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Obsah

Editorial

Speciální číslo časopisu *Scientia in educatione* nazvané „Srovnávací studie matematického a přírodovědného vzdělávání v České republice a ve vybraných evropských zemích“ se zaměřuje na porovnání přístupů ke vzdělávání v matematice a přírodovědných oborech. Celkem osm článků přináší fundované informace o podobnostech a rozdílech týkajících se zařazení matematiky a přírodovědných oborů do struktury národních kurikul, hodinových dotacích pro jednotlivé vzdělávací obory či informace o metodách a přístupech ke vzdělávání pro úroveň nižšího sekundárního vzdělávání. Autoři rovněž detailně analyzují vzdělávací obsah přírodovědných oborů a matematiky ve vybraných kurikulech.

Články autorských týmů pod vedením Vlasty Moravcové, Terezy Jedličkové, Petra Kácovského, Jany Poupové a Evy Stratilové Urválkové se zaměřují na porovnání matematických a přírodovědných kurikul České republiky s kurikuly Slovinska, Estonska a Polska. Jedná se o země s podobným kulturním a historickým vývojem, které se v mezinárodním šetření PISA umisťují v matematické a přírodovědné gramotnosti nejen statisticky významně nad průměrem zemí OECD, ale také nad výsledky České republiky. Články představují unikátní soubor studií, neboť analyzují matematiku a téměř všechny přírodovědné obory – fyziku, geologii, chemii a přírodopis obsažené ve vzdělávací oblasti Člověk a příroda českého národního kurikula. Článek Jakuba Holce věnuje pozornost analýze vybraných témat biologického vzdělávání v pojetí národních kurikul Skotska a Anglie, a přináší tak další střípek poznání v oblasti vzdělávání v přírodopisu. Všechny články mohou být inspirací při uvažování o národním kurikulu v daných oborech.

Kromě komparativních studií speciální číslo mapuje vývoj vzdělávání v matematice a přírodovědných oborech v České republice v posledních třiceti letech. Cílem článků autorských týmů vedených Svatavou Janouškovou a Jarmilou Robovou je ukázat vývoj paradigmat vzdělávání v těchto oborech na základě kvalitativní analýzy relevantních strategických a koncepčních dokumentů Ministerstva školství, mládeže a tělovýchovy České republiky. Oba tyto články sumarizují důležité milníky v matematickém i přírodovědném vzdělávání, které mohou pomoci při orientaci odborné veřejnosti i decizní sféry v úvahách o dalším směřování matematického a přírodovědného vzdělávání.

Informace a poznatky publikované v tomto speciálním čísle časopisu mohou být východiskem pro další výzkumy v dané oblasti. Většina článků je napsána v anglickém jazyce, a může tedy zasáhnout širší čtenářskou obec a poskytnout i zahraničním čtenářům základní přehled o situaci v přírodovědném vzdělávání z hlediska kurikula v České republice.

Svatava Janoušková
Leoš Dvořák
Naďa Vondrová
editoři

Editorial

A special issue of the *Scientia in educatione* journal entitled "Comparative Study of Mathematical and Science Education in the Czech Republic and in Selected European Countries" focuses on comparing approaches to education in mathematics and science. A total of eight articles provide well-founded information about the similarities and differences related to the inclusion of mathematics and science in the structure of national curricula, hourly allocation for individual fields of study or information on methods and approaches to education at lower secondary level. The authors also analyse in detail the educational content of science and mathematics in selected curricula.

Articles by the author teams led by Vlasta Moravcová, Tereza Jedličková, Petr Kácovský, Jana Poupová and Eva Stratilová Urválková focus on comparing the mathematical and science curricula of the Czech Republic with those of Slovenia, Estonia and Poland. These countries all share similar socio-cultural historical developments, and yet in the international PISA survey Slovenia, Estonia and Poland rank not only statistically significantly above the OECD average in the mathematical and scientific literacy, but also above the Czech Republic. The articles represent a unique set of studies, as they analyse mathematics and almost all scientific disciplines – physics, geology, chemistry and biology contained in the educational area Man and Nature of the Czech national curriculum. The article by Jakub Holec pays attention to selected topics in biological education in Scotland and England's national curricula, thus expanding knowledge in the field of biology education. The contribution to the Special Issue provides inspiration for thinking about the relationships and balance between the particular disciplinary fields in the national curriculum.

In addition to comparative studies, the Special Issue maps the development of education in mathematics and science in the Czech Republic over the past thirty years. The aim of the articles by the authorial teams, led by Svatava Janoušková and Jarmila Robová, is to show the development of education paradigms in these fields based on a qualitative analysis of the relevant strategic and conceptual documents of the Ministry of Education, Youth and Sports of the Czech Republic. Both of these articles summarize important milestones in mathematical and science education, and can serve to orient the professional public and decision-makers in the process of considering the direction and development of mathematical and science education.

The information and knowledge published in this Special Issue may provide the basis for further research in the field. Most articles are written in English for wider audience accessibility and provide foreign readers with a basic overview of the situation in science education regarding the curriculum in the Czech Republic.

Svatava Janoušková
Leoš Dvořák
Naďa Vondrová
editors

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A Comparison of Lower Secondary School Education of Mathematics in the Czech Republic and Selected Countries with Respect to Curriculum Documents

Vlasta Moravcová, Petra Surynková, Jana Hromadová

Abstract

Results from the PISA international surveys in 2012 and 2015 show that the performance of Czech pupils in mathematics was statistically comparable with the OECD average. However, in the long-term comparison, the results appear to have statistically worsened in the Czech Republic. The PISA score of other European countries with similar economies in terms of GDP and common historical-cultural development, namely Estonia, Poland, and Slovenia, was higher or even significantly higher. The search for the causes of this leads, among other things, to the study of the mathematics curricula of these states. Our paper gives a brief overview of the education systems of the selected countries, while also conducting a qualitative comparative analysis of relevant curriculum documents for lower secondary education. We place emphasis on the differences between the Czech curriculum and the curricula of the other countries. This is explored with the overall aim of formulating educational objectives pertaining to mathematics learning, the subject matter and its division, and required learning outcomes. In the last chapter we present the most significant differences (the lowest number of mathematics lessons, the absence of general mathematical goals and competencies, the lack of emphasis on home preparation of pupils, the absence of unified testing and insufficiently detailed learning content and outcomes), which could be an inspiration for improving the Czech mathematics curriculum.

Key words: ISCED 2, curriculum, comparative education, mathematics education.

Porovnání přístupu České republiky a vybraných zemí k výuce matematiky na úrovni nižšího sekundárního vzdělávání z pohledu kurikulárních dokumentů

Abstrakt

Ve srovnávacích testech PISA z let 2012 a 2015 výsledky žáků České republiky v testování matematické gramotnosti odpovídaly průměru zemí OECD, v dlouhodobém srovnání se tyto výsledky mírně zhoršují. Jiné evropské státy se srovnatelným HDP a podobným sociálně-kulturním vývojem, konkrétně Estonsko, Slovinsko a Polsko, však dosahují v uvedených letech nepatrně či významně lepších výsledků. Pátrání po příčinách tohoto rozdílu vede mimo jiné ke zkoumání kurikula matematiky těchto států. V příspěvku předkládáme stručný přehled vzdělávacích systémů vybraných zemí a kvalitativní srovnávací analýzu příslušných kurikulárních dokumentů pro nižší sekundární vzdělávání. Důraz je kladen na odlišnosti od kurikula České republiky zejména s ohledem na formulace cílů, řazení a obsah učiva a požadované výstupní úrovně žáků. V poslední kapitole uvádíme nejvýznamnější zjištěné rozdíly (nejnižší počet hodin výuky matematiky, absence obecných matematických cílů a kompetencí, chybějící důraz na domácí přípravu, absence jednotného testování a nedostatečně podrobný obsah a výstupy vzdělávání), které by mohly být inspirací pro zkvalitnění českého kurikula matematiky.

Klíčová slova: ISCED 2, kurikulum, srovnávací pedagogika, vzdělávání matematice.

The contribution compares four countries in the European Union with the common historical-cultural development: the Czech Republic, Estonia, Poland, and Slovenia. The selected countries passed through similar historic events in the 20th century – experienced a number of war conflicts, were occupied several times, their borderlines changed many times. The situation stabilized after the Second World War. Afterwards, all four countries fell within the Soviet sphere of influence (Estonia was part of the Soviet Union) and their economies were centrally planned and tightly linked to the Soviet Union. At the turn of the 1980s and 1990s, the economic systems were changed to a market economy and the systems of government became democratic. In consequence of forty-some years of centrally planned economies the selected countries have similar economic problems – they lag further behind the most developed countries in the European Union and the economies recover slowly. These facts are obvious from the *National Average Wage* and from *Gross Domestic Product* (GDP), that was 89% in the Czech Republic, 77% in Estonia, 70% in Poland and 85% in Slovenia in 2017[1] (Eurostat, 2017a, b). Education directly affects economic growth and vice versa.

All four countries joined the OECD (the *Organization for Economic Co-operation and Development*) – the Czech Republic in 1995, Poland in 1996, Estonia and Slovenia in 2010. As member countries of the OECD, they started monitoring and measuring the educational outcomes because these may have an impact on the economic growth of the country. The most significant global education survey by OECD countries is PISA, (*Programme for International Student Assessment*). Another significant international long-term monitoring of education is organized by IEA (*International Association for the Evaluation of Educational Achievement*). It conducts a number of comparative studies of cross-national achievements, among them TIMSS (*Trends in International Mathematics and Science Study*) which includes testing in mathematics.

