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TIMSS vs Macedonian Physics Curriculum

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Abstract
Over the years, with each subsequent TIMSS assessment, the results of the Macedonian students are poorer. We analyze the primary school physics curriculum and compare the contents that were tested with TIMSS in 1999, when Macedonia had its best result. The analysis reveals that there is a large difference in content between what was tested in 1999 and the content now covered by the current physics curriculum for primary education. Concrete examples of good compliance and high non-compliance are given. Finally, guidelines are proposed to align with world trends and to improve physics curricula.

Keywords: TIMSS, assessment, physics curriculum

1. Introduction (What is TIMSS?)

TIMSS, The Trends in International Mathematics and Science Study is organized and coordinated by International Association for the Evaluation of Educational Achievement (IEA). It appeared under the name of TIMSS in 1995 for the first time, although before that it existed under different names depending on its focus and development. IEA conducts high-quality, large scale comparative studies of education across the world, providing educators and policymakers with insights into students' performance.

TIMSS is an international assessment of students' achievement in mathematics and science at fourth and eighth grade. The study does not merely rank countries, but it provides an in-depth insight into the diversity of the characteristics of education systems all over the world. Most importantly, it is classroom-based, which means that the context of teaching and learning can be related to educational outcomes, such as student achievement [1]. The international reports on these studies provide opportunity for more in-depth, secondary analyses to the participating countries. Data from these studies are freely accessible for further analyses [2] and are used for various purposes. The teaching approach can be analyzed to discover possible national patterns and to find good practices [3]. Coupled with PISA results TIMSS results analysis can give information on students' non-cognitive skills, which can give ideas for potential educational initiatives to maximize educational outcomes of students from diverse cultural and national backgrounds [4].

2. The motivation

Since 1999, when Macedonian 8th grade students took part in TIMSS for the first and had their best result, their performance is decreasing, which can be seen on Fig. 1 [5].

In order to organize the education, follow the achievements, take future steps to improve the education, every country establishes its own educational system, consisting of several elements and subsystems. In a well-built system, elements and subsystems communicate with each other, exchange data, support each other and upgrade each other, thereby upgrading the entire system. Our experience shows that there is a lack of this communication in the Macedonian educational system.

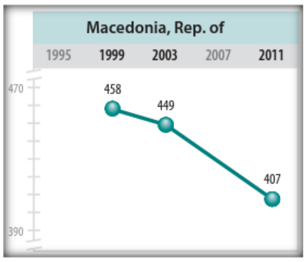

Figure 1: Macedonian 8th grade students' achievement at TIMSS assessment in 1999, 2003 and 2011 [5].

Unfortunately, the competent institutions and policy makers did not make almost any analysis of the TIMSS results and investigation in order to discover the reasons for this steep decrease of the results and to plan and take actions in order to improve the education and thus to bring the students' knowledge and skills to a higher level.

Many things changed ever since, but we have decided to analyze the content thought during 1990's and to compare it with the content thought after the reforms that happened after 2000 and with the content tested with the TIMSS assessment. For this purpose 7th and 8th grade physics curricula and textbooks from 1995 were analyzed.

3. The curriculum and its changes

In this study, the curricula and textbook contents from 2000, 2010, and 2016 were compared to the 1995 curriculum for both grades of elementary school when Physics is taught as a school subject. This comparison was made to determine the difference between the content that was studied over the years when the 1999, 2003, and 2011 TIMSS tests were conducted in the country, but it was also used to review the current program to find a way to improve the results of the next TIMSS tests.

A comparison of the contents between 1995 [6], [7], and 2000 [8] indicated that in 2000 new topics were introduced for the first time, such as Waves, Sound, Earth and Space, Atomic and Nuclear Physics, and Heat transfer, including Seismic waves, Engines, Machines, Electrical installation in the house, Electric energy price, Semiconductor devices, Sensors, and Smart machines. These are important STEM topics that can pique students' interest in science and its relevance in everyday life, as well as prepare them for teamwork, problem-solving, critical thinking, and an understanding of the scientific method. The contents of the 2000 textbook overlap by 63% with those of 1995.

Similarly, an examination of the textbooks used in 2010 [9], [10] and 1995 shows nearly the same difference as in 2000 but without the STEM content. In this case, too, the overlap between 2010 and 1995 is 63%.

