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MATHEMATICS ACHIEVEMENT OF SERBIAN EIGHTH GRADE STUDENTS AND CHARACTERISTICS OF MATHEMATICS CURRICULUM

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Abstract. This paper considers the main results and some educational implications of the TIMSS 2003 assessment conducted in Serbia, in the fields of mathematics achievement of Serbian eighth grade students and the mathematics curriculum context of their achievement. It was confirmed that Serbian eighth graders have made average scale score of 477 points, and with this achievement they are placed in the zone of intermediate international benchmarking level. The average mathematics achievement of the Serbian eighth graders is somewhat above the average international mathematics achievement. The best result was achieved in the content domain of "algebra", and the lower result in the content domains of "measurement" and "data". In the defined cognitive domains the Serbian students have achieved the best results in "solving routine problems" and "knowing facts and procedures", and the weaker result in "reasoning". Statistically significant difference was found in the mathematics achievement between girls and boys in the Serbian TIMSS 2003 sample, so the girls' average scale score was 480 points and the same value for the boys was 473 points. The achieved results raise many questions about the contents of mathematics curriculum in Serbia, its quality and basic characteristics of its implementation. These results can be eligibly used to improve the mathematics curriculum and teaching in Serbian primary school.
Key words: TIMSS 2003, achievement, content domain, cognitive domain, gender differences, mathematics curriculum.

The TIMSS 2003 (Trends in International Mathematics and Science Study) is the third circle in continuing of an international assessment of fourth and eighth grade students in the fields of mathematics and science teaching as well as their achievement dependence of the mathematics and science curriculum contents, school context for learning and instruction, and home context for learning. Three circles of the TIMSS investigation have been carried out so far, that is, every four years, in 1995, 1999 and 2003, and the next circles will be organized in 2007, 2011 and so on. The TIMSS 1995

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investigation circle was originally named as the Third International Mathematics and Science Study, and the TIMSS 1999 as TIMSS-R (Repeat). The TIMSS 2003 was conducted in 49 countries worldwide, and there is a tendency to involve new participating countries in the assessment. It can be concluded that the TIMSS investigation is becoming a kind of a worldwide project, in the true sense of the word, in the field of students' achievement assessment in the mathematics and science teaching.

A wide array of information was collected by the conducted TIMSS 2003 investigation. The information was chosen about the homes, schools, classrooms and the mathematics and science teachers of the involving students, and also about the mathematics and science curriculum for each participating country. In the TIMSS assessment there is a tendency to interpret students' mathematics and science achievement against basic characteristics of curriculum contents, characteristics of school mathematics and science teaching and school environment and its educational influence, and in respect of the characteristics of home context for learning mathematics and science. Pieces of information were summarized and presented in the international mathematics report (Mullis *et al*., 2004) and the international science report (Martin *et al*., 2004). The rank of each TIMSS 2003 participating country is expected to be a relative one, because it depends of a complex group of different factors that teaching and learning of mathematics are influenced by, and a country's rank on the international scale is not a complete explanatory index of each TIMSS 2003 participating country's achievement in mathematics or science. The influencing factors of achievement in the field of mathematics are different and always specific for each participating country. Consequently, mathematics achievement depends mainly of the following factors: mathematics curriculum contents, school equipment, use of computers and calculators in teaching and learning, mathematics teachers' preparation and experience, application of some methods in mathematics teaching, students' motivation and their level of educational aspiration, parent's education level, etc.

Serbia took part in the TIMSS 2003 for the first time. The assessment in Serbia was prepared and administered by the Institute for Educational Research from Belgrade, as the National Research Center for carrying out the assessment in Serbia. All investigation procedures were undertaken in accordance with the TIMSS 2003 international survey procedures and timelines. The field test was conducted in April, 2002, and involved only two primary schools, 4 school classes, with approximately over 100 students. The reasons for this minimal field test sample in Serbia were in the domains of financial and organizational circumstances in Serbia. The main investigation in Serbia was conducted in May, 2003. Secondary analyses of collected data were carried out to provide more statistical and contents indexes on the basis of accepted proposals and suggestions presented in the TIMSS 2003 data user guides and other manuals. Computer software used was International Data Base (IDB) Analyzer which is compatible and operates accompanied by the SPSS 11.0 computer statistical program.

The TIMSS 2003 defined population and sample in Serbia

In the TIMSS and PIRLS IEA studies, the standard target population is defined as the *international desired target population*. There are: population 1 (fourth grade students) and population 2 (eighth grade students). Serbia, as a participating country, has chosen population 2 generally determined in the TIMSS 2003 investigation conception in this way: "All students enrolled in the upper of the two adjacent grades that contain the largest proportion of 13-year-olds at the time of testing. This grade level intended to represent eight years of schooling, counting from the first year of primary or elementary schooling, and was the eighth grade in most countries" (Martin, Mullis & Chrostowski, 2004). Children in Serbia enter school and start compulsory education as 7-year-olds. It actually means that eighth graders in Serbia are 14-year-olds, because the eighth grade is the final grade of compulsory education in the Serbian educational system.