PISA is a triennial international survey first conducted in 2000 which is aimed at the evaluation of education systems worldwide by testing the skills and knowledge of 15-year-old pupils. Pupils are assessed in science, mathematics, reading, collaborative problem solving and financial literacy. The PISA assessment is always focused on one of the domains mentioned above to which is given greater emphasis. Mathematical literacy was the focus of the PISA survey in 2003 and 2012. It is

[1] 100% is the average of EU.

interesting that the results of Czech pupils in 2012 are the worst in comparison to the pupils' results of other monitored countries (OECD, 2014a, b), whereas in 2003 Czech pupils were significantly more successful than Polish ones[2] (OECD, 2004).

The other PISA surveys included mathematics problem solving as minor areas of assessment. The latest results in mathematics from PISA 2015 for the Czech Republic were the same as in 2012 – the worst result among the selected countries and just above the OECD average (OECD, 2018).

TIMSS is an international assessment of mathematics and science. TIMSS data have been collected every four years since 1995 at the 4th and 8th grades of basic schools. The scope of our interest is the results of the 8th grades. From the selected countries only the Czech Republic and Slovenia are participating in TIMSS. The Czech Republic tested 8th grades in TIMSS 1995, 1999, and 2007; the results show declines since 1995. Slovenian grade 8 pupils were tested in TIMSS 1999, 2007, 2011 and 2015. The first two results show a decline since 2007, when the results of Slovenian and Czech pupils were statistically comparable, while the performance of Slovenian pupils has been improving (Martin et al., 2008; Mullis et al., 2012, 2016).

The worsening of Czech pupils' results in international surveys and their comparison with the pupils' results in Estonia, Poland, and Slovenia lead us to reflect on possible causes and to look for the differences in approaches to mathematics education. One aspect of mathematics education is the mathematics curriculum. So we asked ourselves: What are the correspondences and differences in the national curriculum documents for lower secondary education (ISCED 2[3]) of the Czech Republic, Estonia, Poland and Slovenia?

1 Theoretical Framework

Comparative education was established as an international comparison of different education systems in several countries with the intention of gaining knowledge about the possibilities for improvement (Walterová, 2006). The curriculum is one of the main aspects of comparative education. According to the three-dimensional model for identifying various loci of comparative studies by Bray and Thomas (1995), we focus only on a very specific area – the national mathematics curriculum of four European countries by which pupils of lower secondary schools are educated.

A number of Czech research studies have been conducted in the past describing or comparing education systems in different countries (for example Ježková et al., 1996; Ježková & Walterová, 1997). The first of these publications includes chapters devoted to Poland and Slovenia. Currently, we can use OECD[4] and Eurydice[5] publications which are mapping the education systems of EU countries with respect to different indicators. However, we do not know of any publication which compares the mathematics curriculum of the Czech Republic with any of the selected countries.

Walterová (1994) dealt with the issue of Czech curriculum in the international context. She described the international comparison of education as a hidden dimension in creating the key curriculum document *National Programme for the Development of Education*, i.e. a *White Paper* (MŠMT, 2001), which was the starting

[2]Estonia and Slovenia did not participate in PISA 2003.

[3]According to *the International Standard Classification of Education* (ČSÚ, 2008; UNESCO, 2018).

[4]https://www.oecd-ilibrary.org/

[5]https://eacea.ec.europa.eu/national-policies/eurydice/publications_cs

point of the curriculum reforms in the Czech Republic after 2000. Walterová defined the curriculum in a broader context and presented the individual components of the curriculum documents. She also highlighted one of the trends in European countries in the 1990s – the transition to a participative model of curricular policy, i.e. shifting the responsibility for curriculum development from the state to the individual schools. This trend was related to the decentralization of education and to increased school autonomy. It manifested itself in all selected countries when they entered the European Union. These changes are described for example by Čerych et al. (1999) in the Czech Republic, by Karc (2003) and Wiśniewski (2007) in Poland, and by Walterová (2006) or Janík, Maňák and Knecht (2009) in general.

The means of uncovering problems in the curriculum is international testing (Walterová, 2006). Therefore, the decreased success rate of Czech pupils in the PISA and TIMSS surveys and the comparison of their results with the pupils of Estonia, Poland and Slovenia lead us to analyze the mathematics curriculum of these countries. The core of individual testing is different.

PISA is aimed at the evaluation of mathematical literacy, i.e. what pupils have learned for their future lives. Mathematical literacy has been already defined in 2003 as follows[6] (OECD, 2004: p. 26): The capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgments and to use and engage with mathematics in ways that meet the needs of that individual's life as a constructive, concerned and reflective citizen. Fig. 1 shows mathematical literacy in the context of a challenge or problem that arises in the real world. The inner box depicts the mathematical modelling cycle of the stages through which a problem solver moves when exhibiting mathematical literacy.

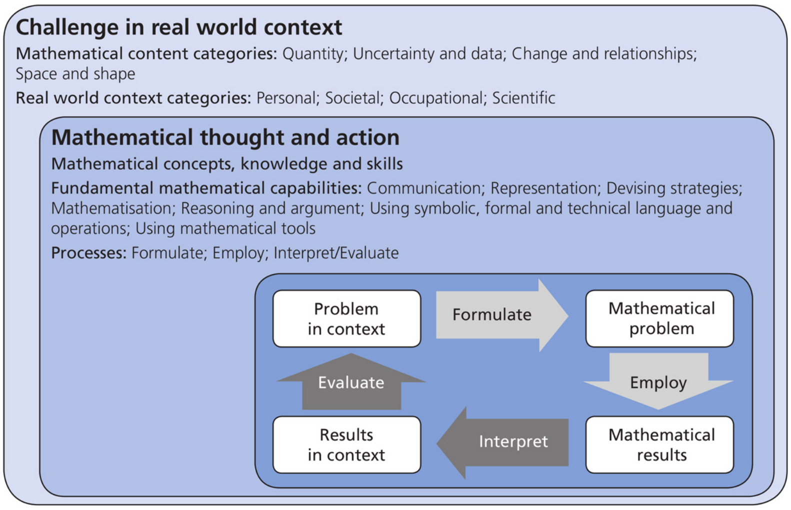

Fig. 1: The PISA model of mathematical literacy (OECD, 2013a: p. 26)

The TIMSS mathematics assessment is based on a content dimension (the topic areas or subject matter to be assessed within mathematics) and a cognitive dimension (thinking processes of pupils to be engaged while solving mathematics problems). In addition to TIMSS tests, pupils, pupils' parents, teachers and school principals complete the specific questionnaires. TIMSS follows a variant approach to the curriculum changes (Janík et al., 2010: p. 13; Maňák, Janík & Švec, 2008: p. 21; Walterová, 2006: p. 199), i.e. TIMSS curriculum model is based on three aspects: the intended curriculum, the implemented curriculum, and the achieved

[6]In 2012 the definition was slightly modified (OECD, 2013a: p. 25).

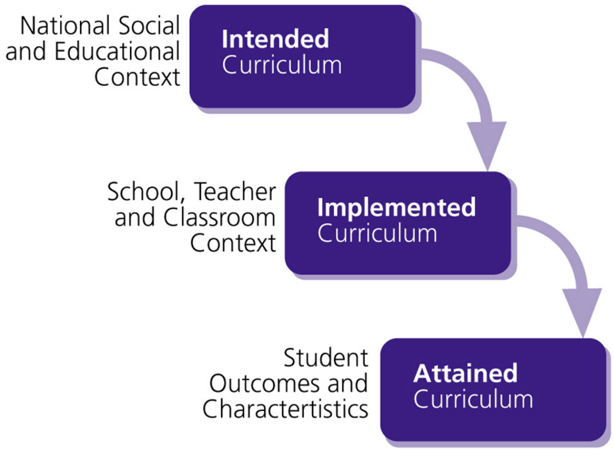

Fig. 2: The TIMSS curriculum model (Mullis et al., 2001: p. 3)

curriculum, see Fig. 2. The intended curriculum is examined primarily through the analysis of syllabi and the most widely used textbooks. The subject matter which is taught in all participating countries is tested. Information about the implemented and the achieved curriculum are obtained from the questionnaires completed by pupils and teachers and from the pupils' tests (Walterová, 2006).

Straková (2015) sees the aim of PISA surveys in influencing educational policy and the main purpose of TIMSS surveys as pedagogical research. Walterová (2006) sees the importance of TIMSS surveys in obtaining the basis for the determination of educational policy goals and in the possibility of following international trends in education. Teachers consider the decreased success rate of Czech pupils in international testing as one of the reasons for changing current curriculum documents (Janík et al., 2011).

It is necessary to realize that the curriculum is a very broad term. For instance, Walterová (1994) or Maňák, Janík and Švec (2008) provide possible definitions and classifications of the curriculum. In our research, we analyze only the official national documents of intended curriculum in which we can find among other things the learning content, time allotment, and educational goals and objectives.

Průcha (1999, 2012) considers comparing the learning content in school education of different countries as a necessity because the curricular policy is not a matter of a single country but it is becoming a subject matter of international interest and cooperation. He also points out that the educational content can be represented not only with the choice of school subjects and learning content but also with the time allotment for the individual educational areas. The goals of school education are an integral part of the curriculum documents. The curricula can be modernized and improved by analyzing them in the context of the content acquisition process. Janík, Maňák and Knecht (2009: p. 17) classify educational goals and objectives vertically by means of *a goals pyramid* – the highest are aims (reflecting the ideals of civilization and culture), then general goals (more specific content of education) and objectives (learning outcomes of the individual subjects) follow and their further specification. *Bloom's taxonomy of Educational Objectives* which was updated by Anderson, Krathwohl et al. (2001) is important for the formulation of objectives.

In this paper, we deal only with mathematics content and objectives and the general goals that are closely related to mathematics with the aim of comparing national curriculum documents for lower secondary education of the Czech Republic and other monitored countries. We mainly focus on differences in above-mentioned items and in other aspects of mathematics teaching.

