Зборник Института за педагошка истраживања УДК 371.26-057
Година 38 • Број 2 • Децембар 2006 • 333-355 Оригинални научни чланак
ISSN 0579-6431 DOI: 10.2298/ZIPI0602333A

ACHIEVEMENT OF SERBIAN EIGHTH GRADE STUDENTS IN SCIENCE

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Abstract. The paper considers the main results and some educational implications of the TIMSS 2003 assessment conducted in Serbia in the fields of the science achievement of Serbian eighth grade students and the science curriculum context of their achievement. There were 4264 students in the sample. It was confirmed that Serbian eighth graders had made average scale score of 468 points in the science, and with this achievement they are placed in the zone of the top of low international benchmarking level, very close to the point of intermediate benchmark. The average science achievement of the Serbian eighth graders is somewhat below the general international science achievement. The best results were achieved in the science content domain of "chemistry", and the lower results in the content domain of "environmental science". Across the defined science cognitive domains, it was confirmed that the Serbian students had achieved the best results in cognitive domain of "factual knowledge" and weaker results in "reasoning and analysis". The achieved results raise many questions about contents of the science curriculum in Serbia, its overall quality and basic characteristics of its implementation. These results can be eligibly used to improve the science curricula and teaching in Serbian primary school.
Key words: TIMSS 2003, science, achievement, content domain, cognitive domain, science curriculum.

Students' achievement in the field of science depends of many contextual factors of teaching and learning science. These factors exert some influence on the level and quality of students' achievement in the field of science. In the TIMSS 2003[1] assessment frameworks the characteristics of science curriculum/curricula are represented as a group of important contextual factors

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[1] 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 curricula contents, school context for teaching and learning and home context for learning. This paper is based on the secondary analyses of collected data, obtained from TIMSS 2003 assessment of the Serbian eighth grade students' sample. Basic and essential results from secondary analyses were previously presented in the book *TIMSS 2003 u Srbiji* (TIMSS 2003 in Serbia), published by the Institute for Educational Research (Antonijević i Janjetović, 2005).

that affect to a large extent students' achievement in the science areas. It is one of the crucial dependences in the relation between level and quality of students' achievement and contexts in which it is generated. Not only overall quality and organization of curriculum, but a complex group of its particular characteristics, especially contents of teaching, applying teaching methods and nature of the concepts in its contents, all determine students' achievement in the fields of science. From this standpoint, it is important to conduct some quantitative and qualitative analyses of crucial connections between science achievement and context of science curricula for the Serbian TIMSS 2003 eighth grade students' sample, like those that have been previously carried out in the field of the TIMSS mathematics achievement (Antonijević, 2006).

In the TIMSS assessment there is a tendency to interpret students' mathematics and science achievement in relation to the basic characteristics of curriculum contents, characteristics of school mathematics and science teaching and school environment and its educational influence, and in relation to the characteristics of home context for learning mathematics and science. These pieces of information are summarized and presented in the international mathematics and science reports (Mullis *et al*., 2004; Martin *et al*., 2004). Achievement 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 mathematics and science 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 the mathematics or science. The influencing factors of achievement in the fields of science are different and always specific for each participating country.

Serbia took part in the TIMSS 2003 for the first time[2]. The assessment in Serbia was prepared and successfully administered by the Institute for Educational Research from Belgrade as the National Research Center for the TIMSS 2003 assessment in Serbia. All investigation procedures were undertaken in accordance with the TIMSS 2003 frameworks, which define all methodological procedures for this international survey. The field test was conducted in April, 2002 and involved only two primary schools, 4 school classes, with approximately over 100 students. 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

[2] Now, Serbia is in the process of conducting the TIMSS 2007 circle of the research. The TIMSS 2007 field test was already successfully administered in Serbia in April 2006.

Base (IDB) Analyzer, which is compatible and operates accompanied the SPSS 11.0 statistics software. The TIMSS 2003 international database (IDB) released by the ISC from Boston was used in order to make some extended statistical analyses which are presented in this paper.

The TIMSS 2003 defined population and sample in Serbia

In te TIMSS and the PIRLS IEA studies, the standard target population is defined as the *international desired target population*. Serbia, as a participating country, has chosen population 2 (eighth grade students), generally determined in the TIMSS 2003 assessment frameworks 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 with compulsory education as 7-year-olds. It actually means that eighth graders in Serbia are 14-year-olds, as well as the eighth grade is the final grade of compulsory education in the Serbian educational system.

The TIMSS 2003 schools' sample and the eighth grade students' sample in Serbia were designed in accordance 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 the 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 the schools in the Kosovo region, schools for disabled students (special education schools) and very small schools (less than ten enrolled eighth grade students). 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. The national defined population of primary schools for the sample in Serbia consisted of 1100 primary schools. The multistage cluster sample model included 149 primary schools proportionally selected from each of the stratified region. An explicit stratification was not made but there was implicit stratification by region (Central Serbia, Belgrade and Vojvodina) and by urban-rural criterion. There were a total of six implicit strata. The Serbian students' sample was represented by 4294 eighth grade students, 2206 boys, or 51.35%, and 2090 girls, or 48.65%. The mean age of tested eighth grade students was 14.9 years.

