Parengta įgyvendinant Nacionalinės švietimo agentūros projektą
Nr. 09.4.1-ESFA-V 713-02-0001 „Profesinio mokymo ir mokymosi visą gyvenimą informacinių sistemų ir registrų plėtra“, finansuojamą Europos Sąjungos struktūrinių fondų lėšomis

Fifteen-year-olds and eighth graders' mathematics and science skills, theoretical models of international PISA-TIMSS studies, and their links with educational programs and textbooks: a secondary data analysis

SUMMARY

Access via internet: https://t3n.de/news/3-gruende-erfolgreiche-setzen-1191810/

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Kaunas – Vilnius
2023

The aim of the study is to analyse the relationship between the mathematical and science achievements of Lithuanian 15-year-old and 8th grade pupils in the international PISA and TIMSS surveys and the national curriculum content, based on the theoretical models of the PISA and TIMSS surveys, the national curriculum content documents, and the teaching tools.
Objectives:
1.1.1. To develop a Secondary Analysis Methodology based on the theoretical models of the international studies PISA and TIMSS (Grade 8), the scientific literature, the General Framework for General Education approved in 2008, the draft curricula for mathematics and science in basic education for 2021, the draft Competences and Child Development Inventories, and considering the requirements in points 2.3 and 2.4.
1.1.2 To analyse the theoretical models of the PISA 2018 international test for 15-year-olds and the TIMSS 2019 international test for Grade 8 mathematics, identifying differences, similarities, and links between the two models.
1.1.3. To analyse the theoretical models of the PISA 2018 for 15-year-olds and the TIMSS 2019 for Grade 8 science, identifying the differences, similarities, and links between the two models.
1.1.4. To analyse the 2008 mathematics core curriculum for basic education in relation to the theoretical models of the international studies PISA 2018 and TIMSS 2019 in the field of mathematics.
1.1.5 To analyse the 2008 Science Framework (Basic Education) and the Social Geography Framework (Basic Education) in relation to the theoretical models of science in the international studies PISA 2018 and TIMSS 2019.
1.1.6. To analyse the educational tools (textbooks) for learning mathematics in basic education in relation to the theoretical models and task features of the PISA 2018 and TIMSS 2019 surveys.
1.1.7 To analyse the educational tools (textbooks) for learning science and geography in basic education in relation to the theoretical models and task characteristics of PISA 2018 and TIMSS 2019.
1.1.8. Using the results of PISA 2018 and TIMSS 2019 in eighth-grade mathematics and natural sciences, draw conclusions on the links between the theoretical models used in international studies and the educational standards and textbooks approved in Lithuania.
1.1.9 To analyse the project 2021 Framework Curriculum for Primary and Secondary Mathematics in relation to the theoretical models for mathematics in the international studies PISA 2018 and TIMSS 2019.
1.1.10. To analyse the draft 2021 Science Primary and Primary General Education Curricula; Biology, Chemistry, Physics Primary General Education Curricula, and the project of the Geography Primary General Education Curricula in the field of Social Studies, linking it to the theoretical models for science in the international studies PISA 2018 and TIMSS 2019.
1.1.11. To analyse the Competences (Communication, Cultural, Creative, Cognitive, Citizenship, Social, Emotional and Healthy Lifestyle) and the Child Development Inventories in relation to the theoretical models of the international studies PISA 2018 and TIMSS 2019.

Theoretical background of the study, empirical basis, methodology

The report provides the detailed comparative analysis of the philosophies and diagnostic approaches of the TIMSS and PISA projects and their comparison with the national education standard. B. Bloom's learning levels and N. Web's depth of knowledge (DoK - Depth of Knowledge) as well as other relevant didactic constructs related to educational diagnostics and curriculum development are revealed. There are also evaluated national educational documents. 1. "The description of child development and competencies 2008". 2. "General programs/standards of mathematics and science education 2021/2022".

The criteria for subject didactic assessment of science and mathematics textbooks based on expert assessments are justified and described. To evaluate the 8th Grade science and mathematics textbooks, 28 experienced teachers were involved as experts. Some of them had confirmed expert qualifications and/or doctoral degrees. Experts evaluated the textbooks according to 19 primary indicators and five aggregate diagnostic blocks.

Conclusion and consequences

The detailed conclusions that are based on the research findings are formulated in the research report. You will find the names of the text sections of the conclusions and comments below as well. While relying on them it is possible to assess the content of the formulated conclusions and the corresponding thematic-problematic field.