2 The education systems

The education systems in all four countries consist of pre-primary, basic, secondary, and tertiary education. The systems are slightly different regarding further division and time organizing. We will describe and compare the systems in this subsection with the emphasis on basic education which represents the scope of our interest. The education systems which we explore were followed up to 2016. The education systems with a focus on basic education of all four countries are schematically illustrated in Fig. 3 (MER, 2018a; MESS, 2018; MNE, 2018; MŠMT, 2018b; MŠMT, 2007).

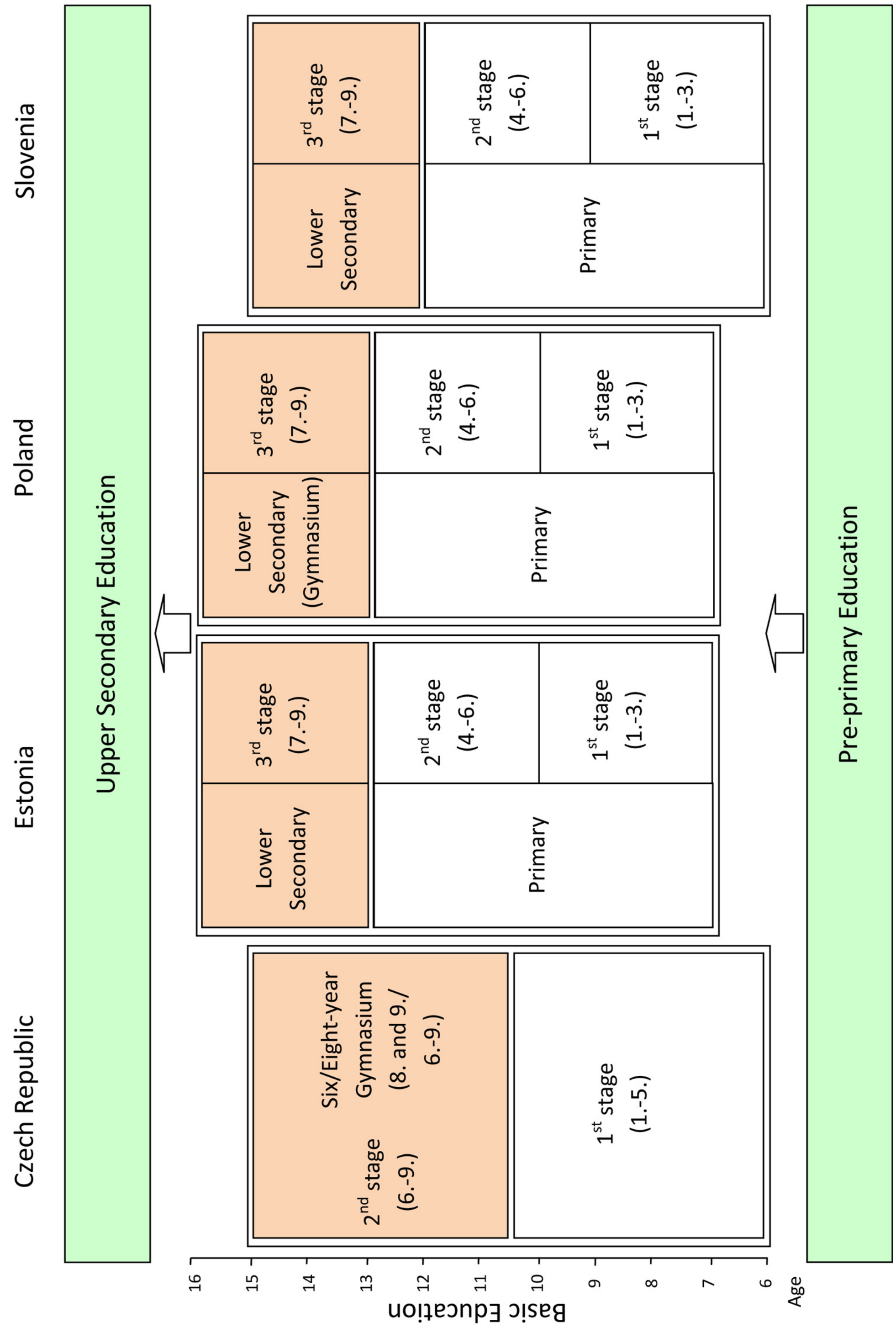

Fig. 3: Education systems in the Czech Republic, Estonia, Poland and Slovenia

The Czech and Slovenian compulsory basic education starts at the age of six, the Estonian and Polish at the age of seven. Estonia, Poland[7], and Slovenia have a three-stage basic education; Czech basic education is divided into two stages.

According to the International Standard Classification of Education (UNESCO, 2018), the scope of our interest is the second level (ISCED level 2) i.e. lower secondary education.

The third stage (grades 7 to 9) is considered as lower secondary education in Estonia, Poland, and Slovenia. In Poland, lower secondary education is covered by the gymnasiums (junior high schools) [*gimnazjum*]. Lower secondary education in the Czech Republic is the second stage of basic education (grades 6 to 9) and can be also realized in six-year gymnasiums (grades 8 and 9) or in eight-year gymnasiums (grades 6 to 9).

3 Analysis of national curriculum documents

The monitored countries entered the European Union in 2004 which significantly affected their approaches to education and curriculum documents. They implemented a two-level participative model of curricular policy according to the European Union's Member States. At the first level the binding national curriculum frameworks are developed, so-called national core curriculum; at the second level, the individual schools define the detailed school educational programmes by themselves, so-called school curriculum (Čerych et al., 1999). All schools are required to follow the national curriculum. The school curricula of the individual schools can differ with respect to the local conditions of a particular school; thus, their comparisons on an international scale dwindle in importance. Therefore, the scope of our interest is only the national curriculum.

3.1 General description

The key document of the national curriculum in the Czech Republic has been the *Framework Educational Programme for Basic Education* (FEP BE) [*Rámcový vzdělávací program pro základní vzdělávání*] since 2005[8] (MŠMT, 2007, 2017). The FEP BE is an open document which is periodically updated. We compare this document to the corresponding documents of Estonia – *National curriculum for basic schools* [*Põhikooli riiklik õppekava*] (HTM, 2011, 2014), of Poland – *Podstawa programowa kształcenia ogólnego dla gimnazjów i szkól ponadgimnazjalnych, których ukończenie umożliwia uzyskanie świadectwa dojrzałości po zdaniu egzaminu maturalnego* (MEN, 2008), and of Slovenia – *Osnovo šolstvo* (MIZŠ, 2018a).

3.2 Learning and educational goals and objectives

The learning and educational goals and objectives are first defined in general and second specifically regarding the concrete educational areas in the national curricula of the selected countries, i.e. related to the learning content of the educational area. We will focus on the learning and educational objectives both in general and in the educational area with respect to the subject mathematics.

[7]The ongoing reform of school system in Poland changes the basic education into eight-year basic schools with two grades.

[8]It has been taught according to the Framework in the Czech Republic since 2007 (MŠMT, 2018a).

3.2.1 Setting of goals and competencies

The *National Programme for the Development of Education*, i.e. a *White Paper* (MŠMT, 2001), is the first binding government document published during the curriculum reforms in the Czech Republic after 2000 which were conducted in the manner of other European countries. The *White Paper* formulates the aims and recommendations, for instance:

> . . . To promote the development of key competencies as an instrument for transforming the encyclopedic conception of education. To apply new methods of active teaching, namely project learning, various forms of cross-curricular integration, such as cross-curricular topics and projects, and other forms of extracurricular activities. To utilize these forms to introduce new topics into curricula. . . (MŠMT, 2001: p. 41).

Key competencies at the second stage of basic education represent the system of knowledge, skills, abilities, attitudes and values that are important to the individual's personal development and to the individual's role in society. At the basic education stage, the national concept of curriculum puts the emphasis on learning competencies, problem-solving competencies, communication competencies, social and personal competencies, civil competencies and working competencies (MŠMT, 2007: p. 12). All competencies are defined in general terms. Evidently, problem-solving competencies are those most related to the educational content of the subject field mathematics but this is not explicitly mentioned in the curriculum document.

Basic education should help pupils to form, shape and gradually develop their key competencies and provide them with dependable fundamentals of general education. Moreover, the scope and principles of basic education is to meet the 9 goals among them – "to stimulate and encourage pupils to creative thinking, logical reasoning and problem solving" (MŠMT, 2007: p. 11). Mathematics is not mentioned within these goals in the Czech curriculum.

A new Estonian general education curriculum with the emphasis on active child participation was established already in the 1990s (Afanasjev & Lepmann, 2006). The current national curriculum (HTM, 2011), defines general goals and general competencies for basic schools; the competencies are also formulated in detail for each stage of the study. The goals are vaguely formulated. The educational content is more clearly defined by means of competence (HTM, 2011: pp. 3–5), which is the aggregate relevant knowledge, skills and attitudes that ensure the ability to operate creatively, in an enterprising way, and flexibly in a particular area of activity or field. Competencies are categorized as general competencies, competencies expected in stages of study, and subject field competencies.

One of the general competencies developed in pupils is mathematics, natural science and technology competence which is defined as the ability to use the language, symbols and methods characteristic of mathematical applications in school and everyday life (HTM, 2011: p. 4). Competencies in the third stage of study summarize in 14 items what the pupil should achieve at the end of the third stage. One of the achievements is directly related to mathematics:

> The pupil is capable of resolving issues arising in various fields in everyday life that require use of mathematical thinking methods (logical thinking and spatial reasoning) and presentation methods (formulae, models, diagrams, graphs). (HTM, 2011: p. 10).

Furthermore, it is pointed out that the pupils should have the ability to clearly and relevantly express themselves and to understand and interpret different types of texts.