Performance of the Serbian students in the science at the international benchmarks

Serbian students attained results in the science areas which are somewhat below the average international achievement. Compared with the international scale, we can see that the Serbian average scale score is 468 points (SE 2.5, 28th rank on the international scale). The same average international score is 474 points (SE 0.6), and the best scores belong to Singapore (578, SE 4.3), Chinese Taipei (571, SE 3.5), Republic of Korea (558, SE 1.6), and Hong Kong (Special Administrative Region – SAR) (556, SE 3.0), etc. In the TIMSS 2003 there are four international achievement benchmarks, two for the mathematics and science achievement each, but differently defined (Martin *et al*., 2004: 60): "advanced" (A), "high" (H), "intermediate" (I) and "low" (L). There are several crucial factors for differentiating students' science performance among the four benchmarking levels, at both the eighth and fourth grades, which are taken into account in the analyses of performance at these benchmarks. These factors are: (1) the depth and breadth of content knowledge; (2) the context of the problem (progressing from practical to more abstract); (3) the level of scientific investigation skills; (4) the complexity of diagrams, graphs and tables; and (5) the completeness of written responses. Like in the field of mathematics, it can also be found that here, i.e. in the science, the principle of cumulativeness is applied in the conception of international achievement benchmarks. Each higher benchmark level also involves requested students' abilities and skills which belong to lower benchmark level(s). On the basis of the general average scale score in the science, it can be seen that Serbian students are, on average, at the low international benchmark level, which is from 400 to 475 scale score points, but they are averagely on the top of the zone, a little below the intermediate international benchmark level. The "low", "intermediate", "high" and "advanced" international benchmarks for eighth grade science achievement are formulated in the following way (Martin *et al*., 2004: 64):

> **"L" level**: "*Students recognize some basic facts from the life and physical sciences*. They have some knowledge of the human body and heredity, and demonstrate familiarity with some everyday physical phenomena. Students can interpret some pictorial diagrams and apply knowledge of simple physical concepts to practical situations".
>
> **"I" level**: "*Students can recognize and communicate basic scientific knowledge across a range of topics*. They recognize some characteristics of the solar system, water cycle, animals, and human health. They are acquainted with some aspects of energy, force and motion, light reflection, and sound. Students demonstrate elementary knowledge of human impact on

and changes in the environment. They can apply and briefly communicate knowledge, extract tabular information, extrapolate from data presented in a simple linear graph, and interpret pictorial diagrams".

"H" level: "*Students demonstrate conceptual understanding of some science cycles, systems, and principles.* They have some understanding of Earth's processes and the solar system, biological systems, populations, reproduction and heredity, and structure and function of organisms. They show some understanding of physical and chemical changes, and the structure of matter. They solve some basic physics problems related to light, heat, electricity, and magnetism, and they demonstrate basic knowledge of major environmental issues. They demonstrate some scientific inquiry skills. They can combine information to draw conclusions; interpret information in diagrams, graphs and tables to solve problems; and provide short explanations conveying scientific knowledge and cause/effect relationships".

"A" level: "*Students* demonstrate *a grasp of some complex and abstract science concepts.* They can apply knowledge of the solar system and of Earth features, processes, and conditions, and apply understanding of the complexity of living organisms and how they relate to their environment. They show understanding of electricity, thermal expansion, and sound, as well as the structure of matter and physical and chemical properties and changes. They show understanding of environmental and resource issues. Students understand some fundamentals of scientific investigation and can apply basic physical principles to solve some quantitative problems. They can provide written explanations to communicate scientific knowledge".

Table 1: Percentages of students that reached each international benchmark of the science achievement (Martin et al., 2004: 66)

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	33 (1.6)	66 (2.3)	85 (1.7)	95 (0.8)	578 (4.3)
Estonia	13 (1.0)	52 (1.6)	88 (1.2)	99 (0.3)	552 (2.5)
United States	11 (0.8)	41 (1.7)	75 (1.4)	93 (0.8)	527 (3.1)
Int. Average	6 (0.1)	25 (0.2)	54 (0.2)	78 (0.2)	474 (0.6)
Serbia	2 (0.3)	16 (1.8)	48 (1.3)	79 (1.0)	468 (2.5)

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

What is the aim of representing students' results in science across the international benchmark levels? In the achievement test there are items which differ in their contents and the level of difficulty. Moreover, there are differences in the sense of problem complexity represented in the items. For instance, there are relatively simple items with routine problems and also multi-step word

problem-solving items in the achievement test. The stretching items' levels of difficulty from relatively simple to more complex ones is based upon conception of a presence of different levels of abilities' and skills' development in students that enable them to solve tasks. Due to the fact of this diversity in complexity of the test items, each item was placed in one of the four international benchmarking zones.

It is interesting to note the percentages that the Serbian eighth graders are at each defined international benchmark and the same results of students in Singapore, the most successful country in mathematics, of Estonia, the most successful European country, and of students in the United States (Table 1). In the Serbian sample there are 79% of students (SE 1.0) at the "L" level (80% in mathematics), 48% of students (SE 1.3) at the "I" level (52% in mathematics), 16% of students (SE 1.8) at the "H" (21% in mathematics), and only 2% of students (SE 0.3) at the "A" level (4% in mathematics). Better results that the Serbian eighth graders achieved in the field of mathematics in each international benchmark are statistically in accordance with the average scale score of the Serbian eighth graders in mathematics (477 scale score points).

Students' achievement across the science content domains

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

The science content dimension for the eighth grade is organized across the science content domains (Martin *et al*., 2001): *life science*, *chemistry*, *physics*, *Earth science* and *environmental science*. The content domains cover the TIMSS 2003 science curriculum and its subject areas that are defined for the assessment. The content domains are organized in a *horizontal linear order*. Each content domain is structured through several sub-topics, and each is explained through a list of objectives, which are mainly presented in a majority of participating countries. In the Serbian primary school there are four separate school subjects in the fields of science: biology, chemistry, physics and geography. The results of the Serbian eighth graders will be separately presented in this paper, in each science area including sub-topics across areas, on the basis of the TIMSS content areas plan.