The TIMSS 2003 Serbian sample of schools and sample of students was designed to comply with the accepted definition of school population coverage and exclusions and with the defined model of school sample design made within the TIMSS 2003 assessment frameworks and in other IEA and ISC documents and manuals. In the TIMSS terminology, *national desired target population* in Serbia is the population of all eighth grade students in Serbia, while *national defined target population* in Serbia consists of all eighth grade students in Serbia, excluding those from schools in the Kosovo region, schools for disabled students (special education schools) and very small schools (less than ten enrolled eighth grade students). The Kosovo region is under UN military and administrative protection, so it was impossible to administer and conduct the investigation in this region by the National Research Center in Belgrade. National desired target population in Serbia did not cover entirety of the international desired target population, and it represents 81% coverage of this defined population. For the eighth grade students' samples in other participating countries, there are similar cases of lesser covering of the international desired target population, for instance, in Lithuania (89%), Indonesia (80%), and Morocco (69%) (Martin, Mullis & Chrostowski: 193-194). The national defined population of primary schools for the TIMSS 2003 sample in Serbia consisted of 1100 primary schools. The multistage cluster sample model in Serbia included 149 primary schools, proportionally selected by cluster model of sampling from each of the stratified region. School-level exclusions consisted of schools near the Kosovo region, special education schools and very small schools. An explicit stratification was not made but there was implicit stratification by the region (Central Serbia, Belgrade and Vojvodina) and by urban–rural criterion. There were a total of six implicit strata. After all kinds of the applied exclusions, the Serbian sample was represented by 4296 eighth grade students, 2206 boys, or 51.35 percent, and 2090 girls, or 48.65 percent. The mean age of tested eighth grade students in Serbia was 14.9 years.

Performance of the Serbian students at the international benchmarks

Serbian eighth graders attained results in mathematics, which are somewhat above the average international scale score achievement. Compared with the international scale, we can see that the Serbian average scale score is 477 points (24^{th} rank on the international scale), the same average international score is 467 points, and the best scores belong to Singapore (605 points, SE 3.6), Republic of Korea (589 points, SE 2.2), Hong Kong (Special Administrative Region – SAR) (586 points, SE 3.3), etc. In the TIMSS 2003 investigation conception there are four international achievement benchmarks: “advanced” (A), “high” (H), “intermediate” (I) and “low” (L). There are three crucial factors for constituting these benchmarks and for differentiating students’ performance among the four benchmarking levels, at both the eighth and fourth grades, which were taken into account in the analyses of performance at these benchmarks. These factors are (1) required mathematical operations, (2) complexity of number or number systems, and (3) nature of the problem situations (Mullis *et al*., 2004: 58). In this case, it can be stated that the principle of cumulativeness is applied in the conception of international achievement benchmarks, which means that each higher benchmark level also involves requested students’ abilities and skills that belong to lower benchmark level(s). On the basis of the general average scale score in mathematics, we can see that Serbian students are, on average, at the intermediate international benchmark, which is from 475 to 550 scale score points. The intermediate international benchmark for eighth grade mathematics achievement is formulated in the TIMSS 2003 assessment frameworks in the following way:

"*Students can apply basic mathematical knowledge in straightforward situations*. They can add, subtract, or multiply to solve one-step word problems involving whole numbers and decimals. They can identify representations of common fractions and relative sizes of fractions. They understand simple algebraic relationships and solve linear equations with one variable. They demonstrate understanding of properties of triangles and basic geometric concepts including symmetry and rotation. They recognize of basic notations of probability. They can read and interpret graphs, tables, maps, and scales" (Mullis *et al*., 2004: 79).

Table 1: Percentages of students that reached each international benchmark of the mathematics achievement (Mullis et al., 2004: 64)

Country	Advanced (A) International Benchmark (625)	High (H) International Benchmark (550)	Intermediate (I) International Benchmark (475)	Low (L) International Benchmark (400)	Average Scale Score
Singapore	44 (2.0)	77 (2.0)	93 (1.0)	99 (0.2)	605 (3.6)
Belgium (Fl.)	9 (0.9)	47 (1.9)	82 (1.2)	95 (0.9)	537 (2.8)
United States	7 (0.7)	29 (1.6)	64 (1.6)	90 (1.0)	504 (3.3)
Serbia	4 (0.4)	21 (1.1)	52 (1.4)	80 (0.9)	477 (2.6)
Int. Average	7 (0.1)	23 (0.2)	49 (0.2)	74 (0.2)	467 (0.5)

( ) Values of standard error are given in parenthesis, because results are rounded to the nearest whole number.

It is interesting to note the percentages of Serbian eighth graders at each defined international benchmark and the results achieved by students in Singapore, the most successful country in mathematics, Belgium (Flemish), as the most successful European country, and results of USA students (see Table 1). In the Serbian sample, 80% of students (SE 0.9) reached the L international benchmark, 52% (SE 1.4) reached the I international benchmark, 21% (SE 1.1) reached the H international benchmark, and only 4% (SE 0.4) reached the A international benchmark.

Students' achievement through the mathematics content and cognitive domains

The assessment in the TIMSS 2003 was carried out through two conceptualized mathematics dimensions, the content and the cognitive dimension, which corresponds to the earlier circles of TIMSS assessment. In the TIMSS 2003 assessment frameworks these two dimensions and belonging domains represent the foundation of the mathematics assessment at the fourth and the eighth grade.

The mathematics content dimension for the eighth grade is organized across the mathematics content domains: *number* (topic areas: whole numbers; fractions and decimals; integers; ratio, proportion and percent), *algebra* (patterns; algebraic expressions; equations and formulas; relationships), *measurement* (attributes and units; tools, techniques and formulas), *geometry* (lines and angles; two- and three-dimensional shapes; congruence and similarity; locations and spatial relationships; symmetry and transformations), and *data* (data collection and organization; data presentation; data interpretation; uncertainty and probability) (Mullis *et al*., 2001). The content domains cover the TIMSS 2003 mathematics curriculum and its subject matter defined for the assessment. The content domains are organized in linear order. Each content domain is structured through several topic areas, and each topic area is explained as a list of objectives, which are mainly in presence in a majority of participating countries.