The education reforms in Poland were conducted at the end of the 1990s. Gymnasium [*gimnazjum*] has been introduced as the lower secondary education corresponding with grades 7 to 9 of basic education in Estonia and Slovenia beginning with the school year of 1999/2000 (Eurydice, 2008: p. 6). The core curriculum document (MEN, 2008) is common for gymnasiums and post-gymnasium schools. In this document, there are formulated three very general goals of education and the most important skills which should be achieved by the pupils. In fact, these requirements are equivalent to the competencies in the curriculum documents of other countries. One of the main goals of learning and education is to help the pupils develop their *mathematical thinking* which is defined as the ability to use mathematical methods in everyday life and to make decisions based on mathematical reasoning (MEN, 2008: p. 1).

Slovenian national curriculum defines 15 goals of basic education, among them the development of literacy and understanding of the text in natural sciences, mathematics, informatics, social sciences and arts. Mathematical literacy is defined as the ability to use mathematical way of thinking in solving real-life problems (Brezovar et al., 2013: p. 4). This includes the ability and readiness for using mathematical thinking modes (logical thinking and spatial reasoning) and presentation modes (formulae, models, constructions, graphs, and diagrams).

General goals of basic education are similar in all four countries. The set of basic competencies is formulated in the Czech Republic and Estonia and the achievement of these competencies is considered as one of the main goals of basic education. In Poland, basic education is based on the development of the specific areas; these areas are equivalent to the Czech and Estonian competencies. The concept of Slovenian curriculum is slightly different. There are more detailed descriptions of various goals but the setting of basic competencies is missing. In general, the goals defined in the Slovenian curriculum are more or less the same as in other countries. The Estonian national curriculum seems to be the most elaborate and detailed document; competencies expected in stages of study are introduced in addition to general and subject field ones. The common competencies for the third and fourth stage, i.e. for gymnasiums and post-gymnasium schools, are presented in the Polish curriculum. The curriculum documents in the Czech Republic and Slovenia define the competencies for the entire basic education, i.e. the competencies are common for both the primary and lower secondary education.

Mathematics is mentioned explicitly in the national curricula of Estonia, Poland, and Slovenia. Moreover, at the end of the third stage of study in Estonia, the emphasis is put on the ability to clearly and relevantly express oneself. Slovenian national curriculum introduces mathematical competence as one of the goals, but very vaguely. Polish national curriculum focuses on mathematical thinking.

3.2.2 Mathematics objectives

Mathematics objectives are described in the following documents: the *Framework Educational Programme for Basic Education* (MŠMT, 2007, 2017) in the Czech Republic, in the third appendix of *National curriculum for basic schools* (MER, 2018b) in Estonia, in *Podstawa programowa kształcenia ogólnego dla gimnazjów i szkól ponadgimnazjalnych, których ukończenie umożliwia uzyskanie świadectwa dojrzałości po* *zdaniu egzaminu maturalnego* (MEN, 2008) in Poland, and in *Matematika – Učni načrt* (MIZŠ, 2018b) in Slovenia.

In general, the number of mathematics objectives is shared by all curriculum documents, and their descriptions are more or less the same (the objectives are very similar, just formulated differently). The objectives which are not common for all four countries are unique.

Firstly, let us focus on the common features in the mathematics objectives of the selected countries. The expected objectives after completing the basic education are summarized in Tab. 1.

Tab. 1: Common features in mathematics objectives

Objective	CR	Est	Slo	Pol
Create and use mathematical models in order to solve problems in different fields of everyday life.	•	•		•
Apply mathematical knowledge and skills in practical activities – for instance estimating, measuring and comparing sizes and distances, orientation.	•	•	•	
Interpret and present information in the form of text, graphs, tables.		•		•
Use abstract, logical thinking, and critical judgment.	•	•	•	
Justify and analyze problems, formulate hypotheses.	•	•		•
Compile and use solution strategies.	•	•		•
Have knowledge of mathematical terms and create a system of terms.	•	•	•	
Trust in their own problem-solving skills and abilities.	•	•	•	

Secondly, let us mention what is unique in the individual curriculum documents of the selected countries.

Basic school pupils in the Czech Republic

- develop their memory by performing numerical calculations and learn necessary mathematical formulas and algorithms;
- learn to express themselves precisely and succinctly by using the language of mathematics, including mathematical symbols, and by performing analyses and keeping records during problem-solving, and by perfecting their graphic abilities;
- learn to co-operate while solving problems and applied tasks.

Basic school pupils in Estonia

- use computer programs and other tools in studying mathematical;
- understand the value of and enjoy mathematics.

Basic school pupils in Slovenia

- receive and experience mathematics as a cultural value.

The most detailed description of general mathematics objectives is given in the Czech curriculum document (MŠMT, 2007, 2017); in comparison, the Polish curriculum document mentions them very briefly. In the Slovenian curriculum, besides general mathematics objectives, there are defined global objectives related to each topic in mathematics. These global objectives are very detailed, for instance, having a basic knowledge of algebraic expressions. The general objectives of mathematics education are also defined in the Estonian curriculum. Moreover, the mathematical learning and educational objectives, after completing every educational stage, are specified there.

3.3 The syllabuses of mathematics

The learning outcomes and content of mathematics in lower secondary education are described in the following documents: the *Framework Educational Programme for Basic Education* (MŠMT, 2007; 2017) in the Czech Republic, in the third appendix of *National curriculum for basic schools* (MER, 2018b) in Estonia, in *Podstawa programowa kształcenia ogólnego dla gimnazjów i szkól ponadgimnazjalnych, których ukończenie umożliwia uzyskanie świadectwa dojrzałości po zdaniu egzaminu maturalnego* (MEN, 2008) in Poland, and in *Matematika – Učni načrt* (MIZŠ, 2018b) in Slovenia.

In the Czech Republic, the educational area is called *Mathematics and its application*. The minimum time allotment for the educational area Mathematics and its application at the second stage of basic education is 15 teaching hours[9] per week at all grade levels of basic education. First, the characteristics of the educational area with the emphasis on the individual thematic parts are given. The description of the objectives of the educational area and its educational content follows. The educational content of the educational field comprises the expected outcomes and the subject matter. Expected outcomes are binding at the end of grade 9. The subject matter is supposed to be a means to achieve the expected outcomes (MŠMT, 2007: p. 16) and is recommended to schools for distribution and further modifying.

The educational content of *Mathematics and its application* is divided into four thematic parts: Numbers and Variables; Dependencies, Relations and Working with Data; Two- and Three-dimensional Geometry; Non-Standard Application Exercises and Problems.

In the Estonian curriculum, the weekly number of lessons for compulsory subjects in basic school for all stages of study is specified. The subject field *Mathematics* is taught in all grades of basic education and in the third stage of study, it is 13 lessons per week. Furthermore, the distribution of weekly hours of subjects within stages is specified in the school curriculum along with expected learning outcomes and learning and educational objectives to be achieved (MER, 2018b: pp. 1–2). The description of the subject field is provided, and mathematics learning and educational objectives, learning outcomes, and learning content are specified in the syllabus of mathematics.

The subject field of *Mathematics* in the third stage of study is divided into five parts: Calculation and Data; Percentages; Algebra; Functions; Geometry.

In Poland, the educational area is called *Mathematics* [*Matematyka*]. The minimum number of teaching hours by this subject in the 3-year period at lower-secondary schools is 385[10] (Eurydice, 2014). The learning outcomes are specified in the syllabus of mathematics for each thematic part. The learning content is not specifically defined in the curriculum document.

The educational content of *Mathematics* is divided into eleven thematic parts: Rational Numbers (positive); Rational Numbers (positive and negative); Powers; Roots; Percentages; Algebraic Expression; Equations; Graph of a Function; Descriptive Statistics and an Introduction to Probability theory; Two-dimensional Figures; Solids.

[9]One teaching hour (lesson) takes 45 min.
[10]This number of hours corresponds to approximately 4 teaching hours per week.

The Slovenian curriculum provides the most detailed description of the syllabus of *Mathematics* [*Matematika*]. The recommended number of hours for each theme of mathematics is provided; the total number of hours for mathematics is 140, 140, and 128[11] hours for the grades, 7, 8, and 9, respectively. It defines compulsory and optional learning outcomes (in Tab. A4 in the Appendix the optional ones are written in italic type). For all educational periods, the learning outcomes and content are suggested.

In every educational period, there are three main themes in *Mathematics*: Geometry and Measurement; Arithmetic and Algebra; Other Content. All themes are divided into thematic parts. For each theme, the global objectives of the educational period are defined. The learning outcomes and content are divided into blocks according to individual grades; the division is only recommended.

The extensiveness of curriculum structure regarding the learning outcomes and content does not allow us to describe all parts of the syllabus of mathematics. Let us focus only on geometry in all four curricula and describe more precisely the learning content and expected outcomes of this part of the subject field of mathematics.

We recommend that the reader follows Tab. A1, A2, A3, and A4 in the Appendix where the learning outcomes and content in mathematics with the emphasis on geometry are summarized and categorized according to the subtopics for each country. The learning outcomes and content for Slovenia are also classified according to grades in which they should be realized.

The Czech Republic introduces the subject matter which is only recommended (MŠMT, 2017: p. 15). The thematic part related to geometry is Two- and Three-dimensional Geometry and the learning content is divided into four parts (two-dimensional figures, characteristics of two-dimensional measurements, three-dimensional figures, and construction tasks). The teachers have to fulfil the binding learning outcomes which are defined quite vaguely; only from the recommended learning content can it be derived how to achieve them. Estonia also has a brief description of the learning outcomes and content of the part Geometry. It is not divided into any subtopics. Poland does not present the learning content at all but has a very detailed description of the learning outcomes which can substitute for it. The Polish thematic parts which are in the scope of our interest are Two-dimensional Figures and Solids. As we can see from Tab. A4 Slovenia provides the most detailed description of the syllabus of mathematics. The theme Geometry and Measurement is divided into two thematic parts – Geometric Terms and Transformations. Moreover, the learning outcomes and content are described individually for each grade.

