

# **Content of textbooks: one of the factors affecting fourth-grader science achievements in TIMSS**

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## **Abstract**

This study analyzes science textbooks for primary school in Latvia, Kazakhstan, Russia, the Ukraine and the USA. It applies TIMSS research framework in order to assess the textbook effect on student achievements. The study observed that TIMSS science exercises for fourth-graders contained substantially larger amount of physical science topics than it is given in test descriptions. It definitely gives advantages for those students having textbooks with proportionally higher amount of topics on these subjects. The study proved that Latvian textbooks available to students and teachers during the research of 2007 were considerably better than those available in 1995. The differences were in content, presentation of subject, expected student activities, and visual layout. The study concludes that the changes in textbooks are one of the causes for increased achievements of Latvian students. By performing thorough analysis of textbooks, one can establish their effect on student average achievements in sciences in several TIMSS participating countries and explain differences and changes in achievements with this effect. One can conclude that textbooks are definitely one of the factors affecting student achievements.

## **Keywords**

Sciences at primary school, textbooks, TIMSS research

## **Aim of the Study**

In TIMSS 1995 research, Latvian student average achievement was 499 points (scale mean – 500, standard deviation – 100), it was 537 points but in TIMSS 2007 research which is generally very high growth from average to excellent results. In international comparative studies in general and in TIMSS research in particular, it is very difficult to explain differences in student achievements across countries and over time. Of course, these changes are not caused by one factor only; they are caused by a combination of factors. The aim of this study is to analyze science textbooks for primary school in Latvia, Kazakhstan, Russia, the Ukraine and the USA within the framework of TIMSS in order to assess their potential effect on fourth-grader achievements and their changes in sciences.

## **Theoretical Background**

Despite the formation and development of different new study methods, one cannot exaggerate the importance of textbooks at school. TIMSS 2007 research shows that 52% of teachers use textbooks as the primary study material, but 34% use it as a supplement. In Latvia, these numbers are noticeably higher: 79% and 21%, respectively. There are no teachers in Latvia not using textbooks. In Iran, for instance, completely all teachers use textbooks as the primary study material. Yet, there are only a couple of countries where teachers almost do not use textbooks. These are Australia and New Zealand among countries participating in TIMSS 2007 (Martin et al., 2008).

Therefore, textbooks most commonly are the ones determining the content of science subjects, topics to discuss, proportion of different topics and how the subject is taught at

school. It seems that study content can be precisely determined by analyzing education standard: a specific and obligatory document in many countries. Often, however, these documents are very conceptual and generic, they mention many topics and themes for study content, but they do not provide particular percentage of these topics. This is also the case of Latvia. In fact, a textbook is a bridge from the planned education content published by a ministry to the education program content implemented at schools. It correspond to the extended TIMSS curriculum model: Intended curriculum (intentions, aims and goals) → Potentially implemented curriculum (textbooks and other organized resource materials) → Implemented curriculum (strategies, practice and activities) → Attained curriculum (knowledge: ideas, constructs, schemes) (Schmidt et al., 1997, Valverde et al., 2002; Johansson, 2005).

### **Scheme of Textbook Analysis**

Textbooks were analyzed by applying methodology developed by TIMSS 1995 (Schmidt et al., 1997). First of all, science textbooks were divided in units that were numbered in sequence. In most cases, each unit corresponded to one chapter, one lesson or one topic of a textbook. The unit amount varied from several pages to twenty or thirty pages.

Dividing in these comparatively wide units simplifies analysis, but it does not allow finding out structure details necessary for further description. Therefore these units were broken down into smaller structures – blocks. Usually, a block was formed as one or more paragraphs united by a theme, as one figure or group of figures. The blocks were subdivided in 10 types – (1) narrative (the most common block type in science textbooks), (2) narrative related to another block, (3) unrelated narrative, for example, separate framed texts to supplement or explain a topic, (4) a figure related to other block (supplementing text block), (5) an unrelated figure, (6) a question or exercise related to other block, (7) an unrelated question or exercise, (8) an activity (for example, laboratory work, observation), (9) an example (for instance, described experiment), (10) other type of block, not qualified as any of the above. The blocks were numbered within each unit.