Similarly, the mathematics cognitive dimension for the eighth grade is organized across mathematics cognitive domains: *knowing facts and procedures* (recall, recognize/identify, compute, use tools) (similarly, in the science area there is *factual knowledge*), *using concepts* (know, classify, represent, formulate, distinguish) (in the science area there is *conceptual understanding*), *solving routine problems* (select, model, interpret, apply, verify/check), and *reasoning* (hypothesize/conjecture/predict, analyze, evaluate, generalize, connect, synthesize/integrate, solve non-routine problems, justify/prove) (in the science area there is *reasoning and analysis*) (Mullis *et al*., 2001). There is no separate mathematics cognitive domain devoted to assessing mathematical communication abilities and skills, but there are assessment items in the area of mathematical communication, similar to the assessment of students' scientific inquiry abilities and skills in science, although both mathematical communication and scientific inquiry were not defined as cognitive domains. The cognitive domains contain sets of different behaviors, abilities and skills, which are expected of students as they engage with the mathematics contents. Each cognitive domain is structured with several abilities and skills. The mathematics cognitive domains and belonging abilities and skills inside are organized in a *cumulative pyramidal order*, which means that more complex cognitive domain contains contents of previous lesser complex cognitive domain. The same characteristics we can be found in the organization of abilities and skills inside each particular cognitive domain. Consequently, we can find the presence of similar kind of cumulative pyramidal order inside lack defined ability or skill, shosen to be assessed. The Serbian eighth graders' achievement across the content domains and cognitive domains is shown in Table 2 and Table 3.

*Table 2: The Serbian students' average achievement across content domains**

Content Domains	M	SE	95% Confidence Interval	
			Lower Bound	Upper Bound
Number	1.60	0.02	1.57	1.64
Algebra	1.20	0.01	1.17	1.22
Measurement	0.81	0.01	0.80	0.83
Geometry	0.96	0.01	0.95	0.98
Data	0.86	0.01	0.85	0.88

* Data in the table are given in row scores.

The Serbian eighth grade students have made the best achievement in the content domain of "number" and the lowest achievement in the content domains of "measurement" and "data". One of the main reasons for poor results of the Serbian students in these two content domains comes from the contents of mathematics curriculum for Serbian primary school, where subject matter devoted to these domains is insufficiently and inadequately represented.

*Table 3: The Serbian students' average achievement across cognitive domains**

Cognitive Domains	M	SE	95% Confidence Interval	
			Lower Bound	Upper Bound
Knowing Facts and Procedures	1.24	0.01	1.22	1.26
Using Concepts	0.99	0.01	0.98	1.00
Solving Routine Problems	1.39	0.01	1.36	1.42
Reasoning	0.73	0.01	0.71	0.75

* Data in the table are given in row scores.

Analyzing students' achievement through cognitive domains, we can see that the Serbian students were the most successful in the cognitive domains of "solving routine problems" and "knowing facts and procedures", and the least successful in cognitive domain of "reasoning". Students were more successful in solving simple problem tasks in the achievement test than in solving more complex multi-step word problem tasks, which requested logical thinking, understanding, applying knowledge and reasoning. In the mathematics curriculum in Serbia and in its implementation, attention is inadequately paid to these elements.

It is interesting to note and analyze differences between the Serbian students achievement across content domains (see Table 4).

Table 4: Statistical significance of differences between students' achievement in various content domains[*]

(I) Content Domains	(J) Content Domains	Md (I-J)	SE	Sig.
Number	Algebra	0.41	0.01	0.00
	Measurement	0.79	0.01	0.00
	Geometry	0.64	0.01	0.00
	Data	0.74	0.01	0.00
Algebra	Number	-0.41	0.01	0.00
	Measurement	0.38	0.01	0.00
	Geometry	0.23	0.01	0.00
	Data	0.33	0.01	0.00
Measurement	Number	-0.79	0.01	0.00
	Algebra	-0.38	0.01	0.00
	Geometry	-0.15	0.01	0.00
	Data	-0.05	0.01	0.00
Geometry	Number	-0.64	0.01	0.00
	Algebra	-0.23	0.01	0.00
	Measurement	0.15	0.01	0.00
	Data	0.10	0.01	0.00
Data	Number	-0.74	0.01	0.00
	Algebra	-0.33	0.01	0.00
	Measurement	0.05	0.01	0.00
	Geometry	-0.10	0.01	0.00

[*] Data in the table are given in row scores.

Post-hoc tests have shown significant differences in mathematics achievement between all content domains. Previous exhibit shows differences, expressed in average row scores, between each pair of content domains (MD), their standard errors (SE) and significance of these differences (Sig.). Each perceived difference between pairs of content domains is statistically significant.

Likewise, it is interesting to analyze differences between the Serbian students' achievement in various cognitive domains (see Table 5).

Post-hoc tests have shown significant differences in achievement between all content domains. Previous exhibit shows differences, expressed in average row scores, between each pair of cognitive domains (MD), their standard errors (SE) and significance of these differences (Sig.). Each perceived difference between pairs of cognitive domains is statistically significant.