The science cognitive dimension for the eighth grade is organized across science cognitive domains (Mullis *et al*., 2003): *factual knowledge* (recall/re-

cognize, define, describe, use tools and procedures) (similarly, in mathematics there is *knowledge of facts and procedures*), *conceptual understanding* (illustrate with examples, compare/contrast/classify, represent/model, relate, extract/apply information, find solutions, explain) (in mathematics there is *use of concepts*), and *reasoning and analysis* (analyze/interpret/solve problems, integrate/synthesize, hypothesize/predict, design/plan, collect/analyze/interpret data, draw conclusions, generalize, evaluate, justify) (in mathematics there is *reasoning*).

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

Country	Life Science	Chemistry	Physics	Earth Science	Environmental Science	Average Scale Score
Singapore	569 (4.0)	582 (4.2)	579 (3.4)	549 (3.9)	568 (3.8)	578 (4.3)
Estonia	547 (2.4)	552 (2.1)	544 (2.4)	558 (2.9)	540 (2.2)	552 (2.5)
U.S.	537 (3.0)	513 (3.2)	515 (2.9)	532 (2.9)	533 (2.9)	527 (3.1)
Int. Aver.	474 (0.5)	474 (0.5)	474 (0.5)	474 (0.5)	474 (0.5)	474 (0.6)
Serbia	468 (2.6)	474 (3.2)	471 (2.6)	471 (3.0)	457 (2.4)	468 (2.5)

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

There is no separate science cognitive domain devoted to assessing problem-solving level, such as in mathematics, but there are assessment items in the area of *scientific inquiry*, similar to the assessment of *mathematical communication* in mathematics, although mathematical communication and scientific inquiry were not defined as cognitive domains. Scientific inquiry represents one of the fields of assessment in the TIMSS 2003. In the TIMSS 2003 the science section of framework scientific inquiry is defined as follows: "The goal of scientific inquiry is to provide explanations of scientific phenomena that help us to understand the underlying principles governing the natural world" (Mullis *et al*., 2003). It is noticeable that scientific inquiry is conceptualized as an overarching assessment model in the TIMSS 2003 science framework that covers each field of science, both content and cognitive components. It was not defined as a particular cognitive domain in the field of science, but it especially existed, first of all, as regular parts of the science cognitive domains of "conceptual understanding" and "reasoning and analysis".

The cognitive domains determine the sets of different students' behaviors, abilities and skills expected of students as they engage in the science content. The science 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 can be found in the organization of abilities and skills inside each particular science cognitive domain.

It is interesting to compare the results of students in Singapore, the most successful country in the TIMSS 2003, Estonia, the most successful European country, the United States, and Serbia. The results of the eighth graders' achievement in these countries across the content domains are shown in Table 2.

It is characteristic that internationally there is the same achievement level in each content domain. We can see that the Serbian eighth grade students, with their average achievement in each content domain, are exactly at the international average level in the science content domain of "chemistry", with the best results in this content domain. Serbian students have shown the lowest achievement in the content domain of "environmental science". The Serbian eighth graders have had achievement statistically significant below the Serbian science overall achievement only in the science content domain of "environmental science".

Students' achievement in life science

The TIMSS content domain of "life science" is represented by the biology curriculum in the Serbian primary school. The school subject of biology is taught from the fifth up to the eighth grade 2 hours weekly, and 72 hours annually, from the fifth to seventh grade, and 68 hours annually in the eighth grade. It is 8% of total instructional time in the eighth grade. It is important to notice that the seventh grade biology curriculum is entirely devoted to the contents of environmental science. For this reason, the TIMSS 2003 life science (biology) sub-topics are taught and learnt through three grades, in the fifth, sixth and eighth grade.

Serbian eighth grade students made average scale score in the content domain of life science on the level of 468 points (SE 2.6). This result is identical with overall average scale score achievement of the Serbian eighth graders in the field of science. However, despite the fact that the results of Serbian sample in each sector are below overall international achievement, it is important to emphasize that only in the area of life science that result is statistically significant.

Table 3: The Serbian students' average achievement across the life science content areas[*]

Content Areas	M	SE	95% Confidence Interval	
			Lower Bound	Upper Bound
Types, characteristics and classification of living things	0.32	0.00	0.31	0.32
Structure, function and life processes in organisms	0.57	0.01	0.56	0.58
Cells and their functions	0.54	0.01	0.53	0.55
Development and life cycle of organisms	0.81	0.00	0.80	0.81
Reproduction and heredity	0.59	0.00	0.59	0.60
Diversity, adaptation, and natural selection	0.50	0.01	0.49	0.51
Ecosystems	0.56	0.00	0.55	0.57
Human health	0.60	0.00	0.59	0.60

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

As it can be seen from the previous table, the Serbian eighth grade students have made the best achievement in the life science content areas of "development and life cycle of organisms" and "human health", and the lowest achievement in the content area of "types, characteristics and classification of living things". It is expected that the Serbian eighth graders may achieve better results in contents devoted to "human health", because the whole eighth grade biology curriculum in Serbia is devoted to human biology. But, it is not in accordance with the expected results they have made in the contents of classification of living beings, because the Serbian biology curriculum gives appropriate opportunities in this area of biology teaching (Ševkušić, Miljanović i Drakulić, 2005). It is interesting to notice that contents about cell, its structure, properties, internal part functions and its significance for living beings, are taught in the fifth grade biology curriculum. Human cell is taught in the eighth grade, because the eighth grade biology curriculum is entirely devoted to human biology contents.