Comparison of the 1995 [11] and 2016 [12], [13] curricula, revealed significant differences. Many fundamental concepts, such as Addition and Decomposition of Forces, Newton's First and Third Laws, Work, Power, Pascal's Law, Archimedes' principle, Electric Field, Capacitors, Electromagnetic Induction, Magnetic field of electric current, Spherical mirrors, Image formation by plane mirrors and spherical mirrors, Total internal reflection, Optical lenses and Image formation by thin lenses, Heat capacity Thermal Expansion of Solids and Liquids, Thermodynamic Processes, and Phase changes are no longer taught in schools. There is just 37% content overlap.

There are certain concepts that are taught nowadays, for example, hydrostatic pressure but not its equation. Voltage and resistors in a circuit are taught widely, but Ohm's law and Kirchhoff's circuit laws are not.

Currently, in the 8th grade, the elastic force is taught first, followed by a shift to body movement, and then back to force and the types of forces. Forces are taught again in 9th grade when the torque is introduced. This is an illogical transition from one content to another, thus pupils are not learning one content consistently and thoroughly.

4. Released item analysis

An investigation of the released items from the TIMSS tests throughout the years has been carried out to better understand how well the curriculum is suited to answer the demands of the test. The focus of this study were the items released in the years in which our students participated, mainly the 1999 and 2011 tests. By comparing the content of the items to the curriculum we can draw some conclusions about the quality of the curriculum.

The released items of the TIMSS1999 test [14] include 21 questions in physics. Out of them, 14 were included in the current curriculum, 3 were not. For the remaining items, classification was difficult because either the topic is included in the science courses from earlier grades, the topic was partially mentioned but not to the extent necessary for the question to be answered, or potentially it is included in the chemistry curriculum. Similarly, the 25 physics TIMSS2011 released items [15] were analyzed, and of them only 8 were included in the current curriculum, 7 were not, and 10 questions were difficult to classify. To stress how dramatic the current curriculum is different to the one that was in power in 2010 [9] [10], we repeat the same analysis against the 2010 curriculum. In this case, 11 items from the 1999 test were in the curriculum plus 5 with questionable classification, and 5 were not, while in the 2011 test 17 items were in the curriculum and only 2 were not.

If we look at a few of the items in more detail, the first thing we notice is that on almost all the released items, the students in Macedonia had scores per item below the international average. To our knowledge, there is only one instance that their answers were above the average. It is on item S05_08 of the TIMSS2011 test; one is pertaining to the heat conductivity of metals. This question is classified as "applying" by the TIMSS qualifications, but we believe that for our students it was in the domain of "knowing", because the same exact example, with the same experiment, has been used in the physics textbooks.

One example which was difficult to determine whether it is covered in the curriculum or not is the item S02_11 of TIMSS2011, where the students are expected to distinguish the kinetic and potential energy in a complicated system of a water wheel. After consulting the textbooks, we understood that even though the terms kinetic and potential energy are used, there is no explanation about what they depend on and how they can be calculated. Exploring the examples further, we noticed that there were a few questions from molecular-kinetic theory, something that was included in our previous curriculum, but not in the current one. Even with the previous curriculum, our students had difficulties in understanding this theory, so with the changes in the curriculum, we have no reason to expect our results would improve in the future.

The main conclusion to be drawn from this section is that the released items give us an opportunity to understand in detail what the demands of TIMSS are, how well our students responded in the past and how well our current curriculum comes up to the TIMSS standards. As expected from the overall achievement of our students, the situation is far from perfect.

5. Conclusions

Just by looking at Fig. 1 we can quickly determine that the educational achievements of the students in Macedonia in science are quite poor and getting worse. Understanding the reasons behind this is difficult and working towards improvements is a cumbersome task that will probably take years if not decades to successfully implement.

By reviewing the recent changes in the physics curriculum in the 8^{th} grade, especially compared to the TIMSS standards, we notice that the number of topics is steadily declining to the point where some very basic and crucial concepts are completely forgotten. Some concepts are still included in the curriculum, but the level is brought down significantly usually by omitting the mathematics behind it. Not only that, but the order of the topics is illogical and makes the teachers' job harder, let alone the students'.

For the moment the situation may seem hopeless, but improvements are possible and necessary. First, a thorough revision of the curriculum contents is required. Second, adaptation and modification of the curriculum to follow the world trends is imperative, especially one that is backed by international research findings such as those by TIMSS. Of course, the wisdom of our domestic experts should be exploited, and this could be done by establishing a national body or council of experts and educators who will be in constant communication with the national authorities concerned. Their task would include monitoring the changes and suggesting further improvements. Finally, a suitable facility for teacher training is necessary for promoting learning through inquiry and developing students' critical thinking. This would further be supported by modernizing the physics classrooms with the equipment necessary for the modern physics education.

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