USAGE OF COMPUTERS AND CALCULATORS AND STUDENTS' ACHIEVEMENT: RESULTS FROM TIMSS 2003

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Abstract. The paper deals with the facts obtained from TIMSS 2003 (Trends in International Mathematics and Science Study). This international comparative study, which includes 47 participant countries worldwide, explores dependence between eighth grade students' achievement in the areas of mathematics, physics, chemistry, biology and geography, and basic characteristics of context for teaching and learning in school and at home. In the sense, different options of using modern technology equipment and its influence to students' achievement are explored in the TIMSS 2003 assessment. The main topic of the paper is using computers and calculators in teaching and its implications to students' overall achievement at the end of primary school education. The TIMSS 2003 international overall results in this area show that using computers in teaching doesn't significantly contribute to better students' achievement in the field of mathematics and also show some level of significant influence on students' achievement in the field of science. Moreover, the results show that using calculators in mathematics teaching improve overall students' achievement. Connectedness between using computers/calculators and students' achievement is especially explored and presented in the frame of students' sample in four countries, the United States, the Netherlands, Bulgaria and Serbia.

Key words: TIMSS 2003, computer usage, calculator usage, student achievement.

The main results of the TIMSS 2003 assessment in the fields of students' mathematics and science achievement in the eighth grade and how they were essentially affected by some characteristics of teaching and learning mathematics and science, especially by using computers and calculators in teaching, represent one of the attractive research topics in the TIMSS 2003 assessment. In order to assist appropriate analyzing of students' achievement in the fields of mathematics and science, some contextual information are presented in the paper, and those information were obtained from the mathematics and science teachers, on the base of gathered extensive data on curricula, and teaching and learning mathematics and science in primary school.

The initial idea was to confirm presence and intensity of some characteristic influences on students' achievement inside the Serbian eighth grade students' sample, in the area of using computers and calculators in mathematics and science teaching. For instance, we could particularly confirm that in the Serbian eighth grade students' sample there is difference in mathematics achievement between two groups of students, students that use and students that don't use computers in the mathematics teaching. Furthermore, we have concluded that it can be very interesting to apply a cross-country comparison of these kinds of confirmation of influences on students' achievement, which arise from mathematics and science teaching and learning characteristics. An appraisal had made that it is interesting to compare students' achievement influences that appear in high developed countries, in comparing to the similar kind of influences that appear in countries in process of social and economic transition. Based on these criteria of designing comparison model, the analyses included investigating of influences on students' mathematics and science achievement in four TIMSS 2003 participant countries: the United States, the Netherlands, Bulgaria and Serbia. Cross-country comparisons of the TIMSS data are often made in order to establish differences in factors affected students' achievement.

Methodology

One of the basic standpoints is general positive attitude towards opportunities of teaching and learning in the direction of advancing development of student cognitive abilities and skills. In the sense, the research topics were mostly targeted to the following: use of computers and calculators in mathematics and using computers in science teaching, and their significance to students' achievement in the areas of mathematics and science. We have applied specific combined model of analysis separate variables in the paper, which includes statistical analysis and content analysis as well. For example, when we discussed obtained statistical indexes, we didn't make only stay at the level of statistically oriented type of analysis. In order to make more complete and thorough analysis of the chosen topics, we have tried to give appropriate connections toward broader context that determines applying of treated teaching methods and activities, through theoretically-based content analysis.

We have formulated the next research question in the study: *What are the levels of influence of using computers and calculators in teaching and learning mathematics and science to students' achievement in the field of mathematics and science across four-country sample of eighth grade students*?

Table 1: Students' average achievement in mathematics across countries

Country	N	Average Achievement	Standard Error
Netherlands (NLD)	3065	536.27	3.8
United States (USA)	8912	504.37	3.3
Serbia (SCG)*	4296	476.64	2.6
Bulgaria (BGR)	4117	476.17	4.3
Intern. Average		467	0.5

* In the TIMSS 2003 unique country abbreviation for Serbia was SCG, but the sample consisted only from Serbian primary schools.

The overall eighth grade students' achievement results in mathematics are given in the Table 1, and for the area of science in the Table 2, as well as number of students in national students' samples. Total number of students in four-country sample is 20390 students. In the following tables numbers of students are mainly different regarding to the data from tables 1 and 2. That is because of the fact that numbers of students belonging to the sub-group of teachers vary depending on number of teachers that gave answers on some questions.