The best results were achieved within the framework of cognitive domain of "factual knowledge", and it is in accordance with the overall achievement of the Serbian eighth grade students, both in the fields of mathematics and science. Weaker results were achieved in the cognitive domain of "conceptual understanding" and the weakest in the cognitive domain of "reasoning and analysis". This line of results decreasing was expected, because there is similar situation for the overall achievement in the field of science.

In the field of life science (biology curriculum in Serbia), one of the basic scientific concepts is the concept of "cell". The importance of this concept in biological science is indisputable and it may be a real epistemological point of forming and advancing a system of biological concepts in biology teaching. Some crucial characteristics of cell are taught and learned in biology teaching. The concept of "cell" is taught in the biology teaching program for

the fifth grade in Serbian primary school, and the concept of "human cell" is also taught in the eighth grade. One of the shortcomings in the process of the concept of "cell" formation is evidenced by the fact that crucial elements, functions and characteristics of "cell" are not discovered through the system of their interconnectedness. A cell is a kind of complex system in itself with numerous connections and relations inside it and in relation to cell environment, considering different kinds of other cells and tissues that differ in their structure and functions. For these reasons, the scientific biological concept of "cell" is an appropriate opportunity for creating a specific polygon in biology teaching program for initializing and advancing a broader system of interconnected biological concepts, and the quality of this concept discovering and attainment determine the overall quality of students' achievement in the TIMSS content domain of "life science". In this sense, the key point is as follows: does the process of the concept of cell attainment enable students to discover its internal essence and its system of functioning?

Table 4: The Serbian students' average achievement in life science across the science cognitive domains[*]

Cognitive Domains	M	SE	95% Confidence Interval	
			Lower Bound	Upper Bound
Factual Knowledge	0.74	0.00	0.74	0.75
Conceptual Understanding	0.57	0.00	0.57	0.58
Reasoning and Analysis	0.36	0.00	0.36	0.37

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

In the biology curriculum for the Serbian primary school there are not enough opportunities for advancing different students' cognitive abilities and skills, defined in the TIMSS 2003 assessment frameworks, and results across science cognitive domains appropriately mirror this kind of the biology curriculum contents' drawbacks. Moreover, there are some characteristics of the biology curriculum, such as overburden of its contents, the absence of more lessons devoted to practical exercises and experiments, the absence of setting of hypothesis, drawing of conclusions, open-air teaching etc. All of those characteristics are important for more profound understanding of fundamental biological concepts.

Students' achievement in chemistry

The content domain of "chemistry" is represented by the same-name separate science subject in the Serbian primary school, which is taught in the seventh

and eighth grade, 2 hours weekly, and 72 hours annually in the seventh grade, and 2 hours weekly, and 68 hours annually in the eighth grade. It is 8% of total instructional time in the eighth grade. Some basic knowledge in the domain of chemistry students can attain through teaching process of school subject named "nature" in the fourth grade of primary school. However, this kind of knowledge does not belong to the scientific concepts, and this kind of "introduction to the world of matter" cannot be a proper basis for further teaching and learning of chemistry in the regular seventh and eighth grade chemistry curriculum. The seventh grade chemistry curriculum is devoted to general chemistry contents, and inorganic chemistry and eighth grade chemistry curriculum is devoted to inorganic and organic chemistry contents.

Serbian eighth grade students made average scale score in the content domain of chemistry on the level of 474 points (SE 3.2). This result is identical with overall international scale score achievement and the Serbian eighth graders have statistically shown the best results just in the field of chemistry.

Table 5: The Serbian students' average achievement across the chemistry content areas[*]

Content Areas	M	SE	95% Confidence Interval	
			Lower Bound	Upper Bound
Classification and composition of matter	0.65	0.01	0.63	0.66
Particulate structure of matter	0.39	0.00	0.39	0.40
Properties and uses of water	0.21	0.00	0.21	0.22
Acids and bases	0.27	0.00	0.27	0.27
Chemical changes	0.62	0.01	0.61	0.63

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

As we can see from the previous table, the Serbian eighth grade students have made the best achievement in the chemistry content sub-topics of "classification and composition of matter" and "chemical changes". These facts show general intention of the chemistry curriculum in Serbia to enable students to get familiar with the procedures of classification of matter and its basic properties, and also with general chemical concepts, which they have attained as abstractions without mutual and essential interconnectedness. These concepts have remained in students' minds as abstractions that students cannot apply to some practical problem-solving spaces in the chemistry teaching. The lowest achievement they have made was in the content of sub-topic of "properties and uses of water". These contents are taught and learnt in the seventh grade chemistry curriculum.

The table 6 leads to a similar conclusion, like the one we could draw in the field of achievement across biology topics. Students have achieved significantly better results in the cognitive domains of "factual knowledge" and "conceptual understanding" and weaker results in the cognitive domain of "reasoning and analysis". The cause for those weaker results can be found in the absence of opportunities in chemistry curriculum that should enable students to develop and exercise thinking operations of reasoning, analysis, synthesis, etc. Moreover, there are few opportunities in the chemistry teaching to enable students to make experiments, connect basic chemistry concepts with problems in every-day life, understand importance of chemistry for development of some technologies, and also there are not enough opportunities for drawing conclusions based on strong evidence etc (Šišović, 2005). A set of scientific concepts in the field of chemistry science represents an entire and logically consistent system of concepts.