Each block was coded using three types of codes according to the framework developed in TIMSS 1995 research. Type 1 code indicates at the content. It is mostly a three-digit code where the first digit describes the branch of science (e.g. code 1 applies to Earth science). The second digit narrows down the topic, e.g. code 11 applies to the topic ‘Characteristics of Earth’. The third digit in the code presents a narrower subtopic, e.g. code 111 applies to the subtopic on the components of Earth (kernel, mantle, crust etc.). Type 2 code indicates at the activities students are expected to perform, e.g. comprehension of complex information, performing experiments etc. Type 3 code applies to perspectives, e.g. establishing positive attitude towards natural sciences.

Each block is coded with at least one Type 1 or Type 2 code. These codes can be more but normally not more than four. It is explained by the fact that one block can contain complex information that corresponds to several codes. For instance, a paragraph on plant reproduction has to be coded with a code corresponding to plants and another code corresponding to reproduction processes. While coding, the number of content codes for one block considerably varied across different textbooks. It also characterizes the complexity and thoroughness of the text. 48–74% of the blocks were coded with one code (on average 55%), 26–42% of the blocks were coded with two codes (on average 35%), 3–17% of the blocks were coded with three codes (on average 9%), 1–4% of the blocks were coded with four codes (on average 2%). The average number of content codes per block was 1.6. In TIMSS 1995 research, the average number of content codes in science textbooks for fourth-graders was 1.4 (Schmidt et al., 1997).

Data analysis included science textbooks for third- and fourth-graders as the authors believe that the knowledge acquired at the third grade is an important base for student

achievements at the fourth grade. Data analysis included textbooks from Latvia, Kazakhstan, Russia, the Ukraine, and the USA. The choice of countries was determined by several factors with the most important factor being the participation of the country in the first population of TIMSS. The authors were interested in the directions of textbook developments in the last 20 years after the transition from very centralized education system of the USSR to several more decentralized systems. They were also interested in the comparison to the USA that has always had high student achievements in natural sciences. All countries investigated but the Ukraine showed student achievements in sciences considerably above the average in TIMSS 2007 research, and the differences in achievements were not statistically different. The achievements of Ukrainian students were substantially lower. From the countries listed above, only Latvia and the USA participated in TIMSS 1995. The achievements of Latvian students had substantially improved in 2007 (56 point difference), but the achievements of American students stayed unchanged.

From the editions in Latvia, the only set of textbooks that was used in 1995 when the first TIMSS research took place was examined (authors: L.Karule and A.Pastore, publisher: Zvaigzne ABC), and both textbook sets disposable for students and teachers in 2007 (publishers: Lielvārds and Zvaigzne ABC). There were only a few textbook sets available in the Ukraine and Kazakhstan in 2007, the authors chose the most popular of those. The students in these countries study in national and Russian language using identical translated textbooks (the original is in Ukrainian in the Ukraine and it is in Russian in Kazakhstan). There are some textbook sets available in the USA and Russian Federation, only the most voluminous were chosen (publishers: McGraw-Hill School Division and Prosvescenie, respectively). The list of textbooks analyzed is attached to the list of references.

### Analysis of TIMSS items

Of course, student achievements in sciences to large extent depend on items and the content included in them. Therefore, TIMSS items were analyzed at the first place. Science exercises for TIMSS tests can be grouped according to their content by science branches, by topics and subtopics. Research descriptions provide the classification according to science branches by TIMSS study center (Martin et al., 1997; Martin et al., 2008), yet, the authors used the methodology described above to code the exercises in 1995 and 2007 by their content. The results obtained are very surprising – there were substantially more exercises containing physical subtopics (40% in both exercise sets analyzed) than presented (31% in 1995 and 35% in 2007). The summary is presented in Table 1 below. Despite that the authors of these items try to prepare them corresponding to one content category, not always they succeed in doing this. Surprisingly, both research show exercise content by coding according to science branches basically equal. Despite the widespread stereotype in Latvia that primary school students should study lakes, rivers, mountains, plants and animals, TIMSS research mostly focus on physical sciences (e.g. physical characteristics of substances and characteristic changes, energy types and sources, magnetism, light).

