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HOW SUCCESSFUL IS MATHEMATICS EDUCATION IN SERBIA ACCORDING TO THE TIMSS 2003 PRIMARY RESULTS AND WHAT SHOULD BE DONE TO IMPROVE IT?

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Abstract. The main Serbian TIMSS 2003 results showed that (a) mathematics achievement of the Serbian students, expressed by average percent correct on all test items, was 41, being equal to the international average; (b) the best achievement of the Serbian students was found for tasks on algebra, whereas the poorest achievement was obtained for tasks on data; and (c) while 21% of the Serbian students had reached the high TIMSS 2003 international benchmark, 20% of them had not attained basic mathematical knowledge and skills. These results were examined the light of the TIMSS 2003 results of other economically and educationally similar entities as well as the results of relevant educational studies realized in Serbia in last twenty years. The article also gives a direction for improvements of the Serbian mathematics education supported by the Serbian TIMSS 2003 results.

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Introduction

Organized by IEA (International Association for the Evaluation of Educational Achievement; see http://www.iea.nl/), the TIMSS project measuring students performance in mathematics and science has started in 1995 with original TIMSS (Third International Mathematics and Science Study) followed by TIMSS-Repeat conducted in 1999. TIMSS 2003 continued with such a measurement in grades 4 and 8 in 50 entities (countries or regions/states) around the world[1]. Among these 50 entities was Serbia where the TIMSS project was realized in grade 8[2]. This article presents the main Serbian results regarding mathematics, examining them in the light of the results of other economically and educationally similar entities as well as the results of relevant educational studies realized in Serbia in last twenty years. The article also gives a direction for improvements of the Serbian mathematics education supported by the Serbian TIMSS 2003 results.

Method

Sample. Determined on the basis of a specifically-designed procedure (Foy and Joncas [3]), the Serbian sample comprised 4,296 students from 149 schools

[1] In grade four, 28 entities was involved.

[2] This was the first time that Serbian students participated in the TIMSS project. The project in Serbia was realized by Institute for Education Research in Belgrade (see http://solair.eunet.yu/ipi/).

across Serbia without Kosovo. The students' average age was 14.9 years and 49% of them were females.

INSTRUMENT. Performance in mathematics was measured for number, algebra, measurement, geometry and data by 194 tasks divided into 14 blocks (each containing 13–14 tasks approximately)[3]. Two such blocks were coupled with four similar blocks with tasks on science (or vice versa) forming a booklet. Twelve booklets were formed and used. On the basis of the subjects' scores, Cronbach's alpha reliability of the applied measure was estimated to .91.

PROCEDURE. Each subjects solved tasks from one booklet in two 45-minute periods with a 20-minute break. The assignment of these booklets to the subjects was done in a random way by utilizing a software provided by the IEA Data Processing Centre, Hamburg, Germany. The test was administered within two weeks in May 2003.

STUDENT SCORES CALCULATION. Although each student solved just a part of all test items (1/7 or 2/7 of the assessment item pool), student scores were obtained on the entire assessment by means of the IRT (Item Response Theory) scaling that uses "plausible values" methodology (Gonzales, Galia and Li [4]). According to this approach, the probability that a person will correctly solve multiple-choice task i is given by

$$P(x_i = 1) = c_i + \frac{1 - c_i}{1 + \exp(-1.7a_i(\theta_k - b_i))},$$

where x_i, θ_k, a_i, b_i and c_i are respectively the response to item i, the proficiency of a person on a scale k (his/her group of test items), the slope parameter of item i that characterizes its discriminativity, the location parameter of item i that characterize its difficulty, and the lower asymptote parameter of item i reflecting chances that student of very low proficiency still selects the correct answer to item i. To preserve the original metric applied in the TIMSS 1995 study, results, based upon the IRT theory, are expressed on a scale with a mean of 500 and a standard deviation of 100 for all entities that participated in the 1999 and 2003 TIMSS studies.

