by the number of students who completed the particular type of secondary school (after [6]):

- Grammar School 52 %
- Secondary Pedagogical School 23%
- Secondary Trade School 22%
- Secondary Vocational School 3 %

Academic year 2006/2007, Faculty of Education University of Prešov, breakdown by the number of students who completed the particular type of secondary school (after [5]):

- Grammar School 24 %
- Secondary Pedagogical School/Academy of Education and Social Work 27 %
- Secondary Trade School 42 %
- Secondary Vocational School 7 %

Academic year 2008/2009, Faculty of Education University of Prešov + Faculty of Education UMB in Banská Bystrica + Faculty of Education, Trnava University (after [4]):

- Grammar School 24 %
- Secondary Pedagogical School 36 %
- Secondary Trade School 29 %
- Secondary Vocational School 7 %

Academic year 2013/2014, Faculty of Education, University of Prešov (according to the admitted applicants's data):

- Grammar School 32%
- Secondary Pedagogical School 25 %
- Secondary Trade School 43 %

The above data provide a partial view on how the composition of students - prospective teachers changed over twenty years according to the type of completed secondary school. The types of secondary schools did no fully comply in each of the individual surveys. However, certain trends can be identified:

- drop in interest for primary teacher training among grammar school graduates,
- stable number of secondary pedagogical school graduates (or educational and social academy),
- increase in the number of graduates of secondary trade schools or secondary vocational schools.

Trainees' mathematical knowledge, skills and experience with which they come to the faculty are important factors for their further mathematical preparation. These are partly contingent to the curricula of mathematics at various secondary schools. Gerová [2] indicates the proportion of mathematics lesson:

	Grammar School			Secondary Pedagogical School/ AoEaSW				Business Academy				Secondary Vocational School, 4-year				
	1.	2.	3.	4.	1.	2.	3.	4.	1.	2.	3.	4.	1.	2.	3.	4.
Number of Classes before 2008/9	4	4	3	3	3/2	3/2	2	-	3	3	2	2	2/3	2	2	2/3
Number of Classes after 2008/9	4	4	3	1	2	2	2	-	3/2	3/2	2	-	2	2	1/2	1/2

(Weekly hours may vary depending on the type of secondary schools and its school curriculum.)

The above facts, the decrease in interest among grammar school graduates in teacher training for primary stage and the decline in the number of math classes in secondary schools are factors that must be taken into account when designing an undergraduate training of prospective teachers in the area of mathematics.

Within the grant project VEGA Analysis of Mathematical Preparation of Students of Preschool and Elementary Education from the Perspective of the Development of Mathematical Literacy the research was conducted (the sample included three faculties in Slovakia) which showed that the students at the outset of their study had major deficiencies in mathematical abilities. This finding does not provide a good starting base indeed for subject-specific training of prospective primary teachers in mathematics.

## Achievements of Slovak Pupils in the TIMSS survey

TIMSS (*Trends in International Mathematics and Science Study*) survey examines in four-year cycles the knowledge of pupils in mathematics and science. Slovak pupils were involved in testing at the end of the year one of basic school between 2007 and 2011 attaining the following results:

2011	Average Score/Ranking of SR										
51 countries			Content		Content	Domain	Content				
	Overall	Results	Don	nain	Geometr	ic Shapes	Domain Data				
2007			Nun	nber	and M	easures	Display				
36 countries	2011	2007	2011	2007	2011	2007	2011	2007			
Slovak Republic	507/25.	496/21.	511	495	500	499	504	492			
OECD Countries Average	521	-	520	-	522	-	525	-			
EU Countries Average	519	-	519	-	519	-	521	-			
TIMSS Average Scale	500	500	494	500	484	500	484	500			

The results of 2007 inform that the Slovak pupils rank statistically between the 16<sup>th</sup> - 25<sup>th</sup> place within in the countries (36) involved in TIMSS 2007 survey. Comparing the achievement of Slovak pupils with the average of the European Union (EU) countries and/or OECD (Organisation for Economic Co-operation and Development) countries, position of the Slovak Republic was below the average of these countries.

In the study by TIMSS 2011 – Mathematics, Slovak students achieved the result significantly below the average of the participating EU countries as well as OECD countries. It was the  $25^{\text{th}}$  position out of the 51 countries in the ranking. The comparison of the changes in the results over the time - trends in pupils' achievement - shows that from a statistical point of view the result of the 2011 is comparable with that of the 2007 study. ([1], [3])

It would not be appropriate, however, to view the achievement of Slovak pupils and the conclusions resulting from it as a totally negative image of mathematical education in the primary stage in Slovakia. The TIMSS tests contain some tasks that are difficult for the Slovak pupils from the aspect of content because they encounter similar tasks only at the second (lover secondary) stage of basic school.

In 2007 and 2011, there were tested Slovak pupils whose mathematical education at the primary level was delivered after the curriculum of 1995 [10]. Another TIMSS study will be implemented in 2015. If Slovakia participates, it will concern the students who will be educated in the 1<sup>st</sup> stage of basic school complying with the State program of Education. It will be interesting to explore which changes in primary mathematical education would have a greater impact on the achievement of Slovak pupils. Whether it is of any importance that the reduction of traditional curricular content and the reduction in the number of mathematical classes would be reflected in the results of Slovak pupils by that their achievement, in an international comparison, would be worse than in 2007 and 2011. Or, on the other hand, would the inclusion of new topics into mathematical education in primary school contribute to improved results of Slovak pupils.

## Conclusion

What are the external factors that influence mathematical abilities of students at the end of the primary stage of education? Firstly, it is the content of mathematical education which is defined in the curricular documents.

Very important (and perhaps the most important) factor seems to be the teacher. His professional and educational competences significantly determine the educational achievements of pupils in general and certainly in mathematics. In this context, it is thus crucial what the undergraduate mathematical training of prospective teacher is like.

Non negligible factor is a societal perception of mathematical education. If a child in the family, neighbourhood and mass-media encounters negative attitudes towards mathematics it is then very difficult to implement efficiently the process of teaching mathematics in school.

One approach that could make teaching mathematics more attractive is to search for and find some positive examples of practice not only in Slovak context but also from foreign countries. Given the ranking of individual countries in the TIMSS study, it is imperative to analyse mathematical education in those countries where students achieve good results in mathematics and to compare foreign and Slovak curricular documents for primary mathematics so as to get inspiration and interesting suggestions.

All effort should be directed towards optimising mathematical abilities of students. But, perhaps even more important aspect is that the attitudes of pupils towards mathematical education were positive at the end of the primary stage of school. That would be the best investment for further education.

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