Table 1. The content by science branches of TIMSS tests in sciences for fourth-graders

Content of TIMSS tests	TIMSS 1995		TIMSS 2007	
	By description	By content codes	By description	By content codes
Life science	42%	37%	44%	38%
Physical science	31%	40%	35%	40%
Earth science	18%	18%	22%	18%
Environmental science, protection of nature and science nature	9%	5%		5%

### ***The comparison of science textbooks by content***

Figure 1 illustrates the comparison of TIMSS 2007 exercises and science textbooks by content (science branches). It corresponds to the first digit in block content codes. The largest differences are among physical science subtopics. While the analysis of TIMSS exercises show that 40% of all codes are related to physical sciences, these topics were not present in textbooks used in Latvia (LVA K) in the beginning of nineties. Also in the textbooks by R.Arājs and co-authors (LVA A), physical sciences are twice less present than in TIMSS exercises. The textbook by L.Karule and A.Pastore (LVA K) describe many life science topics as well as topics related to natural resources, nature protection and other science branches. Figure 1 clearly shows that American textbooks and Latvian textbooks published by Lielvārds (LVA V) are the closest to TIMSS exercises. The analyzed textbooks from Kazakhstan, the Ukraine and Russia were very similar.

Looking at science branches in TIMSS 2007 research, Latvian student achievements were higher in physical sciences when comparing to other science branches; Kazakhstan student achievements – Earth sciences, Ukrainian student achievements – life sciences (Martin et al., 2008). The choice of textbooks is very limited in Latvia, Kazakhstan, and the Ukraine, therefore a large proportion of students and teachers (up to 50%) use the textbooks analyzed and thus we can easily explain the differences observed. In Latvian textbooks, on average 26% of a textbook is devoted to physical sciences, that is a comparatively high indicator (12% in Kazakhstan, 13% in the Ukraine). Kazakhstan focuses more on Earth sciences (34%) that can be explained by the large diversity of the territory and the large resources to acquire mineral deposits. The Ukrainian textbooks concentrate more on life sciences (45%) that are less covered in Latvia and Kazakhstan (30% and 37%, respectively).

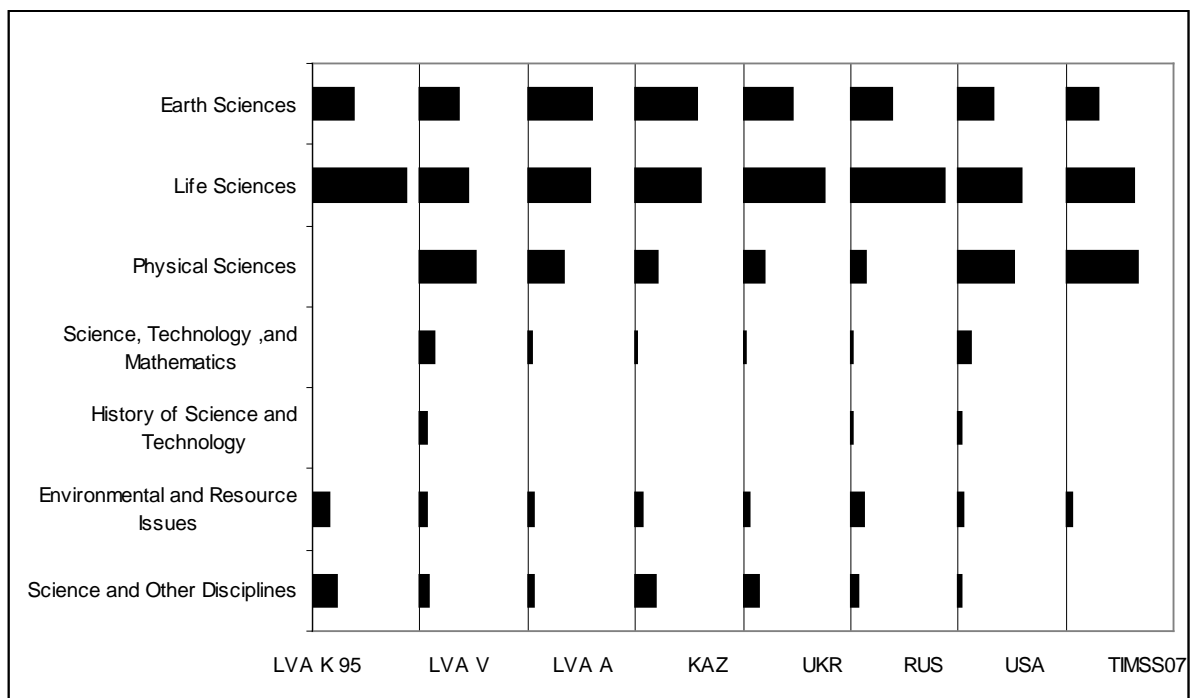


Figure 1. The comparison of TIMSS 2007 research exercises and science textbooks by the proportion of science branches covered. (Latvian textbooks are marked by the initial of the first author's surname)