Table 2: Students' average achievement in science across countries

Country	N	Average Achievement	Standard Error
Netherlands (NLD)	3065	538.44	3.1
United States (USA)	8912	525.31	3.1
Bulgaria (BGR)	4117	478.96	3.8

Intern. Average		474	0.6
Serbia (SCG)	4296	468.48	2.5

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 and 2090 girls), 177 mathematics teachers and 702 science teachers. The mean age of tested eighth grade students in Serbia was 14.9 years.

In our research some statistical procedures were applied and measures were obtained, in the purpose of exploring some characteristics of the quantitative and qualitative dependences between chosen variables analyzed in the research. We had connected variables from four countries' BTM and BTS files (data from eighth grade mathematics and science teachers' questionnaire) and BSA files (eighth grade students' achievement data). Merging of files were done using student-teacher linkage files (BST). These statistical procedures and measures were applied in order to make proper descriptions, on a statistical way, and characteristics of the chosen group of the mathematics teachers and their students in each of four countries, as well as some characteristics cross-country oriented. From variety of statistical procedures, we have included TIMSS mean scale scores, per cent measure, statistical significance, Fisher's coefficient, etc. All estimations of students' achievement in the mathematics are made by calculating with "1st mathematics plausible value" and "1st science plausible value", which exist for each student in the students' BSA files, as well as in the files merged using student-teacher linkage files. DPC IDB Analyzer software was used in carrying out each of defined analysis in the research. Using of this software is associated with the SPSS software, and both accompanied enabled appropriate approach to the TIMSS International Data Base.

Computers and calculators in mathematics teaching

The TIMSS 2003 testing procedures permit of calculators using in the course of testing, both in sectors of mathematics and of science (Mullis *et al*., 2004). In the TIMSS assessments there are some kinds of confirmed dependences between calculator using policy and students' achievement in the mathematics teaching. It might be hypothesized that group of students which were not allowed to use calculators in the mathematics teaching can achieve better results than a group of students were allowed to use calculators. The reason for this can be found in the fact that students not allowed to use calculators had to master all needed abilities and skills in the area of calculating, including development of some concepts related to the used mathematical procedures and operations. Moreover, it may be a topic of discussion whether it really occurs in the mathematics teaching and learning activities, or students, instead of advancing needed concepts in the area of calculating, only have had opportunity to exercise mechanically operations of calculating, without deeper approaching to their internal essence and interconnectedness. It had been suggested by Reynolds & Farrell that the early introduction of calculators, and their too frequent use, is one of the reasons for the relatively poor performance of students in England in mathematics (Keys, 1999)

Table 3: Calculator availability on the mathematics lessons: cross-country

Options	M	Total N	Percentage	S.D.
All	522.74	7770	49.69	76.86
Most	505.46	2883	18.44	79.36
About half	469.31	1049	6.71	85.04
Some	479.45	3589	22.95	82.57
None	457.78	346	2.21	72.01
TOTAL	504.59	15637	100.00	81.86
F=1006.474; df=1; p=.000				

In the Table 3 can be seen that the best achievement in mathematics belongs to the sub-group of students in four-country sample, whose teachers reported of calculators' availability for all students in the mathematics teaching. This fact in not in accordance to the hypothesized expectation that students which don't permit to use calculators are enabled to develop some abilities and skills in the area of calculating and consequently achieve better results in mathematics assessment. A significant negative relationship between the frequency of calculator using and students' mathematics achievement in Japan was identified in the TIMSS 1999 and non-significant relationship for the students' achievement in the United States (House, 2002). In one other study (Keys, 1999), based on the TIMSS 1995 study results, it was confirmed that across countries there was very little association between the extent of calculator use and mean mathematics score (Spearman's rho = -0.17).

Table 4: Calculator availability on the mathematics lessons: separate countries

Country		All	Most	About half	Some	None
BGR	M	522.74	505.46	469.31	479.45	457.78
	S.D.	76.86	79.36	85.04	82.57	72.01
NLD	M	554.01	509.15	432.62	-	-
	S.D.	62.42	64.74	63.17	-	-
USA	M	511.82	508.35	466.34	491.82	482.73
	S.D.	78.16	76.28	75.76	75.34	50.61
SCG	M	461.93	473.17	468.42	476.24	490.76
	S.D.	84.22	84.13	91.32	90.01	88.47

In this case, the variable had chosen that examine using computers as a means for the purpose of "discovering mathematics concepts and principles", considering significance of understanding mathematics concepts and principles for better students' performance in the mathematics. As it is shown from the next table, computers are rarely used in the mathematics teaching, across four countries' eighth grade. It is scarcely over 5% of the mathematics teachers reported of using computers in this purpose.