Table 5: Statistical significance of differences between Serbian students' achievement in various cognitive domains[*]

(A) Cognitive Domains	(B) Cognitive Domains	MD (A-B)	SE	Sig.
Knowing Fact and Procedures	Using Concepts	0.25	0.01	0.00
	Solving Routine Problems	-0.14	0.01	0.00
	Reasoning	0.51	0.01	0.00
Using Concepts	Knowing Facts and Procedures	-0.25	0.01	0.00
	Solving Routine Problems	-0.40	0.01	0.00
	Reasoning	0.26	0.01	0.00
Solving Routine Problems	Knowing Facts and Procedures	0.14	0.01	0.00
	Using Concepts	0.40	0.01	0.00
	Reasoning	0.66	0.01	0.00
Reasoning	Knowing Facts and Procedures	-0.51	0.01	0.00
	Using Concepts	-0.26	0.01	0.00
	Solving Routine Problems	-0.66	0.01	0.00

[*] Data in the table are given in row scores.

The Table 6 shows results of average achievement across each content and cognitive domain, with values of standard errors.

Table 6: The Serbian students' average achievement across content and cognitive domains[*]

Contents Domains	Cognitive Domains	M	SE	95% Confidence Interval	
				Lower Bound	Lower Bound
Number	Knowing Facts and Procedures	1.80	0.02	1.75	1.84
	Using Concepts	1.42	0.02	1.38	1.45

	Solving Routine Problems	2.72	0.03	2.66	2.79
	Reasoning	0.48	0.01	0.47	0.50
Algebra	Knowing Facts and Procedures	1.76	0.02	1.72	1.80
	Using Concepts	1.04	0.02	1.01	1.07
	Solving Routine Problems	1.00	0.01	0.97	1.03
	Reasoning	0.98	0.02	0.94	1.02
Measurement	Knowing Facts and Procedures	1.20	0.02	1.17	1.23
	Using Concepts	0.45	0.00	0.44	0.46
	Solving Routine Problems	1.20	0.02	1.16	1.24
	Reasoning	0.41	0.01	0.39	0.42
Geometry	Knowing Facts and Procedures	0.91	0.01	0.89	0.94
	Using Concepts	0.84	0.01	0.82	0.87
	Solving Routine Problems	1.19	0.02	1.16	1.22
	Reasoning	0.90	0.01	0.87	0.92
Data	Knowing Facts and Procedures	0.55	0.00	0.55	0.56
	Using Concepts	1.20	0.01	1.18	1.23
	Solving Routine Problems	0.83	0.01	0.80	0.85
	Reasoning	0.87	0.01	0.85	0.90

* Data in the table are given in row scores.

It is interesting to note distribution of students' achievement in each content domain, through each cognitive domain, that is, to note how cognitive domains are distributed across content domains. Here, we can see statistically significant interaction between the content and cognitive domains (F=1861.56, d=3, Sig. 0.00). Therefore, we can conclude that there is not constantly lower achievement in the same cognitive domains through all content domains, and it is evident that the lowest achievement is in cognitive domain of "reasoning", but only through some of the content domains (number, algebra and measurement). In the other content domains lowest achievement is in the other cognitive domains: "using concepts" in geometry and "knowing facts and procedures" in data domain.

Gender differences in the mathematics achievement

There are some differences between boys' and girls' achievement which was confirmed in a group of participating countries. (Mullis *et al.*, 2004: 48). The international mathematics average scale score is 467 points for girls (SE 0.6) and 466 points for boys (SE 0.6). Absolute value of difference is only 1 point (SE 0.6) and it is not statistically significant at the international level. In the Serbian sample boys' average scale score is 473 points (SE 2.9) and girls' average scale score is 480 points (SE 2.9). As we can see, absolute value of difference is 7 scale score points (SE 2.8). The gender differences in Serbian eighth grade students sample are statistically significant. We can perceive that statistically significant gender achievement differences are confirmed in eighth grade students' samples of several participating countries (see Table 2). Girls have better results than boys in the eighth grade students' sample of Serbia, Republic of Macedonia, Armenia, Republic of Moldova, Singapore, the Philippines, Cyprus, Jordan (absolute value of difference is 27 points, SE 6.8) and Bahrain (32 points, SE 3.3). Boys are more successful than girls in the eighth grade students' sample of the United States, Italy, Hungary, Lebanon, Belgium (Flemish), Morocco, Chile, Ghana and Tunisia (24 points, SE 1.9). Also, these cases of differences can be found in eighth grade students' mathematics achievement in benchmarking participants' sample of Indiana State (US) and Quebec Province (Canada).

It is too hard to provide appropriate explanation for the confirmed gender differences in eighth grade students' achievement in these participating countries and also for the Serbian eighth grade students' gender differences in the mathematics achievement. We don't consider that reasons for these differences are found in the domain of intellectual abilities' differences between two genders. Reasons for the gender differences can be various, such as teachers' gender participation, students' level of educational aspiration by gender, characteristics of gender general educational aspiration, etc. It is not possible to work out an exact level of the factor influence in this field.