Figure 2 shows the comparison of TIMSS exercises and Latvian science textbooks by topics contained. It corresponds to the first two digits in the block content codes. Figure 2 depicts only those topics that are present in the textbooks or TIMSS 2007 exercises analyzed. In the

beginning of nineties, Latvian textbooks put emphasis on the topics related to the characteristics of Earth (mountains, lakes, rivers etc), the diversity and formation of live beings, as well as their interaction. One can see that the latest Latvian textbooks are more similar to TIMSS exercises by content. It must be one of the reasons for the considerable increase in the achievements of Latvian students. The most similar by content textbooks among the textbooks analyzed are the textbooks in the USA and Latvia (LVA A and LVA V).

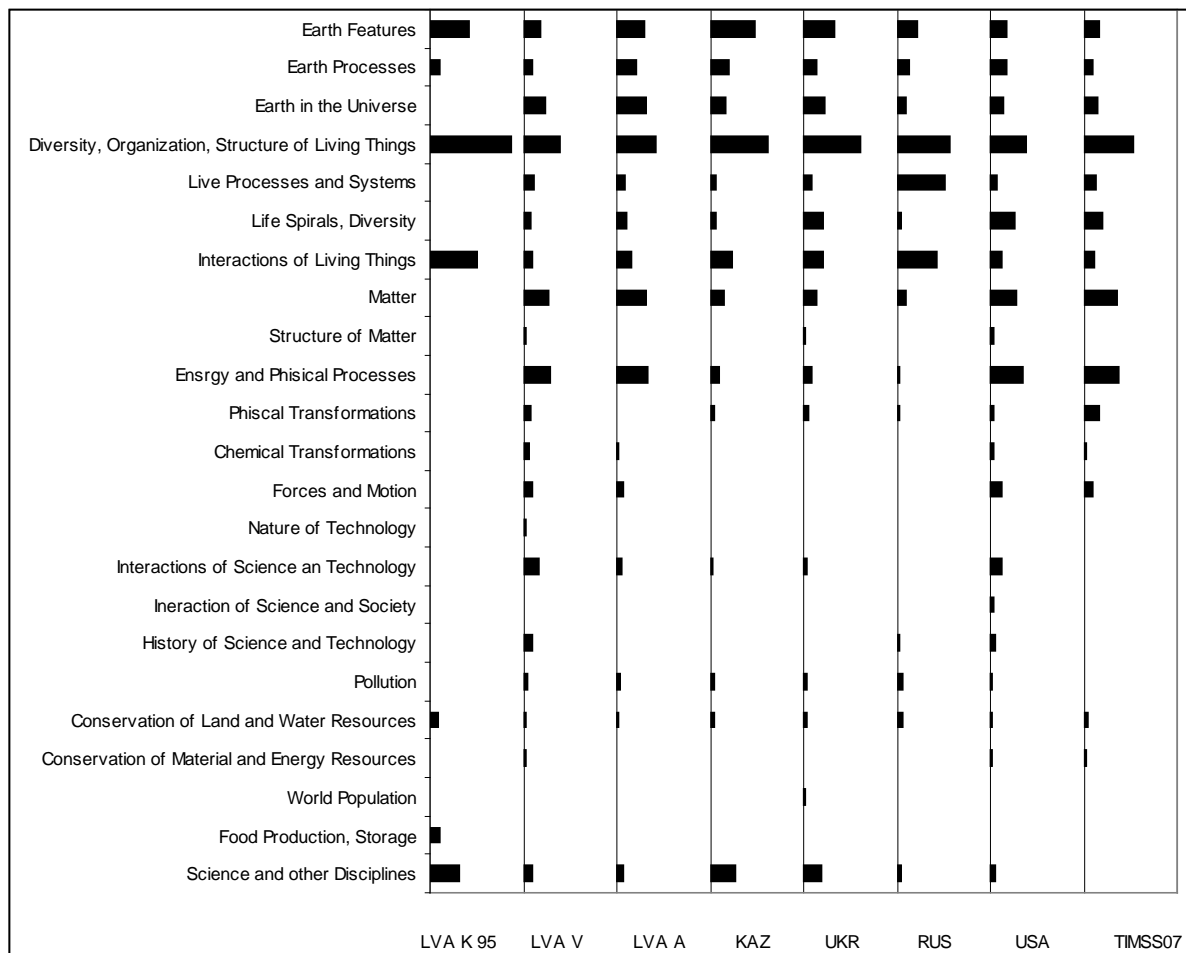


Figure 3. The comparison of TIMSS 2007 research exercises and science textbooks by topics contained. (Latvian textbooks are marked by the initial of the first author’s surname)

In order to compare textbooks with TIMSS exercises by content, the distance from the textbook content to TIMSS exercise content was calculated. The distance calculations were done taking into account the percentage each topic or subtopic covers the whole textbook. The calculations were made three times using (1) the first digit of the content code (science branch), (2) the first two digits (topic), and (3) all three digits (subtopic). Table 2 summarizes the calculations. By content, the analyzed textbooks from the USA and the textbooks from Latvia used by teachers and students in 2007 are the closest to TIMSS items. The textbooks from Latvia that students used in 1995 are located the farthest. It shows with certainty that the change of textbooks in Latvia is definitely one of the factors causing the increase in student achievements.

Table 2. Content distances from textbooks to TIMSS 2007 items (1 digit code – science branch, 2 digit code – topic, 3 digit code – subtopic)

Country	1 digit code	2 digit code	3 digit code
USA	.983	.913	.707
LVA V	.961	.880	.742
LVA A	.788	.857	.680
UKR	.732	.733	.638
RUS	.687	.532	.499
KAZ	.663	.641	.517
LVA K 95	.511	.493	.346

Content analysis alone, however, does not allow explaining the relatively low achievements of Ukrainian students. One can explain them by performing further textbook analysis. Here we are considering only Ukrainian textbooks in comparison to other textbooks analyzed. First of all, the little volume of textbooks should be stressed: the total number of pages in textbooks for the third and fourth grade is 352 of which only 202 pages are devoted to natural