It was interesting to try exploring the connection between using computers in the mathematics teaching and sub-group students' mathematics achievement, and also what is nature of this connection, if it is existed in the field of mathematics. One of the items in the mathematics teachers' questionnaire is formulated through the next question: "In teaching mathematics to the TIMSS class, how often do you have students use a computer for the following activities?" There were four activities for the teachers' appraisal and the most interesting is variable of "discovering mathematics principles and concepts".

Table 5: Using computers for "discovery mathematics concepts and principles": cross-country

Options	M	N	Percentage	S.D.
Every or almost every lesson	480.58	105	2.15	86.08
About half the lessons	491.04	153	3.13	95.55
Some lessons	510.19	2290	46.78	82.46
Never	501.30	2347	47.95	77.49
TOTAL	504.69	4895	100.00	80.85
F=.047; df=1; p=.828				

Results in the previous table have shown that almost 95% of students across four-country sample use computers only in "some lessons" or "never". This important fact points out that computers mostly have not adequate applying in the mathematics teaching and learning, but the most successful sub-group of students in the four-country sample are this one which were enabled to use computers in process of discovering mathematics concepts and principles.

Table 6: Using computers for "discovery mathematics concepts and principles": separate countries

Country		Every or almost every lesson	About half the lessons	Some lessons	Never
BGR	M	-	-	534.05	478.95
	S.D.	-	-	80.07	72.38
NLD	M	-	-	550.25	537.94
	S.D.	-	-	65.92	60.21
USA	M	408.39	495.75	502.54	497.38
	S.D.	54.36	94.34	80.69	78.45
SCG	M	509.45	461.41	436.02	460.41
	S.D.	79.36	100.09	102.07	84.59

The Table 6 shows that, in the cases of Bulgaria's and the Netherlands' mathematics teachers' samples, there are no teachers reported about using computers for discovering mathematics concepts and principles in the options of "every or almost every lessons" and of "about half the lessons", but also in other two samples of the mathematics teachers there are low percentage of teachers chosen these options. Generally, computers have used rarely in the mathematics teaching across countries, as it is the case for using computers in the area of helping student to discover and understand some mathematics concepts and principles. In an analysis of the factors affecting students' achievement in the field of mathematics, applied for Hong Kong, Cyprus and the United States students' samples in the TIMSS 1999 study it was confirmed that the highest means generally belong to students who never used computers, and, in addition, the lowest mathematics score average belonged to the students who used computers for most of their lessons (490.28) (Papanastasiou, 2002). The results of this analysis show that using computers frequently in the mathematics teaching does not necessarily increase students' mathematics achievement.

Computers in science teaching

There is a general tendency of increasing of using computers in teaching and learning science. In many fields of science teaching it is convenient to use different kind of software, in order to improve overall quality of teaching and learning. It is especially important for better and deeper understanding of crucial scientific concepts and laws.

In the TIMSS 2003 science teachers' questionnaire there are several questions devoted to using computers for teaching and learning science. The most significant is question 26, with following formulation: “In teaching science to the TIMSS class, how often do you have students use a computer for the following activities?” And, there are the options: (a) “do scientific procedures and experiments”, (b) “study natural phenomena through simulations”, (c) “practice skills and procedures”, (d) “look up ideas and information”, and (e) “process and analyze data”. I was interesting to explore indexes across first two options inside this question. There is also a general question about using computers in science teaching (25.a. “Do students in the TIMSS class have computers available to use during their science lessons?”) and about access to the Internet (25.b.“Do any of the computers have access to the Internet?”) (see tables 7 and 8).

Table 7: Using computers: separate countries

Country	“Yes” (%)	M	“No” (%)	M
BGR	16.04	484.55	83.96	473.22
NLD	39.16	541.34	60.84	539.05
USA	74.38	531.36	25.62	516.79
SCG	14.07	464.85	83.93	468.62

In the Table 7 we can see percentage of science teachers across the countries which reported about using computers in science teaching. Based on the facts obtained, it can be concluded that Serbian eighth grade students have the least opportunities to use computers in science teaching (14.07%), and the least percentage (Table 8: 42.47%) of computers used in Serbia are connected to the Internet, regarding to the other three countries. Circumstances about using computers in science teaching and access to the Internet are very similar in Bulgaria, such as in Serbia. It can be supposed that situation in this area is much better in the present time, because Serbian Ministry of Education and Sport had supplied primary and secondary schools with great number of computers in the meantime.