Table 7: Average mathematics achievement differences by gender (Mullis et al., 2004: 48)

Countries	Girls		Boys		Difference (AbsoluteValue)
	Students' Percentage	Average Scale Score	Students' Percentage	Average Scale Score	
Int. Average	50 (0.2)	467 (0.6)	50 (0.2)	466 (0.6)	1 (0.6)
United States	52 (0.7)	502 (3.4)	48 (0.7)	507 (3.5)	6 (1.9)
Serbia	49 (0.8)	480 (2.9)	51 (0.8)	473 (2.9)	7 (2.8)
Jordan	49 (1.7)	438 (4.6)	51 (1.7)	411 (5.8)	27 (6.8)
Bahrain	50 (0.4)	417 (2.4)	50 (0.4)	385 (2.4)	32 (3.3)
Indiana*	49 (1.2)	502 (5.1)	51 (1.2)	514 (5.8)	12 (3.4)
Quebec*	50 (1.6)	540 (3.7)	50 (1.6)	546 (3.3)	6 (3.3)

( ) Values of standard error are given in parenthesis, because results are rounded to the nearest whole number.

* Benchmarking participants.

Mathematics achievement through each defined Serbian sample strata

As we have pointed out before, the TIMSS 2003 sample of Serbian primary schools and eighth grade students are separated into 6 strata, based on implicit stratification model. Table 8 shows the results within the framework of these strata. This model of sample stratification was based on the previously discussed and formulated hypotheses that could be applied in general for the Serbian primary school students' achievement in each field of knowledge attainment: (1) students from urban areas achieve better results than students from rural areas; and (2) students from Belgrade region achieve better results than students from other regions in Serbia. There are various reasons for these assumptions and they can be located in the domain of economic power specific for each region and urban or rural area. As consequences of economic strength, there are some factors that actualize influence, directly or indirectly, on students' achievement, such as quantity and quality of school equipment, parents' level of education, home educational capacities, such as computer, the Internet, number of books in home, etc. In southern parts of Serbia there are extremely economically undeveloped communities. These parts of the country belong to the region of Central Serbia, and primary and secondary schools there have no proper conditions for the functioning, and there are many weaknesses in curriculum implementation. For these reasons, lower students' achievement was expected beforehand in primary schools of this region.

Table 8: Mathematics and science achievement in the Serbian implicit strata

Content Domains	F	Df	Sig.
Mathematics	59.29	5.4289	0.00
Number	63.56	5.4289	0.00
Algebra	49.32	5.4289	0.00
Measurement	57.74	5.4289	0.00
Geometry	65.39	5.4289	0.00
Data	59.14	5.4289	0.00
Science	58.91	5.4289	0.00
Biology	61.67	5.4289	0.00
Chemistry	55.03	5.4289	0.00
Physics	56.91	5.4289	0.00
Geography	60.63	5.4289	0.00
Environment Science	42.43	5.4289	0.00

F – Fisher's F-test; Df – Degrees of Freedom; Sig. – Significance.

The Table 8 shows that there are statistically significant differences in students' achievement across 6 implicit strata in the Serbian sample. These differences are confirmed between general mathematics and science achievement and also between each assessed content domain in both mathematics and science areas.

Table 9: Mathematics achievement across the Serbian implicit strata

Implicit Stratum Code	N	MNPV	MNPV SE
Central Serbia: Urban	1707	487	4.5
Central Serbia: Rural	686	442	5.6
Belgrade: Urban	662	506	8.1
Belgrade: Rural	207	449	5.2
Vojvodina: Urban	659	487	4.6
Vojvodina: Rural	375	463	6.5
TOTAL	4296	477	2.6

The Table 9 shows general differences that were confirmed across strata in the Serbian eighth grade students' sample. We can see that the students from Belgrade–Urban strata made the best achievement and the students from Central Serbia-Rural strata made the lowest achievement. Generally, it was confirmed that students from rural areas achieve lower results than students from urban areas, and the decreasing of successfulness in urban areas has the following order: Belgrade–Central Serbia–Vojvodina, however, there is a small difference between students' achievement in Central Serbia and Vojvodina (less than 1 scale score point). The characteristic of students' achievement in rural strata is the fact that students from Vojvodina have better achievement results than students from Belgrade and Central Serbia. The main reason for this order of achievement level across rural strata is bigger economic strength of rural settlements in Vojvodina than that of rural settlements in other two regions in Serbia. Vojvodina is the most powerful agricultural region in Serbia.

Table 10: Mathematics and science achievement across the Serbian urban and rural strata

Content Domains	F	Df	Sig.
Mathematics	245.23	1.4293	0.00

Number	252.95	1.4293	0.00
Algebra	208.96	1.4293	0.00
Measurement	240.16	1.4293	0.00
Geometry	260.77	1.4293	0.00
Data	234.06	1.4293	0.00
Science	208.34	1.4293	0.00
Biology	204.48	1.4293	0.00
Chemistry	230.73	1.4293	0.00
Physics	202.93	1.4293	0.00
Geography	237.64	1.4293	0.00
Environment Science	151.23	1.4293	0.00

F – Fisher's F-test; Df – Degrees of Freedom; Sig. – Significance.

The Table 10 shows that there are statistically significant differences across urban and rural strata in the Serbian sample. These differences are confirmed between general mathematics and science achievement and also between each assessed content domain in both mathematics and science areas.

The Table 11 separately shows students' achievement from urban and rural strata across the mathematics content domain. It is evident that the highest achievement belongs to students from Belgrade–Urban in the area of algebra (512 scale score points, SE 7.3), and the lowest achievement belongs to students from Central Serbia–Rural in the area of data (422 points, SE 5.0). This structure of students' results across the mathematics content domains imagines general scope of results in mathematics across three region strata. Also, it is in accordance with the main characteristics of overall achievement of Serbian eighth grade students in mathematics.