sciences, the rest of pages are devoted to social and human sciences. Textbooks from Russia and Kazakhstan have similar structure that contains both natural and other sciences, but the volume devoted to natural sciences is substantially larger. Of course, it is very difficult to compare it to the analyzed American large sized textbooks having 910 pages. In a Ukrainian textbook for the third grade, only 11 lessons cover natural sciences and 30 lessons for the fourth grade that is less than in any other set of textbooks analyzed. If the textbook structure is examined by the block types (narrative, figures, exercises and activities) contained, then Ukrainian textbooks contain comparatively few figures (14% of all blocks, average among all textbooks – 30%), figures are usually drawings, photos are unlikely. It has a lot of questions and exercises (37% versus 19% on average). The textbook uses small-sized letters, only 3 colors (black, blue and red). Overall, one can observe that the Ukrainian textbooks analyzed are very different from all the other textbooks analyzed and these differences are not positive in terms of opportunities to master sciences.

### ***Conclusions***

It was concluded that TIMSS exercises in natural sciences for the fourth grade cover considerably more physical science topics than it is given in test descriptions. It definitely is advantage for those students using textbooks covering a larger proportion of topics related to this subject.

The content of TIMSS exercises is very similar to the content of the analyzed textbooks from the USA. It can explain the high achievements of American students demonstrated in all cycles of TIMSS research.

The analysis of textbooks by content alone does not provide strong conclusions on the differences in student achievements across countries; further textbook analysis by volume, structure, typographic design is necessary.

After the analysis of natural science textbooks for primary school in Latvia available for teachers and students during TIMSS 1995 and TIMSS 2007 research, we can clearly claim that the changes in natural science textbooks is one of the causes for improved student achievements. The textbooks have changed by their content, by presentation of topics, by design. Their content has become more similar to TIMSS exercises; they have less narrative and more activities for students to perform. The textbooks have become more colorful, with more photos; they more often invite students to perform research activities.

This study concludes that textbook is definitely a factor that determines student achievements.

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