Table 6: The Serbian students' average achievement in chemistry across the science cognitive domains[*]

Cognitive Domains	M	SE	95% Confidence Interval	
			Lower Bound	Upper Bound
Factual Knowledge	0.49	0.00	0.49	0.50
Conceptual Understanding	0.50	0.00	0.49	0.51
Reasoning and Analysis	0.29	0.00	0.29	0.30

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

This kind of system should be applied in the chemistry curriculum in order to enable students to form their knowledge and concepts more systematically in the area of chemistry. In the area of chemistry concepts development the following questions can be posed: what is nature and quality of chemistry concepts in teaching, do chemical concepts in the teaching mirror real essence of chemical concepts in the science, does the process of knowledge attainment in chemistry teaching, in each particular case, enable students to discover real internal nature of referring subject matter, etc. Despite these chemistry curriculum deficiencies, the results of the Serbian eighth grade students in the field of chemistry are satisfactory.

Students' achievement in physics

The TIMSS 2003 content domain of "physics", as well as chemistry, is represented by the same name separate science subject in the Serbian primary school. There are 2 hours weekly, and 72 hours annually, in the sixth and

seventh grades, and 2 hours weekly, and 68 hours annually, in the eighth grade. It is 8% of total instructional time in the eighth grade. Some basic and general physical concepts and principles students are enabled to attain through the curriculum of school subject named "nature", in the fourth grade. However, similar to the field of chemistry, these concepts and principles are mostly poor in their contents and interconnectedness.

In the content domain of physics Serbian eighth grade students made average scale score on the level of 471 points (SE 2.6). This result is somewhat below the overall international scale score achievement and above the overall achievement of the Serbian eighth graders in the field of science.

Table 7: The Serbian students' average achievement across the physics content areas[*]

Content Areas	M	SE	95% Confidence Interval	
			Lower Bound	Upper Bound
Physical states and changes in matter	0.40	0.00	0.39	0.41
Energy types, sources, and conversions	0.27	0.00	0.27	0.28
Heat and temperature	0.42	0.00	0.41	0.43
Light	0.38	0.00	0.38	0.39
Sound and vibration	0.54	0.00	0.53	0.54
Electricity and magnetism	0.57	0.00	0.56	0.57
Forces and motion	0.45	0.00	0.44	0.46

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

As we can see from the previous table, the Serbian eighth grade students made the best achievement in the physics content areas of "electricity and magnetism" and "sound and vibration", and the lowest achievement in the content area of "energy types, sources, and conversions". It is important to notice that contents of "electricity and magnetism" belong to the eighth grade physics curriculum. The weakest results in the content sub-topic devoted to studying the types and transformation of energy can be found in the fact that these physics teaching contents belong to the physics curriculum for the seventh grade. But, maybe there are some other reasons present in the teaching and learning of physics, such as depth in knowledge attainment in this field, applied teaching methods, instructional time, presence of discovering and attainment of the genuine physical concepts, etc (Luković i Verbić, 2005).

In the content domain of physics the fact about the best results in cognitive domain of "conceptual understanding" can be observed. The result was unexpected, because the Serbian eighth graders showed averagely the best results just in this cognitive domain. The weakest results were made in the science cognitive domain of "factual knowledge" and this was also unexpected,

because of the fact that the Serbian eighth graders have generally shown the best results both in the fields of mathematics and science, in the area of factual knowledge assessment.

Table 8: The Serbian students' average achievement in physics across the science cognitive domains[*]

Cognitive Domains	M	SE	95% Confidence Interval	
			Lower Bound	Upper Bound
Factual Knowledge	0.28	0.00	0.28	0.29
Conceptual Understanding	0.58	0.00	0.58	0.59
Reasoning and Analysis	0.43	0.00	0.43	0.44

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

These results indicate that the Serbian eighth grade students have mastered the best some cognitive skills, or possess some developed cognitive abilities in the area of physical concepts' understanding. Anyway, students' achievement results obtained are the picture of teaching contents overall quality, applied teaching methods and teaching aids. Concerning physics curricula, from the sixth to eighth grade, it is important to analyze all presented types of physical concepts that emerge within the framework of physics teaching contents, as well as the process of their attainment in teaching, the nature of this process and its main properties. The discovered characteristics in the area could be useful, in the sense of improving overall quality of physics teaching and its efficiency.

Students' achievement in Earth science

The content domain of "Earth science" is completely covered by the geography curriculum in Serbia. There is 1 hour weekly, and 36 hours annually, in the fifth grade, 2 hours weekly, and 72 hours annually, in the sixth and seventh grades, and 2 hours weekly, and 68 hours annually, in the eighth grade. It is 8% of total instructional time in the eighth grade. Some general physical concepts are taught and learnt within the framework of the school subjects named "nature" and "society" in the fourth grade. These concepts are most general and without mutual interconnectedness, and they cannot make a proper basis for further teaching and learning in the field of geography.

Serbian eighth grade students made average scale score in the content domain of Earth science on the level of 471 points (SE 3.0), the same result as in the field of physics. This result is somewhat below the overall international scale score achievement and above the overall achievement of the Serbian eighth graders in the field of science.

As it can be seen from the previous table, the Serbian eighth grade students made the best achievement in the Earth science content area of "Earth's structure and physical features" and the lowest achievement in the content area of "Earth's processes, cycles, and history". The TIMSS 2003 Earth science sub-topics and their contents that appear in the TIMSS test are taught in the Serbian geography curriculum mainly in the fifth and sixth grade. Besides, concepts which students have attained in the geography teaching are not enough mutually interconnected or interrelated with the concepts from other areas of science, such as biological and physical concepts. These are some causes of weaker students' achievement in the field of geography than expected.