Table 11: Mathematics achievement across the Serbian implicit strata and the mathematics content domains

Content Domains / Implicit Stratum Code	Number	Algebra	Measurement	Geometry	Data
Central Serbia: Urban	487 (4.9)	498 (4.4)	486 (4.9)	481 (5.7)	465 (4.7)
Central Serbia: Rural	444 (4.9)	457 (4.5)	440 (4.8)	434 (4.7)	422 (5.0)

Belgrade: Urban	507 (8.6)	512 (7.3)	506 (7.9)	500 (8.4)	487 (8.9)
Belgrade: Rural	449 (4.2)	461 (5.6)	445 (3.6)	449 (6.3)	436 (6.2)
Vojvodina: Urban	486 (4.5)	497 (4.5)	485 (4.9)	483 (5.6)	466 (4.0)
Vojvodina: Rural	466 (7.1)	477 (6.1)	461 (6.0)	460 (7.0)	444 (6.8)
TOTAL	477 (2.8)	488 (2.5)	475 (2.5)	471 (3.0)	456 (2.6)
OVERALL	477 (2.6)				

Comparison with the groups of countries' achievement and with the international mathematics achievement

It is interesting to make some kinds of comparison between Serbian students' achievement and students' achievement in other relevant groups of the TIMSS participating countries. For that purpose, we have chosen the possibility to compare Serbian achievement and that of the Balkan countries (Bulgaria, Republic of Macedonia, Romania, Hungary and Slovenia), European countries and achievement at the international level. These kinds of comparisons are presented in Table 12.

As we can see, the Serbian students have achieved the best results in the cognitive domains of "solving routine problems" and "knowing facts and procedures" and the lowest results in the cognitive domain of "reasoning". Compared with the group of the Balkan countries, which have similar educational systems to the Serbian, students in Serbia have better achievement in all content areas in the cognitive domain of "reasoning", and the best achievement in the content domain of "geometry". In the same reasoning-geometry cognitive-content areas, Serbian students have better achievement than the international average achievement, but not better than the average achievement of European sample.

Table 12: Serbian, Balkan, European and the international mathematics achievement[*]

Content Domains / Cognitive Domains		Number	Algebra	Measurement	Geometry	Data
Knowing Facts and Procedures	Int. Level	1.43	1.42	1.11	0.96	0.54
	Europe	1.61	1.61	1.29	1.08	0.60

	Balkans	1.56	1.58	1.15	0.90	0.49
	Serbia	1.80	1.76	1.20	0.91	0.55
Using Concepts	Int. Level	1.38	0.97	0.46	0.89	1.22
	Europe	1.54	1.08	0.53	0.98	1.37
	Balkans	1.35	0.98	0.43	0.87	1.21
	Serbia	1.42	1.04	0.45	0.84	1.20
Solving Routine Problems	Int. Level	2.83	0.94	1.25	1.15	0.96
	Europe	3.07	1.04	1.43	1.25	1.08
	Balkans	2.73	0.94	1.19	1.18	0.84
	Serbia	2.72	1.00	1.20	1.19	0.83
Reasoning	Int. Level	0.53	1.07	0.42	0.84	0.96
	Europe	0.59	1.17	0.47	0.95	1.10
	Balkans	0.47	0.95	0.39	0.88	0.85
	Serbia	0.48	0.98	0.41	0.90	0.87

* Data in the table are given in row scores.

The mathematics curriculum for Serbian primary school

In the TIMSS 2003 assessment frameworks there is the mathematics and science curriculum model conceptualized at three levels, or there are three aspects of the curriculum: (1) *intended curriculum*, (2) *implemented curriculum*, and (3) *attained curriculum* (Mullis *et al*., 2001: 3). The intended curriculum represents basic characteristics of national, social and educational context as a basis for structuring the scope and contents of curriculum and teaching process realization. This aspect is explained as a prescriptive level of curriculum. The implemented curriculum represents school, teacher and classroom context, with their basic characteristics, which is essential for organizing teaching in classroom. The attained curriculum is the aspect which refers to student outcomes and characteristics in terms of knowledge, abilities and skills which students are able to develop and attain in the process of mathematics and science teaching.

In Serbian educational system there are school subjects' curricula as well as mathematics curriculum, defined at national level, with the support of the Ministry of Education in the domain of fulfilling all needed requests for its efficient implementation, such as providing proper instructional guides, a system of school inspections and monitoring, and supplying schools with recommended textbooks and other instructional materials.

Instructional time in the framework of mathematics curriculum is one of important factors in students' achievement, but not a crucial one, in explaining the results in the TIMSS 2003 assessment. Instructional time *per* *se* has to be connected with other characteristics of mathematics curriculum, in order to provide a more complete explanation. In the lower grades of primary school in Serbia (from the first to the fourth grade) there are 5 hours weekly and 180 hours annually for mathematics teaching. In the upper grades, the fifth, sixth and seventh grades, there are 4 hours weekly and 144 hours annually, and in the eighth grade there are 4 hours weekly and 136 hours annually for mathematics teaching.

One of the characteristics of the Serbian mathematics curriculum is the fact that important mathematics concepts are attained through separate instruction units and integral proceedings are not applied in solving problems. The basic mathematics concepts need to be attained and developed through continuity in the mathematics curriculum implementing, and later to be interconnected into some kind of students' conceptual systems. This characterizes the main concepts in the geometry area, but insufficient attention is directed to those concepts. There is not enough instructional time for these concepts in the scope and contents of mathematics curriculum. It is very important that geometric concepts are mutually interconnected and with other mathematics concepts, because of the fact that there are complex tasks in geometry area, which request more interconnected knowledge for their solving in mathematics teaching.