1. Conclusions from the comparison of the philosophical concepts of PISA 2018 and TIMSS 2019
1.1 The PISA 2018 and TIMSS 2019 studies, their philosophies and methodological approaches have important similarities.
1.1.1 The scientific genre of both studies (TIMSS and PISA) is the so-called Large-Scale Study.
1.1.2 The comparative studies of PISA 2018 and TIMSS 2019 use almost identical dependent and independent research variables. In terms of content, PISA is broader in scope (diagnosing reading proficiency).
1.1.3 TIMSS and PISA studies traditionally share a high methodological and cultural standard.
1.1.4 The TIMSS and PISA studies are characterized by almost identical goals:
(a) to draw indirect but objective databased conclusions about the functioning of the respective countries (economies) and their education systems;
b) to provide a creative impulse for the reform and improvement of educational systems through the internationally comparative assessment of educational performance.
From this point of view, the TIMSS and PISA projects have been performing a public service of global importance for many years, both for individual countries and for the international community as a whole.

1.1.5 Both studies (TIMSS and PISA) provide an indirect comparative assessment of the respective country's level of well-being, potential and investment attractiveness.

1.1.6 Both projects (and the PISA project in particular) attempt to conceptualize the constructs "learning performance" or "knowledge/learning", their variants of expression and levels of development, drawing on classical concepts recognized by the scientific community such as Bloom's Taxonomy and N. L. Webb's Depth of Knowledge (DoK).

1.1.7 Despite the differences in some philosophies and theoretical models of the compared projects, both TIMSS and PISA measure and diagnose the same construct - learning achievement, as evidenced by the extremely high correlation between the estimates of both projects. The coefficient of determination is high - r^2 =0.76, which shows that the predictive power of the estimates for both projects matches as much as 76 percent.

1.8 Notably, Lithuania's achievements in the TIMSS project are relatively better than in the PISA project. The conditionally better achievement of Lithuania in TIMSS can hypothetically be partly explained by the fact that the previous content and standards of science and mathematics education in our country were relatively more sensitive to the philosophy and diagnostic concept of TIMSS, not of PISA.

1.2 The philosophies and theoretical models of the TIMSS 2019 and PISA 2018 projects have some fundamental differences.
1.2.1 According to the TIMSS philosophy, mathematical and scientific knowledge means a high depth of knowledge, knowledge of the sub-disciplines and topics of the respective science. The focus is on the content of academic knowledge to be mastered by students. Such moments as the relationship between theory and practice, the application of knowledge and its practical benefits, problem solving, etc., can appear in tests only because such moments are naturally present to some extent in science and in the research process itself. The knowledge ideal and the paradigm of test item construction of PISA are based on a somewhat different philosophy. The most important thing here is the ability of students to solve specific problems and challenges that may arise in real-world activities, in everyday life, in their careers. These problems and challenges must be solved with the help of mathematical and scientific knowledge, its application, interdisciplinary integration, modelling, including application in new situations, transfer to other contexts. In the PISA tests, there is a moment like problem solving when complete information is not available, when the tests deliberately provide for the possibility of choosing different ways and methods to solve the problem. Relatively more than TIMSS, PISA emphasizes the uncertainty, openness, probability, multiple data manipulation, analytical work with incomplete information, etc. of the application of mathematics and science.

1.2.2. The TIMSS project is more sensitive to the specific content of school curricula than the PISA project in the construction of test items. TIMSS is perceived more as an academic-scientific project whereas PISA is regarded as an educational policy, reform and emancipatory project.
1.2.3 Even though TIMSS is formally an interdisciplinary project, it falls far short of the interdisciplinary and intercultural claim that characterizes PISA. Compared to TIMSS, the PISA project is characterized by a much stronger focus on holistic education. This means that in the PISA philosophy, not only the cognitive depth of knowledge and learning, but also the non-cognitive qualities of the educated, such as ideological values, especially ecological values, ethics, responsibility, tolerance, citizenship, etc., are considered to be the essential outcome of education. In this respect, the PISA project offers a radical innovation with respect to traditional cognitive studies. It is a theoretical and methodological decision to try to measure the so-called global competencies. This innovation corresponds to the spirit of the times and the challenges of modern society. At the same time, it creates the need to change the methodological identity of the project without proper conceptual preparation.