INTERNATIONAL BENCHMARKS. What students know and can do in mathematics has been defined by the following international benchmarks of mathematics achievements:

- advanced (evidenced by a score at or above 625): students can organize information, make generalizations, solve non-routine problems, and draw and justify conclusions from data;
- high (550): students can apply their understanding and knowledge in a wide variety of relatively complex situations;
- intermediate (475): students can apply basic mathematical knowledge in straightforward situations;
- low (400): students have some basic mathematical knowledge (Mullis et al. [12; p. 62]).

[3]Performance in number was measured by 57 tasks valued 60 score points. For algebra, 47 tasks valued 53 points were used. For measurement, 31 tasks valued 34 points were used. The same occurred for geometry. For data, 28 tasks valued 34 points were used.

Results

Table 1 presents average percent correct on test items and Gross National Income for selected countries, some of which (indicated by grey cells) can be considered as economically and educationally similar entities. Note that the international average of average percent correct on all test items was 41: while students from Singapore correctly solved on average as much as 71% of the whole assessment item pool, students from Ghana did so for just 15% of the pool.

Table 1. Average percent correct on test items and GNI for selected countries

Country	Average percent correct on all test items	Average percent correct on selected test items (matching country curriculum)	Gross National Income (per capita in $)
Netherland	55	59	23,390
Hungary	55	55	5,290
Estonia	54	55	4,190
Russian federation	49	52	2,130
Slovak Republic	49	49	3,970
Latvia	48	48	3,480
Lithuania	47	47	3,670
England	46	47	25,510
Slovenia	44	45	10,370
Italy	43	47	19,080
Romania	42	42	1,870
Serbia	41	41	1,400
Bulgaria	41	40	1,770
Armenia	39	39	790
Norway	37	39	38,730
Cyprus	37	38	12,320
Moldova	37	37	460
Macedonia	33	34	1,710

Source: Exibit 3 and Exibit C.1 in Mullis et al. [12]

According to the original metric applied in the TIMSS 1995 study (the 500±100 scale), the Serbian average score on all items was 477, which was higher than the international average (467). By utilizing the same metric, Table 2 summarizes the average Serbian achievement for mathematical content areas. Compared with the international average scale score (467) at a .05 significance level, the Serbian average scale score was higher for number, algebra and measurement, equal to for geometry, and lower for data[4].

Table 2. Average achievement in mathematics content areas for Serbia

Area	Average scale score
Number	477
Algebra	488
Measurement	475
Geometry	471
Data	456
All areas	477

Source: Exibit 3.1 in Mullis et al. [12]

Table 3 presents the percentages of students reaching the four TIMSS 2003 international benchmarks for selected countries. While in England, Russian Federation, Slovak Republic and Slovenia only nearly 10% of students have not attained basic mathematical knowledge and skills, in Bulgaria, Romania and Serbia about 20% of students demonstrated this deficiency.

Table 3. Percentages of students reaching the four TIMSS 2003 international benchmarks for selected countries

Country	Advanced (percentage of students reaching it)	High (percentage of students reaching it)	Intermediate (percentage of students reaching it)	Low (percentage of students reaching it)
Hungary	11	41	75	95
Slovak Republic	8	31	66	90
Russian Federation	6	30	66	92
England	5	26	61	90
Romania	4	21	52	79
Serbia	4	21	52	80
Slovenia	3	21	60	90
Bulgaria	3	19	51	82
Macedonia	1	9	34	66
International average	7	23	49	74

Source: Exibit 2.2 in Mullis et al. [12]

[4]Girls outperformed boys in solving test items on algebra (496 vs. 480), geometry (475 vs. 467) and all areas in total (480 vs. 473).

Discussion

Three important findings emerged from this study. First, mathematics achievement of the Serbian students, expressed by average percent correct on all test items, was 41, being equal to the international average. Second, the best achievement of the Serbian students was found for tasks on algebra, whereas the poorest achievement was obtained for tasks on data. Third, while 21% of the Serbian students have reached the high TIMSS 2003 international benchmark, 20% of them have not attained basic mathematical knowledge and skills.