The analysis of achievement in the TIMSS 2003 test items shows that Serbian eighth grade students are less successful in items which request logical thinking and operations of reasoning, as well as in items which request understanding conceptual essence and interrelationships, and the least successful in items which request analyzing different situations and real applying of this knowledge. The Serbian eighth graders have shown better achievement in items which request knowledge of facts and procedures, and application of this kind of mathematical knowledge and skills. Of course, the reasons for such composition of students' achievement in Serbia are found in the characteristics of the Serbian mathematics curriculum. In the mathematics curriculum and its implementation in the teaching process attention is not directed to developing complex thinking operations, such as reasoning, understanding, logical thinking etc, which are needed for solving complex mathematical problems.

The TIMSS 2003 achievement test is based on many items in the domain of problem-solving, and this kind of tasks is chosen because it is present in the mathematics curriculum of many TIMSS 2003 participating countries. However, in Serbian mathematics curriculum problem-solving tasks are present to a small extent and this is the reason why Serbian students achieved lower results in items involving complex non-routine problems and multi-step word problems. The Serbian students are more successful in solving routine problems, which is a characteristic of the mathematics curriculum in Serbia. To illustrate this kind of deficiency in mathematics teaching in Serbia, we are presenting an item example and achieved results from the international mathematics report (Mullis *et al*., 2004). It is a kind of complex multi-step word problem from the data content domain, which belongs to the advanced international benchmark. This item requires of students to select relevant information from the given table, in order to calculate which of the two phone plans would be less expensive for the users, and then justify their answer in terms of the monthly fee and free minutes for telephoning in each phone plan. The top-performing countries in this item were Japan (49% of success, SE 2.2), Australia (44%, SE 2.2), and Serbia is ranked 30th with 12% of success (SE 1.3). The international average in this item was 21% of success (SE 0.3). Achievement in this item properly illustrated characteristics of the Serbian mathematics curriculum and teaching in the area of possibilities given for problem solving exercising and developing these kinds of students' mathematical abilities and skills. In other words, to develop any kind of cognitive ability or skill in mathematics teaching means to provide preliminary curricular and teaching contents' possibilities for these processes.

One of the reasons for lower achievement of Serbian students can be found in the fact that Serbia belongs to the group of participating countries which use testing the least as a method of assessment and evaluation in the mathematics teaching. Concretely, in the Serbian primary school mathematics teaching, as well as in teaching other school subjects, standardized assessment tests are not used. There is a practice of using non-standardized series of mathematics tasks which are not adapted to the levels of individual students' abilities and skills in the mathematics area. These series of the mathematics tasks are not a proper factor to influence students' development of mathematical abilities and skills. Also, some kind of standardized system of evaluation and monitoring of students' progress in this area has not been established. Obviously, training students for the final exam at the end of primary school is not enough to prepare and get Serbian eighth graders used to the testing methods of assessment and testing atmosphere, characteristic of the TIMSS 2003 testing of achievement.

Evidently, one of the elements characterizing the mathematics curriculum implementation is that there is too much formalism, which can be expressed by the phrase "semantics is hidden by syntax". Many students need, first of all, “translation” of tasks’ content, that is, appropriate explanation of the real subject-matter in mathematics tasks to better understand the inner essence of cognizing subject matter. It is somewhat absent in many cases in the Serbian mathematics curriculum. The Serbian eighth grade students were restricted in the area of mathematical communication, which is one of the elements present in the TIMSS 2003 curriculum. In some test achievement tasks some students had a problem to discover the main request in the task, and this is the reason for their lower achievement results on the tasks. In general, it seems that the presence of complex task text meaning is restricted for students who were deprived in the domain of the mathematics communication exercising, and it is also one of the characteristics of the Serbian mathematics curriculum.

Some elements of the mathematics curriculum enable students, first of all, to adopt and exercise the procedures for solving mathematical tasks, such as solving equations, practical use of Pythagorean theorem, solving more or less complex mathematical tasks in the area of two- or three-dimensional shapes in geometry etc. The adopting and exercising these mathematical procedures represent the main part of implemented mathematics curriculum in Serbian primary schools. Those are important activities in mathematics teaching, but not sufficient for developing mathematical concepts in teaching. On the contrary, there is a strong need for organizing students’ activity to enable them to discover the contents of scientific mathematical concepts. This would prepare students for adequate transfer of the attained mathematical abilities and skills, which are assessed in the TIMSS mathematics achievement test. It is especially significant to provide possibilities for students’ development in solving complex multi-step problems as mathematically arranged problems from everyday living. Coupled with mathematical concepts’ development, it can be a proper way for improving students’ mathematics achievement in the Serbian primary school.

The mathematics curriculum for the Serbian primary school is traditionally conceptualized in accordance with the old didactic and methodological standpoints, mostly rejected in the mathematics curriculum in other countries. In attempts to modernize the mathematics curriculum some reform steps were made to unburden students in mathematics teaching. One of the reasons for lower results than expected is students’ overburden in mathematics teaching, and the similar situation can be perceived in curricula of other school subjects in the Serbian primary school. In this sense, the mathematics and science curricula enable students to memorize a great amount of information in instructional process, which overburden them and deprive them of other activities in cognizing process in teaching. In the procedure of conceptualizing modern mathematics curriculum for the Serbian primary school, it must be taken into account those students' educational needs and aspirations are different compared with the period of 10 years ago and before that time, when the present Serbian mathematics curriculum was conceptualized.