2. Conclusions are derived from the analysis of the national curriculum in relation to the PISA 2018 and TIMSS 2019 studies.
2.1 Concerning the national "regulations on the child's competence development" and their links with the PISA - TIMSS philosophy and the preparation of test aids.
2.1.1 The current regulations of competencies and child development has modern claims in terms of educational philosophy and harmonization with TIMSS and especially with PISA philosophy.
2.2 On the philosophy and conceptualization of mathematics and science education. General curricula, links to PISA and TIMSS.

2.2.1 On the refinement of proficiency levels in general and threshold proficiency criteria in general programs. Compared to 2008, analogous to the year.
The latest (2021/2022) general curriculum projects for mathematics and science, when compared with the analogous curriculum projects of 2008, show some positive change and greater convergence with the philosophy of TIMSS and PISA in particular, and with modern educational philosophy in general. "Critical knowledge" and, accordingly, the provision of feedback to the textbook developers and the teacher on the lowest level of the subject matter to be mastered is

extremely important. Where is the limit, the criterion, when to assume that the student or the whole group has not yet reached the critical limit of knowledge and material absorption? Especially since in the system of modern general education there is practically no phenomenon and instrument like the student's falling behind in the same class. The criterion "threshold" is important not only for school education and performance diagnostics. This is a universal category of practical educational diagnostics. Often, when the applicant does not meet the examination requirements, a principle question arises. In other words, under what failed criteria is the applicant denied the delivery of the driver's license or certificate?

2.2.2. Concerning the clarification of the autonomy degree of the pupil in the acquisition of learning materials and in the completion of tasks in the general curriculum. Another positive aspect of the 2021/2022 General Programmes are the consistent attempt to clarify the degree of autonomy of learning activities (and thus of the tasks used to diagnose achievement).
2.3. On the links between the textbooks for mathematics and science education of the 8th grade and philosophy and diagnostic concepts of the PISA and TIMSS
2.3.1 For a more detailed expression of the parameters of the threshold knowledge criteria in textbook material:
According to the experts, the majority of the teaching material in the textbooks, in accordance with its degree of difficulty, is oriented to the intermediate achievement group, whose knowledge is of the middle level. There is a relative lack of content oriented towards the extremes of learning achievement. The relative lack of textbook material reflecting threshold knowledge can be defined as a limitation of the educational content that has existed so far, and at the same time as a missed opportunity for future improvement.
2.3.2. For a more detailed expression of the parameters of knowledge levels and depth of knowledge in textbook material
2.3.3. For the basic components of human culture and educational content to be more fully expressed in textbook content
2.3.4. Reflecting the emotional values and worldview components of education in the content of textbooks
2.4. The relevance of the national curriculum content in mathematics and science in terms of the criterion of didactic accessibility of learning materials

Eight detailed recommendations are formulated. They are addressed to the National Agency for Education, specialists involved in the development of educational content, the central government - the Ministry of Education, the Government, and the Seimas. The titles of the sections of the recommendations are given below. They give an indication of the thematic-problem field of the recommendations.

1. Regarding on the diversification of the national educational content and learning materials
2. Due to the clarification of threshold knowledge criteria and increased attention of educational content developers to the weakest students
3. Due to the need to clarify the existing descriptions in the frameworks (2021-2022), fill them with proven examples and illustrations from real school educational practice
4. The necessity to continuously test the educational content and textbook materials in real school education practice in an empirical-experimental way and to provide sufficient resources for such testing, to mobilise networks of cooperating teacher-educators, to create a coordinating organisational platform, e.g. on the basis of the National Agency for Education.
5. On the organization of international comparative monitoring of educational standards and educational materials.
6. Regarding the initiation of studies to monitor the quality of teaching in the country, regarding the initiation of a study on video monitoring of lessons at the national level.

7. Regarding methodological-organizational risks of the PISA project
8. On the advantages and limitations of orienting national curriculum developers to the philosophy of PISA and TIMSS.

The research report covers 191 pages, and the results are presented in 64 tables and 32 figures.

Abbreviations used in the report:
NŠA - National Agency for Education
PISA - Programme for International Student Assessment
TIMSS - Trends in International Mathematics and Science Study.
OECD/EBPO – Organisation for Economic Co-operation and Development
ŠMSM – Ministry of Education, Science and Sport
MDS - Multidimensional Scaling