Table 9: The Serbian students' average achievement across the Earth science content areas[*]

Content Areas	M	SE	95% Confidence Interval	
			Lower Bound	Upper Bound
Earth's structure and physical features (lithosphere, hydrosphere and atmosphere)	0.76	0.00	0.75	0.77
Earth's processes, cycles, and history	0.63	0.00	0.62	0.64
Earth in the solar system and the universe	0.71	0.01	0.70	0.72

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

Table 10: The Serbian students' average achievement in Earth science across the science cognitive domains[*]

Cognitive Domains	M	SE	95% Confidence Interval	
			Lower Bound	Upper Bound
Factual Knowledge	0.66	0.01	0.65	0.67
Conceptual Understanding	0.86	0.01	0.85	0.88
Reasoning and Analysis	0.58	0.00	0.57	0.58

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

Serbian eighth grade students have achieved the best results in the cognitive domain "conceptual understanding" and the weakest results in "reasoning and analysis". In this case, the reasons for these results can be found in the absence of emphasis on mastering and developing students' abilities and skills in the geography curriculum that have been defined in this cognitive domain in the TIMSS assessment frameworks in this area. One of the main characteristics of the Serbian geography intended curriculum is its overburden with great amount of separate facts, often unessential for understanding some geographical concepts, and students spend much time to memorize simple facts in this

area (Đerić i Dragović, 2005). This way of knowledge attainment does not enable students to develop some reasoning and analysis operations. This is one of the main reasons for weaker results in the science cognitive domain of "reasoning and analysis".

Students' achievement in environmental science

There is no separate science subject devoted to environmental science area in the Serbian primary school and the TIMSS 2003 sub-topics in this area are taught only in the seventh grade. It is one of the specifics of environmental science contents in the Serbian primary school. The content domain of "environmental science" is covered by the seventh grade biology curriculum which is entirely devoted to the "ecology" contents and partially to the contents in the field of "environmental protection" as a complete subject-matter devoted to the environmental science. Thus, in the Serbian primary school environmental science is taught only in the seventh grade, 2 hours weekly, and 172 hours annually. It is 7% of total instructional time in the seventh grade. There are different definitions of the concepts of "ecology" and "environmental science" in the biology curriculum for Serbian primary school. Ecology is defined as the science of the relationships between organisms and their environments. This branch of science is also called bionomics and those kinds of explanations are given in the contents of biology textbook for the seventh grade. On the other side, environmental science is defined as a branch of biology concerned with the importance of the environment for living beings and with the protection of the environment. Both "ecology" and "environmental science" are entirely parts of the seventh grade biology curriculum.

Serbian eighth grade students have achieved the weakest results just in the content domain of "environmental science", in regard to other science content domains. It is on the level of 457 points (SE 2.4).

Table 11: The Serbian students' average achievement across the environmental science content areas[*]

Content Areas	M	SE	95% Confidence Interval	
			Lower Bound	Upper Bound
Changes in population	0.10	0.00	0.09	0.10
Use and conservation of natural resources	0.71	0.01	0.70	0.73
Changes in environment	0.30	0.00	0.29	0.30

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

As it can be seen from the previous table, the Serbian eighth grade students have made the best achievement in the environmental science content sub-

topic of "use and conservation of natural resources", and the lowest achievement in the content area sub-topic of "changes in population", on the low level of results. Good results in the area of learning about use and conservation of natural resources are the consequence of the emphasis on environment protection sub-topic in the intended curriculum contents. Students' bad achievement in the area devoted to teaching and learning about changes in population is very significant. The concept of "population" is one of the crucial scientific concepts in the field of biology and its deeper understanding is important for further understanding of concepts in the area of evolution, which is also taught in biology teaching. In the Serbian biology curriculum concepts about evolution and its essential properties are taught in the sixth grade. The concept of "population" is taught in the seventh grade biology (environmental science) curriculum, despite the fact that the concept of "population" must be taught beforehand. Here, it can be noticed that contents from different grades and science school subjects are not mutually and essentially interconnected and synchronized.

Table 12: The Serbian students' average achievement in environmental science across the science cognitive domains[*]

Cognitive Domains	M	SE	95% Confidence Interval	
			Lower Bound	Upper Bound
Factual Knowledge	0.41	0.00	0.40	0.42
Conceptual Understanding	0.18	0.00	0.18	0.19
Reasoning and Analysis	0.52	0.01	0.50	0.53

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

The stretching of the students' achievement results across science cognitive domains in the area of environmental science is unexpected, in regard to the science achievement as a whole. Unlike other areas of science, in this area, the best results were attained in the science cognitive domain of "reasoning and analysis" and the weakest results in the science cognitive domain of "conceptual understanding". Despite some drawbacks of the environmental science curriculum, the Serbian eighth grade students are good at applying operations of reasoning, analysis, drawing conclusions, etc, in this area of science (Ševkušić, Miljanović i Drakulić, 2005).

Teaching contents in the area of environmental sciences do not enable students to achieve more connected knowledge and concepts from adjacent areas, such as biology, chemistry and geography. Furthermore, learning separate concepts in the area do not enable students to enter deeply into the subject matter and understand internal causal mechanisms which determine connec-

tions and other relations between environmental phenomena. Anyway, the Serbian students' achievement in the area of environmental science, the weakest in the field of science is unexpected, because environmental science is completely covered and thoroughly studied in the seventh grade biology teaching.