If we compare the individual learning outcomes and content of the selected countries, we can find several distinctions. Regarding two-dimensional geometry, all curriculum documents point out several two-dimensional figures which should be taught. All countries particularly refer to triangles, quadrilaterals (trapeziums and parallelograms), and regular polygons. In addition to these Poland and Slovenia also mention rhombi and only Slovenian learning outcomes and content distinguish kites within quadrilaterals. The other interesting topics in two-dimensional geometry are angles. Only Poland has the recognition of central angles among the learning outcomes. Only Estonia refers to trigonometric functions of acute angles. Regarding three-dimensional geometry all curriculum documents mention calculation of the volume and surface area of solids among learning outcomes. Vertical parallelepipeds are considered among the solid figures only in Estonia; in all four countries the list

[11] These numbers of hours correspond to approximately 4 teaching hours per week.

of solid figures consists of cube, cuboid, vertical prism, pyramid, cylinder, cone, and sphere. Only the Slovenian curriculum describes additional learning outcomes and content related to solids – for example to create models of solids and draw their nets. Only Estonian curriculum document reflects the usage of technological tools in the learning outcomes to discover regularities and formulate hypotheses. The Slovenian learning outcomes place emphasis on the calculation with and without calculators.

4 Teaching methods, assessment, and other aspects of the national curricula

The description of teaching methods in the Czech curriculum is limited only to the recommendation to apply different methods of active teaching, namely project learning, various forms of cross-curricular integration and other forms of extracurricular activities. The specific teaching methods for mathematics are not described.

The Estonian curriculum provides a little more regarding the description of teaching methods:

> A diverse selection of study methods is used with emphasis on active study methods: independent work, conversation, debate, discussion, work in pairs, project study, group work. (MER, 2018b: p. 6).

It is worth mentioning that homework is also included in the curriculum as one of the important study activities.

In the Slovenian curriculum, there are added didactic recommendations to each educational period and to each theme – for example, regarding the theme *Geometry and Measurement*, there is advice provided on which models can be selected for the representation of the studied figures (edges, faces, solids). Furthermore, there are some specifications like: "we solve the tasks using trial and deliberation, not formally by solving equations in the 7^{th} grade. We consider formal solving of equations in the 9^{th} grade" (MIZŠ, 2018b: p. 46). The Slovenian curriculum puts emphasis on the integration of education with everyday life to make it more understandable and reasonable to pupils. It is necessary to apply various learning styles, different methods and formats, didactic aids, and modern technologies. It is essential to perceive the learning content in depth over the mere recall of symbols. At the same time, it is highlighted that rote learning plays an important role in the learning process and in developing computational skills and that making it automatic is necessary.

The Polish curriculum does not mention teaching methods, only several didactic recommendations which are divided according to the age of pupils can be found there.

The Estonian and Slovenian curriculum briefly comments on pupils' assessment in mathematics.

The description of the assessment of learning outcomes is specified in the general part of the Estonian curriculum. Detailed assessment procedures are introduced, and formative assessment and summarizing grading are used in assessment. In formative assessment, the primary focus is on comparing a pupil's development with his or her previous accomplishments. In summarizing grading, a pupil's accomplishments are compared with required learning outcomes. Both result and process are assessed in case of practical assignments and problems (MER, 2018b).

A mention of pupils' assessment can be found in the Slovenian curriculum document too. In addition to written and oral examination, it is recommended to use other forms of assessments – presentation of seminar works and projects, mathematical and statistical research, practical tasks, and monitoring of homework (which is considered as an important part of the learning process because of pupils' self-education, developing their good work habits, persistence, and precision). The oral exam should assess pupils' knowledge which can be hardly examined in the written tests.

The Czech Republic and Poland do not mention pupils' assessment in mathematics in the national curriculum documents.

The final examinations in mathematics can provide significant extrinsic motivation for learning for the pupils. In Estonia, Poland, and Slovenia all ninth-grade pupils have to take the unified basic school final examination in mathematics established by law.

In Slovenia, the results are considered as additional information about the level of pupils' knowledge and do not have any bearing on the grades (Eurydice, 2017; Wiseman, 2010). A satisfactory grade on the examination is not a necessary condition for graduation from basic school but the results are taken into account in entrance examinations to secondary schools.

In Poland, at the end of lower-secondary education pupils take a compulsory external examination which has a strong bearing on admission to upper-secondary schools (Eurydice, 2014). Examination results are related both to schools' effectiveness and pupils' accomplishments (Anczewska & Charzyńska, 2012). They help to revise curricula and encourage the introduction of more effective teaching methods. The final examination is not a necessary condition for graduation from basic school.

In Estonia, the national examinations take place at the end of basic education and have a certification function (Santiago et al., 2016), i.e. passing the basic school final examination is the condition for graduation from basic school and completing the third stage of study (MER, 2018b: p. 19). Results of these examinations are used by some selective upper secondary schools for admission purposes. Thus, national assessments do have formal consequences for students. Estonia reports a higher level of use of central student assessments for formative purposes than for summative purposes. In PISA 2012 (OECD, 2013b), for example, Estonia reported more use of assessment data than other OECD countries to make decisions about student retention or promotion or to identify aspects of instruction or the curriculum that could be improved (OECD, 2016).

In the Czech Republic, there is no unified basic school final examination. In addition to international PISA and TIMSS surveys which are used as an assessment tool in the Czech Republic, there are assessments carried out by the Czech School Inspectorate. These assessments are not held every year and not in all basic schools. The sole extensive state-guaranteed examination in mathematics for grade 9 pupils is the unified entrance examination to secondary schools which is taken only by pupils who want to enter secondary schools. This examination has been used since the 2016/2017 school year.

5 Discussion and Conclusion

Comparing the curriculum documents of the Czech Republic with the curriculum documents of Estonia, Poland, and Slovenia we can identify several significant differences:

- The minimum time allotment in mathematics in lower secondary schools is the lowest in the Czech Republic.
- The general goals in the Czech curriculum do not put proper emphasis on mathematics education.
- In the Czech curriculum, there is no mention of the importance of the self-reliant systematic home preparation of pupils.
- There is no national assessment tool in the Czech Republic which compares pupils' performance in mathematics at the end of lower secondary school education.
- The learning outcomes in the Czech curriculum are specified only briefly; the learning content is neither binding nor concrete enough.

The time allotment is defined for the entire educational period, in the Czech Republic for the grades 6 to 9 and in Estonia, Poland, and Slovenia for the grades 7 to 9. The distribution of hours between the grades is left to the school principals. In reality, the school shall use the available time allotment.[12]

The time allotment for mathematics education is the lowest in the Czech Republic in comparison with the monitored countries (see Tab. 2, in which the average time allotments per week in one year of study are compared; the numbers present a number of mathematics lessons, one lesson takes 45 min).[13]

Tab. 2: The average time allotment for mathematics per week in lower secondary schools

Czech Republic	Estonia	Poland	Slovenia
3.75	4.3	4	4

Based on some empirical research (e.g. Lavy, 2015), there is a relationship between the amount of time that an individual spends on studying, and the amount of knowledge and skills that he/she can mine from it. According to several studies (e.g., Blank, 2013; Desimore & Long, 2010), student performance increases with more instructional time. On the other hand, TIMSS research shows that there is no direct correlation between time allotment in school and pupils' knowledge, but "it depends on how effectively and efficiently the time is used" (Mullis, Martin & Loveless, 2016: p. 46). However, the information from TIMSS research led to a recommendation to increase the number of primary school hours in Iceland in the past (Walterová, 2006: p. 200). According to Cattaneo, Oggenfuss and Wolter (2016: p. 14): "prescribed hours also might not adequately depict the reality in schools" and "the additional instructional time has a significant impact on learning outcomes measured with PISA test scores, but the effectiveness of an additional hour of instruction is only between thirty to forty percent of the impact that they would expect from an average hour of instruction". Other surveys indicate that the additional instructional time for mathematics has a positive effect, though they also mention other significant aspects such as the classroom setting (Rivkin & Schiman, 2013) or the teacher quality (Woessmann, 2016) at the same time. Therefore, it

[12] According to questionnaires completed by teachers during TIMSS, the actual average number of mathematics lessons in the 8th grade of basic education was 3 hrs. 14 min./week in 2007 and 3 hrs. 34 min./week in 2015 (Mullis, Martin & Loveless, 2016). Thus, a slight increase of the time allotment can be observed.

[13] On the other hand, the total time allotment for mathematics for the grades 6 to 9 recommended by the Ministry of Education, Youth and Sport is 18, i.e. 4.5 lessons per week in one year of study (MŠMT, 2011). It is worth mentioning that mathematics in lower secondary schools in Czechoslovakia/Czech Republic was being taught 5 lessons per week until 1991 and at least 4 lessons per week between 1991 and 2005 (MŠ, 1987; MŠMT, 1991; MŠMT, 1996).

cannot be simply said that the lowest time allotment is the cause of the decreased success rate of Czech pupils in international testing.

The decentralization of the Czech education system after 2000 is related to the transfer of emphasis from the content of the curriculum to key competencies. Janík, Maňák and Knecht (2009) found focusing on key competence to be a new positive element of basic education goals. However, Slavík and Janík (2012) pointed out the problem of emptying the content.

We have found that the development of mathematics competence, understanding mathematical texts, using mathematical symbols and the like belong among the general goals of education of lower secondary schools in all monitored countries except the Czech Republic. Including or not including these skills among general goals and competencies expresses their importance in education. The natural consequence of their inclusion in the curriculum can be a gradually increasing integration of the development of mathematical competencies (such as using diagrams, percentages, etc.) in other subjects. We also consider the ability of pupils to understand technical terms and to express themselves correctly as crucial (not only for mathematics). Understanding text is one of the general goals in the curriculum document of Slovenia; the ability to formulate mathematical ideas is among the general competencies of education in Estonia. A similar general goal or competency is missing in the Czech curriculum.