The Serbian students on average correctly answered to 41% of the tasks on mathematical knowledge. Such a performance was almost identical to the achievement of students from Romania and Bulgaria (two countries that are economically and educationally similar to Serbia) and better, for example, than that of students from Macedonia (a country that is economically and educationally similar to Serbia), and Norway and Cyprus (two wealthy countries, especially Norway). Furthermore, the demonstrated level of success is in accord with relevant educational studies realized in Serbia in last twenty years, which evidence that mathematics achievements are as a rule in the range 30–50%. The outcomes of some of these studies are given in Table 4.

Table 4. Outcomes of four studies on mathematics achievement of Serbian students

Grade	Year	Sample size students, schools	Average percent correct on all test items	Source
5	1986	2738; 96	48	Marinković [6]
6	1987	2665; 98	40	Marinković [7]
7	1988	2619; 100	33	Marinković [8]
8	1990	35,303*	46 **	Milovanović, Hotomski [11]

*60% of the population **estimated, most of the subjects took the mathematical test

That Serbian students were best at tasks on algebra and poorest at tasks on data is not surprising. Students in Serbia start to express relationships by letters already in primary mathematics education and this approach might have contributed to this outcome above the international average. However, to base algebra on arithmetic in a more successful way, appropriate means of linking arithmetic to algebra need to be clarified and widely utilized (see Marjanović and Kadijević [10]). A relative failure in solving tasks on data (the success rate below the international average) was result of the fact that mathematics teachers in Serbia usually neglect this area, the treatment of which is formally required by the curriculum under the working label "graphical and tabular representation of states, events, and processes". When, some years ago, teachers suggested what areas should be excluded from the curriculum, data was their first choice (Marinković, [9]), probably because this topic, found by them as not that mathematical, has been inappropriately treated in their professional development. However, the authorities did not exclude it (Serbian Ministry of Education and Sports, [15]), but most teachers seem to have done so.

Similarly to Romania and Bulgaria, nearly 20% of the Serbian students reached the TIMSS 2003 high benchmark, whereas about the same percentage of these students have not attained basic mathematical knowledge and skills. These may be realistic percentages as in an average 30-student class in Serbia 5–6 students are usually bad at math, whereas nearly the same number are good at it. Although a benchmark-centred research has not been realized in Serbia so far, the data on first semester marks in mathematics in grade 9 in 24 secondary schools[5] in Belgrade in the school year 1994/95, given in Table 5, seem to support such a percentage of those who may be either good or bad at mathematics. According to Milovanović and Hotomski [11], just 12% of the examined students ($N = 26,377$) gained 75% of the total test score or more on the uppersecondary education entrance examination test in mathematics organized across Serbia in June 1990.

Table 5. Distribution of first semester marks in mathematics in 24 secondary schools

School type	No. of students; no. of schools	Mark				
		5 (highest)	4	3	2	1 (lowest)
gymnasium	2302; 7	170	445	662	734	291
vocational schools	4185; 17	120	450	949	1688	978
Total	6487; 24	290	895	1611	2422	1269
	100%	4%	14%	25%	37%	20%

Source: Kadijević [5] **18%** **20%**

To summarize: if, apart from the TIMSS 2003 results of other economically and educationally similar entities as well as the results of relevant educational studies realized in Serbia in last twenty years, we have in mind poor economic conditions and complex societal issues in Serbia in the last fifteen years that have created a constantly stressful living and learning environment for the majority of students (see Nahod and Brkić, [13]; Brkić, Stojković and Najdanović-Tomić, [2]; Brkić, [1]), the TIMSS 2003 mathematics achievement of the Serbian students should be evaluated as good. The achievement might be higher since, as the Serbian TIMSS 2003 quality control monitor observed in visited TIMSS classes, unfamiliar and demanding test settings reduced the subjects' initial strong motivation to solve TIMSS tasks as the testing time went on. Although the Serbian TIMSS 2003 results cannot provide a full picture of the state of mathematics education in Serbia (as in any other entity), it seems that, apart from an inappropriate treatment of data, the main shortcoming of the Serbian mathematics education are poorly developed students' abilities to solve non-routine problems, apply mathematical knowledge and skills,

[5] from four-year education classes only

and give mathematical argumentation[6]. As the outcomes of the TIMSS project have influenced the development and (re)design of mathematics and science education curricula in a number of countries (see Robitaille, Beaton and Plomp, [14]), these Serbian TIMSS 2003 results and other results that will be obtained through secondary analyses of the Serbian TIMSS 2003 data should direct the improvement of mathematics education in Serbian for the benefit of all students and their teachers.