Table 8: Internet access: separate countries

Country	“Yes” (%)	M	“No” (%)	M
BGR	68.69	485.40	31.31	482.33
NLD	94.49	539.53	5.51	533.85
USA	96.85	529.50	3.15	529.21
SCG	57.53	462.19	42.47	477.26

The previous table shows the fact that the sample of primary schools from the United States has the biggest per cent of computers used in science teaching with the Internet access (96.85%), and then the sample of the Netherlands (94.49%). The facts are in accordance to a level of general socio-economic power and wealth in these two countries. It is interesting that difference in students’ achievement across categories of “yes” and “no” is the lowest just in the case of the United States sample of eighth grade students (M for “yes” subgroup is 529.50 and for “no” subgroup is 529.21). It is unexpected that the Serbian eighth-graders have better average science achievement in “no” subgroup.

Table 9: Using computers for “do scientific procedures and experiments”: cross-country

Options	M	N	Percentage	S.D.
Every or almost every lesson	451.29	292	2.59	78.20
About half the lessons	505.07	242	2.14	79.41
Some lessons	525.46	4617	40.88	79.87
Never	515.67	6144	54.40	81.35
TOTAL	517.78	11295	100.00	81.50
F=25.043; df=1; p=.000				

Overall students’ achievement in science across four-country sample, in the variable devoted to exploring of using computers for exercising some of scientific procedures and experiments, shows the fact that the best achievement is discovered in category “some lessons”. It would be hypothetically unexpected to conclude that using computers on “every or almost every lesson” can enable lower students’ achievement in science. Problem of using computers is more complex and it implies a necessity to explore concrete ways of their using in teaching and learning science. In the TIMSS 2003 it was not completely done, with the applied structure of variables.

Table 10: Using computers for “do scientific procedures and experiments”: separate countries

Country		Every or almost every lesson	About half the lessons	Some lessons	Never
BGR	M	-	501.08	495.20	481.02
	S.D.	-	71.21	88.35	84.48
NLD	M	-	520.99	538.09	541.98
	S.D.	-	29.14	60.66	55.71
USA	M	450.69	510.31	533.36	531.02
	S.D.	59.68	94.20	79.46	78.32
SCG	M	451.43	457.84	479.90	464.17
	S.D.	82.06	71.78	81.38	93.71

The Table 10 shows that, in the cases of Bulgaria's and the Netherlands' science teachers' sample, there are no teachers reported using computers for "do scientific procedures and experiments" in the option of "every or almost every lessons". However, on the base of the results inside the variable we cannot make some precise conclusion and similar case we have in the next variable, which results are presented in the tables 11 and 12. These variables explore presence of some activities of using computers in science teaching, in a common sense. There is no adequate information about contents and quality of these activities, as well as no information about contents and quality of computer software used, as the base of their realization in science teaching.

Table 11: Using computers for "study natural phenomena through simulations": cross-country

Options	M	N	Percentage	S.D.
Every or almost every lesson	460.71	306	2.73	79.39
About half the lessons	532.10	208	1.86	79.76
Some lessons	528.19	4896	43.72	77.32
Never	512.68	5789	51.69	82.64
TOTAL	518.41	11199	100.00	81.15
F=.13; df=1; p=.000				

From the Table 11 we can see that the best results are achieved in subgroup of students, whose teachers have chosen the category of "about half the lessons". Thus, on the base of these results, it can be concluded that using computers for "study natural phenomena through simulations" is of greater importance for students' achievement in science, than using computers for "doing scientific procedures and experiments".

Table 12: Using computers for "study natural phenomena through simulations": separate countries

Country		Every or almost every lesson	About half the lessons	Some lessons	Never
BGR	M	-	468.12	511.66	479.38
	S.D.	-	43.81	91.28	81.03
NLD	M	-	-	541.88	539.61
	S.D.	-	-	55.67	57.60
USA	M	463.00	553.56	533.65	528.98
	S.D.	68.10	72.49	77.24	82.34
SCG	M	459.64	457.84	473.65	464.62
	S.D.	84.24	71.78	83.02	92.81

The Table 12 shows that, in the cases of Bulgaria and the Netherlands' science teachers' samples, there are no teachers reported about using computers for "do scientific procedures and experiments", in the option of "every or almost every lessons" (Bulgaria, the Netherlands) and in the option "about half the lessons" (the Netherlands). Here is also shown the fact that results in the Serbian students' sample give us opportunity for good prediction in some new cases of exploration of using computers in the area named as "study natural phenomena through simulations", on the base of the present conception and quality of science curricula for the Serbian primary school.