Mathematics education requires continuous and systematic preparation of pupils. This can be achieved through solving assigned homework problems. The impact of homework as a part of the learning process was examined in several studies. The strength of the relationship between homework and pupil achievement in mathematics is not yet fully clear; the results of studies are inconsistent. Some researchers found a positive relationship (e.g., Cheema & Sheridan, 2015; Abdelfattah & Lam, 2018), some studies generated contradicting findings (Cooper, Robinson & Patall, 2006; Dettmers, Trautwein & Lüdtke, 2009). Dettmers, Trautwein and Lüdtke (2009) showed in their study rooted in PISA 2003 a significant positive relationship between the students' scores in mathematics and the time spent doing homework at the group level. On the other hand, there was a negative relationship at the student level across countries. Based on the results of TIMSS surveys, Güven (2019) concluded that the frequency of homework significantly affects pupil achievement in the 8^{th} grade but not in the 4^{th} grade. Similarly, Cooper, Robinson and Patall (2006) found that homework-achievement relationship differs at different grade levels.

Homework enables pupils to develop their own initiative and to deepen and strengthen their knowledge. The curriculum documents of Estonia and Slovenia mention it; in the Czech curriculum, these aspects are not considered. On the contrary, the current tendencies (especially the pressure from parents, and not only in the Czech Republic) are against it – pupils should not be overloaded with homework (ČŠI, 2018; Güven, 2019). PISA 2012 showed that pupils in Poland and Estonia spend about twice more time with homework than pupils in the Czech Republic and Slovenia (OECD, 2014c). Abdelfattah and Lam (2018), based on the results of TIMSS in 15 Arab countries, determined that longer homework (taking more than 60 minutes) is annoying for the pupils, while shorter and less frequent homework (1 to 4 times a week) reflects an important way to improve their achievement. According to Maňák (1992), pupils must be sufficiently motivated to do homework. The perceived low motivation of current Czech pupils is also considered to be one of the factors that caused a statistically significant worsening of Czech pupils in PISA surveys in recent years (ČŠI, 2016).

The Czech educational policy declares the necessity of national testing at all levels of education as the main tool for monitoring the outcomes of education. This need is closely interconnected with increasing school autonomy (MŠMT, 2001: p. 92). The Czech Republic has not developed a national testing system yet (Dvořák, 2015). An exception is the unified and compulsory entrance examination to secondary schools beginning with the 2016/2017 school year which covers Czech language and mathematics. The school principals can create further conditions for admission to secondary schools but at least 60% of the results of the unified entrance examination to secondary schools must be taken into account by law (561/2004 Sb.). However, the entrance examinations are not compulsory for everybody; only pupils who wish to continue their studies are taking them. On the contrary, in Estonia, Poland and Slovenia, all pupils must take the unified final examination at the end of the lower secondary school (Eurydice, 2009).

The majority of European countries have introduced regular national examinations in an attempt to increase the effectiveness and efficiency of their education systems. In the school year 2008/2009, only the German-speaking community of Belgium, the Czech Republic, Greece, Wales and Liechtenstein did not administer national tests in compulsory education.

The majority of learning outcomes and learning content is the same in all countries; nevertheless, distinctions can be found. Only Estonian curriculum document mentions the usage of technological tools in the learning outcomes. In the Slovenian curriculum document, it is pointed out several times to use or not to use calculators in the tasks. The use of calculators and technologies is also mentioned in the Czech curriculum, but not in relation to teaching geometry.

In general, we can say the Czech school curricula of the individual schools are probably more difficult to create than the school curricula of the other countries because the learning outcomes in the Czech national core curriculum are defined very briefly. Especially, the Slovenian curriculum document could serve as a good example of a detailed, well-elaborated material.

Slovenia provides the most detailed description of the syllabus of mathematics. This is the main difference from other countries of the European Union where there has been an evident trend of moving away from a detailed description of subject matter in curriculum documents since the 1990s (Ježková & Walterová, 1997). A detailed description can be the starting point for teachers who can simply follow the learning content from the curriculum documents in their classes. Moreover, the division of the topics according to individual grades can help Slovenian teachers orient themselves in the extensive content of the subject field of mathematics. This can be useful especially for novice teachers. We have found Slovenian curriculum to be a very inspiring source for the Czech curriculum documents regarding their prospective modifications.

The transformation of goals and objectives into the learning content is the basis for the successful implementation of the educational process (Janík, Maňák & Knecht, 2009). However, the inaccurate specification of mathematics learning outcomes and learning content gives great freedom to schools (teachers) to determine this learning content. It is necessary to realize that the teacher is responsible for the final form of the curriculum, i.e. the implemented model of curriculum (Janík, Maňák & Knecht, 2009). That's why an important aspect of each curriculum reform is its acceptance by teachers (Maňák, Janík & Švec, 2008; Pešková, Spurná & Knecht, 2017; Roter, 2003). Dvořák (2015) points out the problem of conceptual framework of the national curriculum in a participative model of curricular policy.

Straková (2007) described the teachers' opinion on curriculum reform in the Czech Republic after 2000 as inconsistent. Janík (2013) states the implementation of the current Czech curriculum reform has resulted in mere formalism. The problematic and slow adoption of reforms in the 1990s in Slovenia is described by Ježková et al. (1996).

Teachers play an irreplaceable role in the education process and can significantly influence the pupils (Martínková, Goldhaber & Erosheva, 2018; Akiba, LeTendre & Scribner, 2007; Blomeke, Olsen & Suhl, 2016). According to a survey by Earnets and Amador (2019), the teachers cover the subject matter to varying extent using curriculum documents. The question arises whether the curriculum documents are to bind or to allow some level of latitude for teachers.

We have identified the specific differences in the national curriculum documents for lower secondary schools of the selected countries. We cannot conclude that only curriculum documents have an impact on the quality of education and on better results of pupils in the national testing. We also do not know how the curriculum documents are used in practice and if and how the teachers work with them. In general, there are even more aspects which can improve or worsen pupils' results – inner factors (pupils' aptitude, handicaps etc.) and outer factors (social environment, family, teacher etc.). The curriculum document is only one component which can influence the school instructions.

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Vlasta Moravcová, morava@karlin.mff.cuni.cz
Petra Surynková, surynkova@karlin.mff.cuni.cz
Jana Hromadová, jole@karlin.mff.cuni.cz
Charles University, Faculty of Mathematics and Physics
Department of Mathematical Education
Sokolovská 83, 186 75 Prague 8, Czech Republic

Appendix

Tab. A1: The learning outcomes and content in mathematics with the emphasis on geometry in the Czech Republic

	Learning outcomes	Learning content
Czech Republic		
Two- and Three-dimensional Geometry	• reason and apply the positional and metric properties of basic two-dimensional figures when solving tasks and simple practical problems; use necessary mathematical notation • characterise and classify basic two-dimensional figures • measure and calculate angles • estimate and calculate the area and circumference of basic two-dimensional figures • use the concept of the set of all points of a given characteristic to describe a figure and solve positional and non-positional tasks • sketch and construct two-dimensional figures • apply theorems on congruent and similar triangles when making argumentations and calculations • sketch and construct a two-dimensional figure with central and reflection symmetry, identify centrally-symmetric and reflection-symmetric figures • identify and describe basic three-dimensional figures (bodies) and analyse their characteristics • estimate and calculate the volume and surface area of bodies • sketch and construct basic bodies • sketch and construct simple bodies in a plane • analyse and solve applied geometric tasks using newly acquired mathematical skills	• **two-dimensional figures** – lines, rays, line segments, disks, circles, angles, triangles, quadrilaterals (trapeziums, parallelograms), regular polygons, relative position of two lines on a plane (types of angles), congruence and similarity (theorems on congruent and similar triangles) • **characteristics of two-dimensional measurements** – types of angles, distance of a point from a line, triangle inequality, Pythagoras' theorem • **three-dimensional figures** – cuboids, cubes, right circular cylinders, pyramids, right circular cones, spheres, right prisms • **construction tasks** – multiples of all points of a given characteristic (segment bisectors, angle bisectors, Thales' circle), reflection symmetry, central symmetry

Tab. A2: The learning outcomes and content in mathematics with the emphasis on geometry in Estonia

	Learning outcomes	Learning content
Estonia		
Geometry	• draw and construct (both by hand and computer) plane figures on the basis of given elements • calculate linear elements, perimeter and area and volume of figures • know figures, the midline of a triangle and trapezium, the median of a triangle, the circumscribed and inscribed circles of a triangle and the central angle and peripheral angles of triangle • describe properties of figures and classify figures according to common properties • identify the 'theorem', 'postulate', 'assertion' and 'proof', explain train of thought of proving certain theorems • solve open-end problems with geometrical content • find the linear elements of a right-angled triangle • use similarity between triangles and polygons when solving open-end problems • use technological tools in discovering regularities and formulating hypotheses	• definition, theorem, assumption, assertion and proof • polygons (triangle, parallelogram, trapezium and regular polygon), perimeter and area of polygons • circle and circumference • central angle • peripheral angle, Thales' theorem • tangent of circumference • inscribed and circumscribed circles of triangle and regular polygon • criterion of parallel straight lines • midline of triangle and trapezium • median and centre of gravity of a triangle • similarity properties of triangles • similarity of polygons • planning of areas • Pythagoras' theorem • trigonometric functions of acute angles • solid figures (vertical parallelepiped, vertical prism, pyramid, cylinder, cone and sphere), their area and volume