REFERENCES

[1] Brkić, P., *Problems that may be expected among students at the beginning of the school year 1999/2000* (in the Serbian language), Beograd: Ministarstvo prosvete - Sektor za istraživanje i razvoj obrazovanja, 1999.

[2] Brkić, P., Stojković, N. & Najdanović-Tomić, J., *Role of school in postwar conditions 1999/ 2000* (in the Serbian language), Beograd: Ministarstvo prosvete - Sektor za istraživanje i razvoj obrazovanja, 1999.

[3] Foy, P. & Joncas, M., *TIMSS 2003 sampling design*, In: Martin, M. O., Mullis, I. V. S. & Chrostowski, S. J. (Eds.), *TIMSS 2003 Technical Report* (pp. 109–122), Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College, 2004.

[4] Gonzales, E. J., Galia, J. & Li, I., *Scaling methods and procedures for the TIMSS 2003 mathematics and science scales*, In: Martin, M. O., Mullis, I. V. S. & Chrostowski, S. J. (Eds.), *TIMSS 2003 Technical Report* (pp. 253–273), Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College, 2004.

[5] Kadijević, Dj., *The development of intelligent tutoring programs for individual mathematics learning*, Ph. thesis (in Serbian), Technical Faculty "Mihajlo Pupin", University of Novi Sad, 1994.

[6] Marinković, B., *Report on monitoring the realization of societal aims in lower secondary education (Mathematics, Grade 5)* (in the Serbian language), Beograd: Republički zavod za unapređivanje vaspitanja i obrazovanja, 1986.

[7] Marinković, B., *Report on monitoring the realization of societal aims in lower secondary education (Mathematics, Grade 6)* (in the Serbian language), Beograd: Republički zavod za unapređivanje vaspitanja i obrazovanja, 1987.

[8] Marinković, B., *Report on monitoring the realization of societal aims in lower secondary education (Mathematics, Grade 7)* (in the Serbian language), Beograd: Republički zavod za unapređivanje vaspitanja i obrazovanja, 1988.

[9] Marinković, B., *Some opinions and proposals for improving primary and lower secondary mathematics curriculum in the Republic of Serbia* (in the Serbian language), Beograd: Ministarstvo prosvete Republike Srbije, Sektor za osnovno obrazovanje, 1995.

[10] Marjanović, M. & Kadijević, Dj., *Linking arithmetic to algebra*, In: Chick, H., Stacey, K., Vincent, J. & Vincent, J. (Eds.), *Proceedings of the 12th ICMI Study Conference The Future of the Teaching and Learning Algebra* (Vol. 2, pp. 425–429), University of Melbourne: Department of Science and Mathematics Education, 2001.

[11] Milovanović, Lj., & Hotomski, S., *Results of the realized uppersecondary education entrance examinations in the school year 1990/91* (in the Serbian language), Nastava i vaspitanje, **39**, 4–5 (1990), 298–315.

[12] Mullis, I. V. S., Martin, M. O., Gonzalez, E. J. & Chrostowski, S. J., *TIMSS 2003 International Mathematics Report*, Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College, 2004.

[13] Nahod, S. & Brkić, P., *Primary and lower secondary education in the conditions of sanction*, International Conference "Children and War on the Territory of Former Yugoslavia" (in the Serbian language), Sremski Karlovci: Institut srpskog naroda, 1994.

[6] The reader should here recall how the advanced and high benchmarks are defined and examine the content of pages 72, 73, 76 and 77 in Mullis et al. [12].

[14] Robitaille, D. F., Beaton, A. E. & Plomp, T. (Eds.), *The Impact of TIMSS on the Teaching and Learning of Mathematics and Science*, Vancouver: Pacific Educational Press, 2000.

[15] Serbian Ministry of Education and Sports, *Mathematics Curriculum for Primary and Lower Secondary Education in the Republic of Serbia* (in the Serbian language), Beograd: Arhimedes, 2002.

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