Discussion

Achievement results and their dependence of some contextual factors of teaching and learning mathematics and science through chosen subset of variables explored across four-country sample and across countries separately show that there are differences in influence of some factors of teaching and learning mathematics and science across four countries. In addition, some variables chosen for analysis of achievement influence are not reliable predictors of students' success in the fields of mathematics and science. In some cases they show predictable measures, but in some other cases these results are unexpected.

The using computers in the mathematics and science teaching, as teachers from four countries reported, imply mainly better results of students' achievement in mathematics and science. But, there are also some unpredictable results, which don't enable withdrawing of more complete conclusions in the area.

The problem of using calculators in mathematics teaching is not properly covered with the chosen items and their variables in the mathematics teachers' questionnaire. For example, when it was intention to examine by some questionnaire items purpose of using or non-using calculators in the mathematics teaching, it was intended to explore the most general facts in this area by chosen items. It was objectively supposed that sub-group of students which were not permitted to use calculators in the mathematics teaching can achieve better results in the field of mathematics, because they have had opportunity to advance some calculating abilities and skills. However, there were no items which could explore if there are developed concepts in the area of calculating, following of calculators' non-using. Given students' achievement results across countries show broader diversity and it is hard to fully explain them on the base of chosen variables as predictors of students' achievement. It represents one of the shortages seen in the structure of the mathematics teachers' questionnaire, as well as in secondary analysis generally.

Across four-country eighth grade students' sample some structure of students' achievement is made, which varies in accordance to the separate conditions in each chosen TIMSS 2003 participant country, in the area of using computers and calculators in the mathematics and science teaching. The facts obtained from the TIMSS 2003 show some differences which arise from levels of general socio-economic power and wealth in the United States, the Netherlands, Bulgaria and Serbia.

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References

Antonijević, R. (2006): Mathematics achievement of Serbian eighth grade students and characteristics of mathematics curriculum, *Journal of the Institute for Educational Research*, Vol. 38, No. 1, 225-246.

Antonijević, R. (2006): Achievement of Serbian eighth grade students in science, *Journal of the Institute for Educational Research*, Vol. 38, No. 2, 333-355.

Antonijević, R. (2006): Differences in teaching and learning mathematics and students' mathematics achievement in TIMSS 2003, retrieved from http://www.iea.nl/fileadmin/user_upload/IRC2006/IEA_Program/TIMSS/Antonijevic.pdf, 10th January, 2007.

Arora, A, M.J. Ramírez (2004): Developing indicators of educational contexts in TIMSS; in C. Papanastasiou (Ed.): *IEA International Research Conference – Proceedings of the IRC-2004 TIMSS, Volume 2* (1-18). Nicosia: Cyprus University Press.

Bos, K. & W. Kuiper (1999): Modeling TIMSS data in a European comparative perspective: exploring influencing factors on achievement in mathematics in grade 8, *Educational Research and Evaluation*, Vol. 5, No. 2, 157-179.

House, J.D. (2002): Instructional practices and mathematics achievement of adolescent students in Chinese Taipei: results from the TIMSS 1999 assessment, *Child Study Journal*, Vol. 32, No. 3, 157-178.

Keys, W. (1999): What can mathematics educators in England learn from TIMSS?, *Educational Research and Evaluation*, Vol. 5, No. 2, 195-213.

Kuiper, W., K. Boss & T. Plomp (1999): Mathematics achievement in the Netherlands and appropriateness of the TIMSS mathematics test, *Educational Research and Evaluation*, Vol. 5, No. 2, 85-104.

Mullis, I.V.S., M.O. Martin, T.A. Smith, R.A. Garden, K.D. Gregory, E.J. Gonzales, S.J. Chrostowski & K.M. O'Connor (2003): *TIMSS assessment frameworks and specifications 2003: 2nd edition*. Chestnut Hill, MA: Boston College.

Martin, M.O., I.V.S. Mullis, E.J. Gonzales & S.J. Chrostowski (2004): *TIMSS 2003 international science report: findings from IEA's trends in international* *mathematics and science study at the fourth and eighth grades*. Chestnut Hill, MA: Boston College.

Mullis, I.V.S., M.O. Martin, E.J. Gonzales & S.J. Chrostowski (2004): *TIMSS 2003 international mathematics report: findings from IEA's trends in international mathematics and science study at the fourth and eighth grades*. Chestnut Hill, MA: Boston College.

Turner, J.C. & D.K. Meyer (2000): Studying and understanding the instructional contexts of classrooms: using our past to forge our future, *Educational Psychologist*, Vol. 35, No. 2, 69-85.