Tab. A3: The learning outcomes and content in mathematics with the emphasis on geometry in Poland

	Learning outcomes	Learning content
Poland		
Two-dimensional Figures	• use relationships between angles formed by a straight line that crosses two parallel straight lines • recognize the mutual position of a line and a circle, recognize a tangent to a circle • use the fact that the tangent line to a circle at a given points is perpendicular to the radius of a circle to that point • recognize central angles • calculate the length of a circle and the length of an arc of a circle • calculate the area of a disk, an annulus, and a circular sector • apply Pythagoras' theorem • use the properties of angles and diagonals in rectangles, parallelograms, rhombuses, and trapeziums • calculate the area and perimeter of triangles and quadrilaterals • convert units of area • calculate the sizes of a polygon enlarged or reduced in a given scale • calculate the ratio of areas of similar polygons • recognize congruent and similar polygons • apply the properties on congruent triangles • use the properties of similar right-angled triangles • recognize pairs of symmetric figures with respect to the line and the point; construct pairs of symmetrical figures • recognize figures that have an axis of symmetry, and figures that have a center of symmetry; indicate the axis of symmetry and the center of symmetry of the figure • recognize a line segment bisector and an angle bisector • construct a line segment bisector and an angle bisector • construct 60°, 30°, 45° angles • construct an inscribed and circumscribed circle of a triangle • recognize regular polygons and use their basic properties	not specifically defined
Solids	• recognize correctly regular prisms and pyramids • calculate the surface area and volume of a right prism, pyramid, cylinder, cone, sphere (also in tasks with a practical context) • convert volume units	not specifically defined

Tab. A4: The learning outcomes and content in mathematics with the emphasis on geometry in Slovenia

	Learning outcomes	Learning content
Slovenia		
Geometry and Measurement	*Geometric Terms* **grade 7** • learn the concept of the orientation on the line and in the plane • mark the vertices of a given two-dimensional figure in a required orientation • describe a triangle (denote vertices, sides, and angles), classify triangles according to angles and sides and learn the relationship between the lengths of the sides (triangle inequality) • distinguish the interior and exterior angles of a triangle • know and use the sum of the interior and exterior angles of a triangle in the tasks of drawing and calculation • know the relationships between the interior angles and the sides of a triangle and use them in the tasks of drawing • know and use the necessary and sufficient conditions for the congruent triangles in the tasks of drawing • know and use the altitude when drawing a triangle • *know and use triangle centers in the tasks of drawing* • *know and use the center of gravity, the medians, the radius of an inscribed and circumscribed circle of a triangle when drawing a triangle* • inscribe and circumscribe a circle of a triangle • recognize and draw equilateral triangles • calculate the area and perimeter of a triangle using formulas and convert units • describe and name the quadrilateral and denote it (vertices, sides, angles, diagonals) • recognize a trapezium, define and describe it: bases, legs, altitude, midline • know and use the sum of the interior angles of the quadrilateral in calculations • know the characteristics of the quadrilateral and draw it from the given data • recognize and draw axially symmetric and centrally symmetric quadrilaterals (isosceles trapezium, kite, parallelogram) and describe their properties • know the concept of an altitude in a parallelogram and a trapezium and use it in drawing • calculate the perimeter and area of a parallelogram, a trapezium, a rhombus, and a kite using formulas • use the concept of the congruence of two-dimensional figures in transformations • observe and recognize types of faces of prisms and pyramids and create nets of three-dimensional figures	*Geometric Terms* **grade 7** • orientation on the line and in the plane • solids – adopting the spatial abilities • triangle • quadrilateral • parallelogram • rhombus • trapezium • kite • the area and perimeter of two-dimensional figures • two-dimensional figures on the solids (the net of solids)

Tab. A4: continue

	grade 8 • describe the polygon and denote it (vertices, sides, angles, and diagonals) • know the sum of the interior and exterior angles of a polygon • adopt the concept of a regular polygon • know and use the strategies for drawing polygons • use the strategies for calculating the perimeter and area of polygons (for example using a formula, by measuring, by transforming to another two-dimensional figures) • understand the concept of the number π • calculate the circumference and area of the disk using formulas • *calculate the length of a circular arc and the area of a circular sector using formulas* • understand and use the length of the circular arc as the part of the length of the circle and the area of the circular sector as the part of the area of the disk • solve the tasks with a circle (with or without calculators) • know the properties of a right-angled triangle and name the sides • know Pythagoras' theorem and apply it to calculate the lengths of sides in a right-angled triangle • solve the tasks using Pythagoras' theorem in the plane (with or without calculators) • know the concept of the cube and cuboid • calculate the surface area and volume of the cube and cuboid (with or without calculators) • apply Pythagoras' theorem in tasks with the cube and cuboid • use the area and volume formulas for the cube and cuboid to calculate unknown variables	**grade 8** • polygon • circle, disk • circular sector, circular arc • cube • cuboid • Pythagoras' theorem

Tab. A4: continue

	grade 9 • define the relationships between points, lines, and planes in the three-dimensional space (using models) and the relationship denote symbolically • define and use the ratio of the line segments to calculate the unknown lengths • partitioning a line segment in a given ratio • recognize similar triangles and know the related terms: corresponding sides and congruent angles • define and use the concept of similar triangles • know and use Thales' theorem • know the concept of the prism, cylinder, pyramid, and cone • calculate the surface area and volume of the prism and cylinder (with or without calculators) • understand and use the concept of mass, density and volume of the solid • create models of solids and draw their nets (regular prisms and cylinders, regular pyramids and cones) • calculate the lateral surface, surface area and volume of pyramids and cones (direct and indirect tasks) • use formulas to calculate the surface area and volume of prisms, cylinders, pyramids, and cones and calculate the unknown variables • apply Pythagoras' theorem in tasks with the solids • *adopt the concept of an axial cross section of the cone and solve the related tasks* • *describe the sphere* • *solve the tasks related to the surface area and volume of the sphere* • *know the cylinder and cone as the solid of revolution*	**grade 9** • three-dimensional figures • similarity • prism • cylinder • pyramid • cone • sphere
	Transformations • know transformations (reflection, translation, rotation) and their properties • reflect a point, a line, a segment line, an angle, a two-dimensional figure across a given line or point • describe the properties of reflection and write it symbolically • adopt the concept of a line segment bisector and an angle bisector and solve the construction tasks • use various strategies to construct an angle with a compass and a ruler • recognize angles with the pair of parallel sides (alternate angles) and determine the relationship between their sizes • find the vertical and adjacent angle to a given angle • solve the tasks with a pair of angles • form the formulas of rotation and reflection	*Transformations* **grade 7** • the properties of geometric transformations • axial symmetry • point reflection • rotation **grade 8** • transformations of polygons **grade 9** • transformations in coordinate system

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Physics at Lower Secondary Schools: Comparison between the Czech Republic, Estonia, Poland and Slovenia

Petr Kácovský, Věra Koudelková, Marie Snětinová

Abstract

Results of the worldwide PISA study in science performance from past years (2009, 2012 and 2015) show that Czech pupils are placed in the OECD average, whereas some countries with similar cultural and historical background are statistically significantly above it as well as above the results of the Czech Republic. As an example, Estonia, Poland and Slovenia belong to these countries and therefore they were chosen for the presented comparative study. The study focuses on comparison of national curricula of these countries, especially on fundamental aspects important for physics education at lower secondary schools. The study highlights the comparison of teaching content and learning outcomes in physics, interdisciplinary education and cross-curricula subjects, educational methods and assessment and field-specific key competences. One of the most evident differences that this study has detected is in the level of autonomy that the curricular documents give schools in deciding what the learning process will look like. This result as well as other findings will be discussed in the paper.

Key words: comparative study, curriculum, lower secondary education, physics.

Fyzika na 2. stupni základní školy: Porovnání České republiky, Estonska, Polska a Slovinska

Abstrakt

Mezinárodní šetření PISA z posledních let (2009, 2012 a 2015) ukazuje, že výsledky českých žáků v přírodovědné gramotnosti jsou srovnatelné s průměrem zemí OECD. Některé země s podobným kulturním a historickým vývojem se nicméně umisťují nejen statisticky významně nad průměrem OECD, ale i statisticky významně nad výsledky České republiky. Mezi takové země patří Estonsko, Polsko a Slovinsko, a proto byly vybrány pro účely této srovnávací studie. Ta se zaměřuje na porovnání národních kurikulárních dokumentů vybraných zemí, zvláště pak na základní aspekty, které jsou důležité pro fyzikální vzdělávání na vyšším stupni základních škol. Studie se soustředí zejména na porovnání vzdělávacího obsahu a výstupů ve fyzice, na mezipředmětové vzdělávání a průřezová témata, vzdělávací metody a hodnocení a oborově specifické kompetence. Jedním z nejvýznamnějších rozdílů, který tato studie odhalila, je míra volnosti, kterou dané kurikulární dokumenty poskytují školám při rozhodování o tom, jak bude výuka jejich učitelů vypadat. Toto i další zjištění jsou podrobněji diskutovány v článku.

Klíčová slova: srovnávací studie, kurikulum, druhý stupeň ZŠ, fyzika.

1 Introduction

In our hectic information age, social demands on education are rapidly changing. Ongoing automation and upcoming massive digitization (known as Industry 4.0) are leading some professions to extinction, while some are made indispensable. Unfortunately for educators of the entire world, it is difficult — if not impossible — to predict, which knowledge and skills are going to be needed by pupils who are starting school in these days. Educational systems of developed countries try to face this challenge by supporting the trend of teaching pupils to think critically and solve problems instead of memorizing facts. However, in some countries this shift is prescribed by official curriculum, while in others it has the nature of a recommendation or the obligatory documents even keep silent on the topic completely.