Educational implications

The results that Serbian eighth grade students achieved in the TIMSS 2003 assessment in mathematics are somewhat above the international average achievement. These results don't support expectations in the field, based on rich tradition and potentials for mathematics education in Serbian educational system. One of the main reasons for this achievement level can be looked for in the fact that contents of the mathematics curriculum for the Serbian primary school don't fully cover the TIMMS curriculum scope, content domains and chosen topic areas inside.

However, Serbian eighth grade students don't achieve better results in other assessments, for example, at the final exam at the end of eighth grade. In other words, the reasons for these levels of results in the TIMSS assessment have to be found in mathematics teaching practice and in its characteristics. To make some steps of improving the mathematics teaching achievement, we have to search for appropriate answers to the following questions: What is the nature of the mathematics subject matter in all grades of primary school? What should mathematics teacher know about mathematics fundamentals? How much is the mathematics curriculum directed to developing students' cognitive abilities and skills? Are different instructional methods used really literally or essentially? What kinds of psychological and methodological knowledge and practical experiences do mathematics teachers possess? How much is the mathematics teaching methodology really developed and used in the mathematics teaching process? What elements of the mathematics teachers' preparation can be improved? etc. All these questions are initialized *inter alia* by the Serbian eighth grade students' mathematics achievement in the TIMSS 2003 assessment.

There is an urgent need for making some kind of new foundations of the modern mathematics curriculum, which will overcome, completely or partially, the present deficiencies in the Serbian mathematics curriculum contents, its conception and strategy of implementation. On the basis of the mathematics achievement of Serbian eighth graders and of the findings about crucial characteristics of the mathematics curriculum for the Serbian primary school, obtained by the secondary analysis of the TIMSS 2003 assessment data, it is needed to make strategic thorough reconstruction of the mathematics curriculum by taking into account that modern informatics era requests some different conception and organizational solutions.

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ПОСТИГНУЋЕ ИЗ МАТЕМАТИКЕ
УЧЕНИКА ОСМОГ РАЗРЕДА У СРБИЈИ
И КАРАКТЕРИСТИКЕ НАСТАВНОГ ПРОГРАМА МАТЕМАТИКЕ

Апстракт

У раду се разматрају главни резултати и одређене педагошке импликације истраживања TIMSS 2003 реализованог у Србији, у области утврђивања постигнућа ученика осмог разреда из математике, у контексту наставног програма математике. Установљено је да су ученици осмог разреда у Србији постигли резултат од 477 скалних поена и са овим резултатом они се налазе у области средњег међународног референтног нивоа. Најбољи резултат из математике постигнут је у области »алгебра«, а најслабији резултати у областима »мерење« и »подаци«. У оквиру дефинисаних когнитивних домена, осмаци у Србији постигли су најбоље резултате у оквиру домена »решавање рутинских проблема« и »знање чињеница и поступака«, а најслабији резултат у оквиру домена »резоновање«. Статистички значајна разлика утврђена је за постигнуће девојчица и дечака, у оквиру TIMSS 2003 узорка у Србији, тако да је просечан резултат девојчица 480 скалних поена, док је просечан резултат дечака 473 скалних поена. Постигнути резултати отварају бројна питања о садржају наставног програма математике у Србији, његовом квалитету и реализацији. Ови резултати могу бити на одређени начин коришћени у циљу унапређења наставног програма и наставе математике у основној школи у Србији.
Кључне речи: TIMSS 2003, постигнуће, домен садржаја, когнитивне разлике, полне разлике, наставни програм математике.

Радован Антониевич

ПОСТИЖЕНИЯ УЧАЩИХСЯ ВОСЬМЫХ КЛАССОВ СЕРБСКИХ ШКОЛ В ОБЛАСТИ МАТЕМАТИКИ И ХАРАКТЕРИСТИКИ УЧЕБНОЙ ПРОГРАММЫ ПО МАТЕМАТИКЕ

Резюме

В работе рассматриваются главные результаты и определенные педагогические импликации проведенного в Сербии исследования TIMSS 2003 в области выявления постижений учащихся восьмых классов по математике, в контексте учебной программы по математике. Учащиеся заключительных классов восьмилетних школ в Сербии добились результата, равняющегося 477 баллам предложенной шкалы, который находится в области среднего международного референтного уровня. Лучших результатов учащиеся добились в области альгебры, а худших в областях «измерение» и «данные». В рамках определенных когнитивных сфер, восьмиклассники в Сербии лучших результатов добились в сферах «решение рутинных проблем» и «знание фактов и поступков», а худшего результата в рамках сферы «умозаключения». Статистически значимы отличия между постижениями девочек и мальчиков, так что средний результат девочек равняется 480 баллам предложенной шкалы, в то время как средний результат мальчиков равняется 473 баллам. Постижения учащихся открывают многочисленные вопросы о содержаниях учебной программы по математике в Сербии, а также о качестве и реализации программы. Результаты исследования могут быть определенным образом использованы в целях повышения эффективности учебных программ по математике и самого процесса обучения математике в восьмилетних школах Сербии.
Ключевые слова: TIMSS 2003, постижение, сфера содержаний, когнитивные отличия, половые отличия, учебная программа по математике.