Common characteristics of the science curricula for the primary school

In the TIMSS 2003 assessment frameworks there is the mathematics and science curriculum model which is conceptualized at three levels, or three aspects of the curriculum: (1) *intended curriculum*, (2) *implemented curriculum*, and (3) *attained curriculum* (Mullis *et al*., 2001: 3). The intended curriculum represents national, social and educational context, as bases for structuring scope and contents of curriculum and teaching process realization. This aspect is 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 the classroom. The attained curriculum is an aspect referring 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.

The science curriculum for the Serbian primary school is an integrated one on the level of lower grades, from the first to the third grade, and is named "nature and society" school subject. In the fourth grade there are two separate science curricula named "nature" and "society". The subject of "nature" involves topics in the fields of life science, chemistry, physics and environmental science. This science subject curriculum develops into the subjects' curricula, such as biology, chemistry and physics, from the fifth up to the eighth grade. In the subject of "society" there are some topics that belong to the Earth science and environmental science. This school subject develops on the level of upper grades into geography curriculum and partly in the ecology curriculum in the seventh grade. Despite the fact that some concepts in the areas of science are attained through teaching subjects contents in lower grades, those concepts are generally and empirically oriented, naïve in their nature and non-interconnected. They are not a kind of real scientific concepts. They cannot represent a real basis for developing some kind of conceptual system. For these reasons, those concepts do not essentially contribute to the process of improving students' achievement in the upper grades of primary school in the field of science.

Instructional time in the science curricula is one of important factors in students' achievement, but not a crucial one, in explaining the results in the TIMSS 2003 assessment. Instruction time *per se* has to be connected with

other characteristics of science curriculum, in order to provide more complete explanation. Instructional time for the science curricula, by weekly and annually hours, is given in the Table 13.

Table 13: Science curricula instructional hours per week and annually

Science Curricula	Grades							
	1.	2.	3.	4.	5.	6.	7.	8.
Nature and Society	2 (72)	2 (72)	2 (72)	-	-	-	-	-
Nature	-	-	-	2 (72)	-	-	-	-
Society	-	-	-	2 (72)	-	-	-	-
Biology	-	-	-	-	2 (72)	2 (72)	2 (72)	2 (68)
Chemistry	-	-	-	-	-	-	2 (72)	2 (68)
Physics	-	-	-	-	-	2 (72)	2 (72)	2 (68)
Geography	-	-	-	-	1 (36)	2 (72)	2 (72)	2 (68)

( ) Instructional time hours annually are given in parenthesis.

Concerning the total instructional time for all school subjects across the eighth grade subjects' curricula, instructional time devoted to natural sciences' teaching is on the level of 28%. In the field of mathematics instructional time is on the level of 14%. Thus, in each field of science it is the level of 7% instructional time devoted to each separate science. Similar relations between science instructional time and total instructional time are presented across the fifth, sixth and seventh grade school subjects' curricula.

Nature and quality of the knowledge that contains science curricula is a very important factor of students' achievement in the field of science. According to the theory of developmental teaching, established by Russian psychologists V.V. Davydov and D.B. El'konin (Matusov, 2001), if there are scientific concepts and knowledge in the contents of teaching, it can be concluded that this kind of teaching may be an actuator of the student cognitive development and student operations of scientific thinking in teaching. In this way, scientific concepts within the framework of teaching contents become a real basis for integration of the processes of knowledge attainment and cognitive development in students into one and inseparable process. Serbian science curricula contents do not facilitate opportunities for the science teaching contents to be a real actuator of the student cognitive development. The reason for the curricula drawback in this sense can be found in the lack of opportunities for discovering an internal subject-matter of the genuine scientific concepts. This can be attributed to the fact that scientific concepts are present in the contents of the science curricula, but in general abstract forms.

Deeper structural analysis of the achievement on the TIMSS 2003 test items shows that Serbian eighth grade students are weaker in items which request logical thinking and operations of reasoning, understanding concep-

tual essence and internal non-self-evident and rather hidden connections and relationships, analyzing of different situations and real applying of this knowledge through problem-solving. Similar situation was found in the analysis of relations between students' achievement and mathematics curriculum for the Serbian primary school (Antonijević, 2006). Problem-solving in the field of science teaching is not of the same type as problem-solving in the mathematics teaching, and it also differs from one to another area of science. The presence of problem-solving tasks in the science curricula contents enables generally students to discover new knowledge and develop thinking abilities and skills, instead of attaining reproductive knowledge in the science teaching process. Moreover, problem-solving in the science teaching process enables students to connect concepts and knowledge from different areas of science. One of the general shortcomings of the Serbian science curricula contents is the lack of the problem-solving in their contents, especially lack of solving non-routine problems, as fundamental basis for developing student cognitive abilities and skills. The Serbian eighth graders have shown better achievement in items which request knowledge of facts and procedures, more or lesser simple, and applying this kind of knowledge and skills in science, similar to the field of TIMSS 2003 mathematics achievement.

In the Serbian science curricula there are not enough opportunities for enabling students to carry out some procedures of scientific observations and investigating some scientific problems in the area of scientific inquiry in the teaching process, despite the fact that scientific inquiry has become a part of contemporary science curriculum/curricula in many countries, with significant emphasis placed on activating students in the field. Presence of scientific inquiry procedures in scientific curricula may imply giving students some opportunities, such as: posing scientific questions and hypothesis, planning and conducting investigations to gather evidence, formulating explanations based on conducted observations, showing scientific understanding, which may be directed to more advanced types of inquiry important for preparing future scientists, etc. All of these elements of scientific inquiry are not present in the scope and contents of the Serbian science curricula and this makes one of their conception weaknesses.

There are some kinds of natural interconnectedness between separate science areas, such as biology-chemistry, physics-chemistry and geography-biology. It is important to incorporate interconnectedness into science curriculum/curricula contents, which reflects qualitative relations in the science. Low level of interconnectedness across different areas of science teaching, in regard to the science school subjects' contents, also characterizes the Serbian science curricula. Any kind of model of science areas' interconnectedness has

not been established in the course of the science curricula development and design. The existence of separate scientific concepts and principles across the science areas does not enable students to integrate concepts and knowledge in the entire and logically consistent system of scientific concepts.

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 teaching of sciences. Concretely, in the Serbian primary school science teaching, as well as in teaching other school subjects, standardized assessment tests are not used. There is a practice of administering non-standardized tests (series of tasks) in the science areas, not adapted to the levels of individual students' abilities and skills, actually developed or in the zone of proximal development. These series of tasks are not a proper factor of influence in the direction of developing students' abilities and skills in the field of science. Not any kind of standardized system for evaluation and monitoring of students' progress in this area has been established. Moreover, unlike the field of mathematics, there is no final exam in the fields of science at the end of primary school and there is no possibility to compare the TIMSS science achievement and results from a final exam.

* * *

The results that Serbian eighth grade students have achieved in the TIMSS 2003 assessment in science are somewhat lower compared to the international average science achievement. One of the reasons for this achievement level can be looked for in the fact that contents of the science curricula for the Serbian primary school does not adequately cover the TIMMS curriculum, in the sense of study depth, its scope, content domains and chosen sub-topics inside. But, it is not the only reason for lower achievement of the Serbian eight-graders. In other words, we have to find the causes for these low-level results in the TIMSS assessment in the main characteristics and overall quality of the science curricula and characteristics of separate science subjects' teaching in the Serbian primary school. In order to make some steps forward in the science teaching efficacy, we have to find appropriate answers to the following questions: what is the nature of the science subject matter in all grades of primary school, what are kinds and quality of knowledge interconnectedness across separate science school subjects and their contents, what should be the science teacher knowledge about the fundamentals of science, how much is the science curricula directed to develop students' cognitive abilities and skills, etc? All these questions are very important for improving

students' science achievement and they are all initialized by the Serbian eighth grade students' science achievement in the TIMSS 2003 assessment.

Note. This article is the result of the project »Education for knowledge-based society« No 149001 (2006-2010), financially supported by the Ministry for Science and Environmental Protection Republic of Serbia.

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Примљено 31.07.2006; прихваћено за штампу 24.10.2006.

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ПОСТИГНУЋА УЧЕНИКА ОСМОГ РАЗРЕДА У СРБИЈИ
У ОБЛАСТИ ПРИРОДНИХ НАУКА

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 природних наука, у контексту наставних про-

грама за природне науке. Установљено је да су ученици осмог разреда у Србији, узорак од 4.296 ученика, постигли резултат од 468 скалних поена и са овим постигнућем они се налазе у врху ниског међународног референтног нивоа, веома близу границе средњег међународног нивоа. Просечно постигнуће ученика осмог разреда је нешто испод општег међународног просека у области природних наука. Најбољи резултат постигнут је у области хемије, а најслабији резултат у области науке о животној средини. У оквиру дефинисаних когнитивних домена за природне науке, утврђено је да су ученици осмог разреда у Србији постигли најбоље резултате у оквиру когнитивног домена »знање чињеница« а најслабије резултате у оквиру домена »резоновање и анализа«. Постигнути резултати отварају бројна питања о садржају наставних програма за природне науке у Србији и карактеристикама њихове имплементације. Ови резултати могу бити на одређени начин коришћени у циљу унапређења наставног програма и наставе природних наука у основној школи у Србији.
Кључне речи: TIMSS 2003, природне науке, постигнуће, домен садржаја, когнитивни домен, наставни програм природних наука.

Радован Антониевич

УСПЕВАЕМОСТЬ УЧЕНИКОВ ВОСЬМОГО КЛАССА В СЕРБИИ В ОБЛАСТИ ЕСТЕСТВЕННЫХ НАУК

Резюме

В работе рассматриваются основные результаты и некоторые педагогические импликации исследования ТИМСС 2003, реализованного в Сербии, в сфере определения успеваемости учеников восьмого класса, в области естественных наук, в контексте учебных программ по есественным наукам. На примере 4 296 учеников восьмого класса установлено что они, получив 468 шкалных баллов, занимают вершину низкого международного референтного уровня успеваемости, очень близко к границе среднего международного уровня. Средняя успеваемость учеников восьмого класса немного ниже общей международной средней успеваемости в области естественных наук. Самый хороший результат был достигнут в области химии, а самый плахой – в обсти изучения окружающей среды. В рамках отдельных когнитивных сфер в области естественных наук установлено, что ученики восьмого класса в Сербии добились лучших результатов в рамках когнитивной сферы «знания фактов», а самые плохие результаты обнаружены в рамках сферы «обсуждение и анализ». Полученные результаты поднимают ряд вопросов о содержании данных учебных программ и характеристиках их имплементации. Эти результаты могут быть использованы в целях актуализации программ обучения и преподавания естественных наук в основных школах в Сербии.
Ключевые слова: естественные науки, успеваемость, сфера содержания, когнитивная сфера, учебные программы по естественным наукам.