Nowadays, an opportunity to make curriculum changes is opening in the Czech Republic, where the basic educational document, Framework Educational Programme, will undergo potentially significant revisions. Because educational systems in general are considered rather conservative, every change done today will most likely first bear fruit after couple of years; additionally, it will not be easy to replace it with another change. That is the reason why thorough analysis and discussion should precede every curriculum revision, containing also a study of already existing models used in culturally close (and successful) countries. This paper provides such a study focused on comparison between Czech Republic, Estonia, Poland and Slovenia based on analysis of physics-related curriculum documents in these countries at lower secondary level. In the whole paper, we analyse documents influencing the mainstream of pupils' population, i.e. we do not deal with the modifications of curriculum for e.g. gifted pupils, pupils with special needs or national minorities.

2 Characteristics of selected countries

2.1 Historical and economic background

There are plenty reasons why compare just these four countries. Since the Second World War, all of them have shared similar historical development including tens of years under the communist dominance and fundamental politic and social changes in early nineties leading to the triumph of parliament democracy.

In 2004, all four countries became members of the European Union (EU) and the living standard of their inhabitants is continuously approaching the EU average. Nowadays, the Czech Republic, Estonia, Poland and Slovenia show very similar Human Development Index (United Nations Development Programme, 2016) and quite close values of gross domestic product purchasing power parity per capita (World Bank, 2017), as shown in Fig. 1.

If we focus on the segment of education, all the four countries spend on it typically 4-5% of their gross domestic product, and annual expenditure per student ranges between 7 000–10 000 USD (OECD, 2017); for comparison, e.g. in Austria it is more than 14 500 USD. Another similarity is represented by a ratio of students who are visiting privately managed schools, which varies around 3% (OECD, 2012) placing all four countries among those with the lowest ratio within the EU. In detail, all these data is summarized on the scheme in Fig. 1.

In all four countries, the ratio of people finishing their tertiary education is continuously growing, as it is evident from Fig. 2, which illustrates the development in the last ca. two decades (OECD, 2017). However, despite the significant increase, the Czech Republic remains significantly behind the remaining countries.

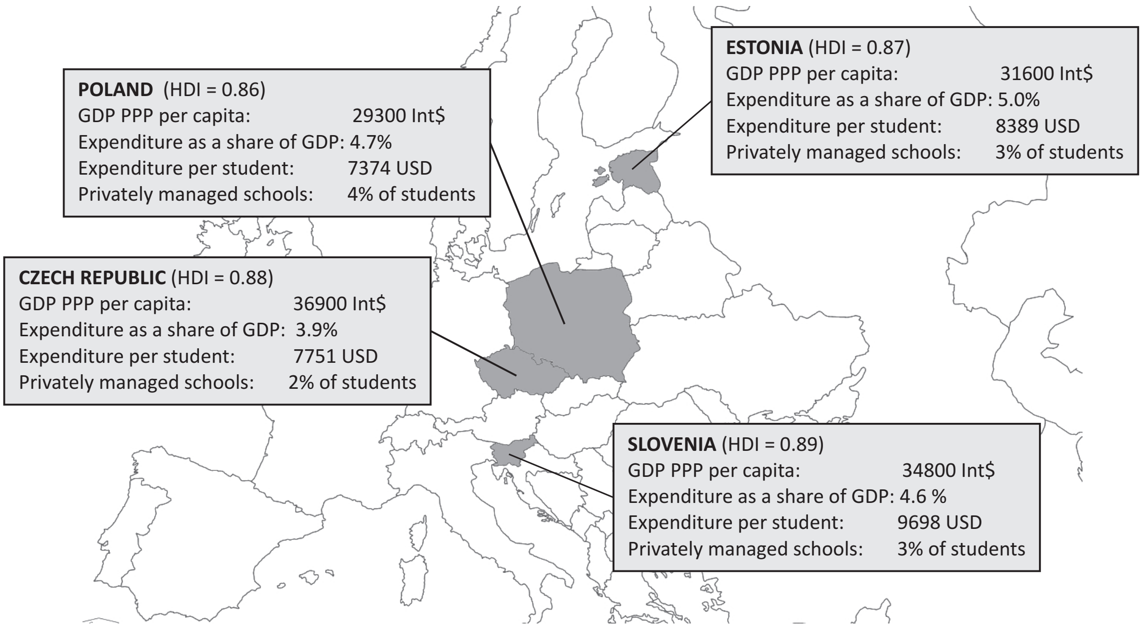

Fig. 1: For each country, the values of Human Development Index (HDI), gross domestic product purchasing power parity (GDP PPP) per capita, expenditure on education as a share of GDP, annual expenditure per student and the ratio of students attending privately manage schools are indicated

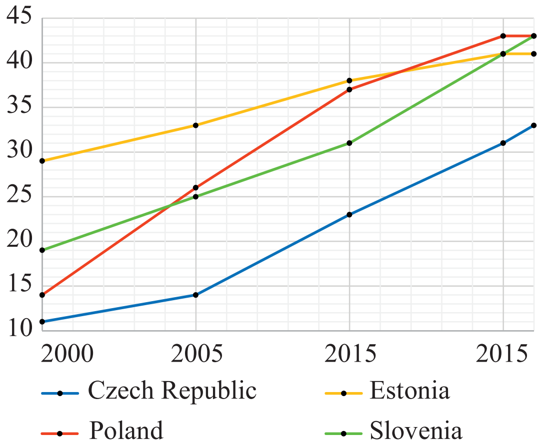

Fig. 2: The ratio of people aged 25–34 with finished tertiary education

2.2 International surveys

It is obvious that similar historical and economic characteristics as those mentioned in section 2.1 are shown also by other post-communist countries such as Slovakia, Hungary, Latvia etc. However, for us as Czech educators, Estonia, Poland and Slovenia are more inspiring due to their results in international measurements of scientific literacy. Starting with the most frequent one, PISA, data shows that pupils in Estonia, Poland and Slovenia have reached higher score in three PISA measurements in a row (2009, 2012, 2015) when compared with Czech pupils (OECD iLibrary, n.d.); with an exception of Slovenia in 2012, all these differences are statistically significant. In the last PISA in 2015, Czech pupils remained in the OECD average, while their peers in other three countries achieved the statistically significantly better results; the graph on the left side of Fig. 3 summarizes their national scores in scientific literacy between 2000 and 2015.

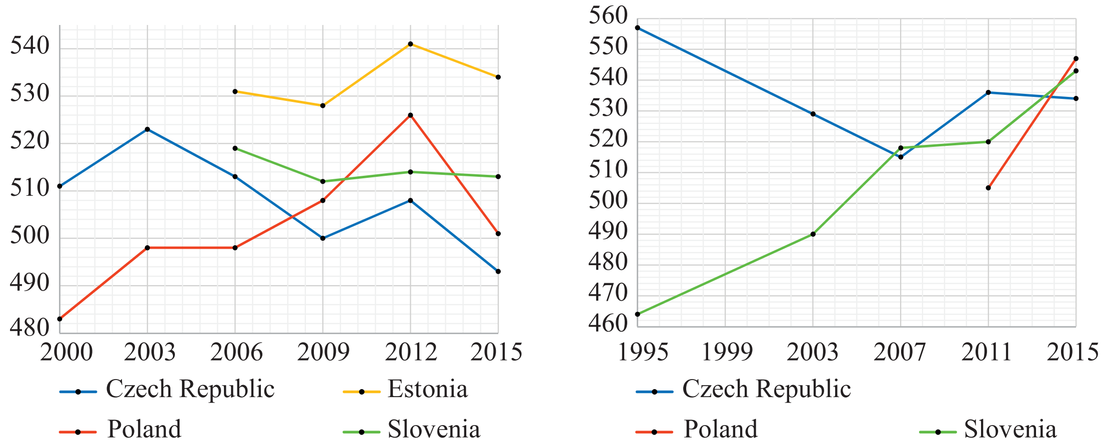

Fig. 3: On the left the PISA national scores in scientific literacy; Estonia and Slovenia have participated since 2006. On the right the TIMSS national scores for 4th grade pupils

The TIMSS study, which focuses on both mathematics and science, does not provide as a complex comparison due to partly missing data — Estonia have not taken part in this study yet and Poland have taken place only in the two last measurements. However, the graph on the right side of Fig. 3 shows an unprecedented improvement of Slovenia in the last two decades, while Czech pupils are lagging behind (TIMSS & PIRLS International Study Center, n.d.). The graph compared 4th grade, i.e. ca. ten years old pupils.

In conclusion, Estonian, Polish and Slovenian pupils are more successful in international measurements in the recent years and do not follow the Czech descending trend. This motivates us to look at science and more specifically physics education in these countries closer.

2.3 Educational systems

Important note: In the case of Poland, this paper only describes the state before the essential educational reform in 2016. We also neglect the introduction of compulsory pre-primary education in the Czech Republic since 2017. The reason is that these changes have not been able to influence national results in international surveys yet.

In all mentioned countries, the so-called single structured education (integrated primary and lower secondary education[1]) is established (Eurydice, n.d.) with two deviations:

- In the Czech Republic, the basic education is organised mostly within the single structure system, nevertheless the multi-year general secondary schools and eight-year conservatoires can provide lower secondary education as well.
- In Poland, the lower secondary education is held at three-year lower secondary schools (*gimnazjum*) which have been phased out since 2017. Pupils graduating from the 6th grade of primary school become pupils of grade 7 in a new 8-year primary school, i.e. the level of Polish lower secondary school will be included in a single structure as well. Moreover, a compulsory external exam at the end of grade 6 of primary education is cancelled due to the introduction of the new structure.

[1] To unify the designation of educational levels (which differs in national curricula), we will use this terminology in the following text: Basic education/school = ISCED 1 + 2 (together), primary education/school = ISCED 1, lower secondary education/school = ISCED 2 (UNESCO, 2012).

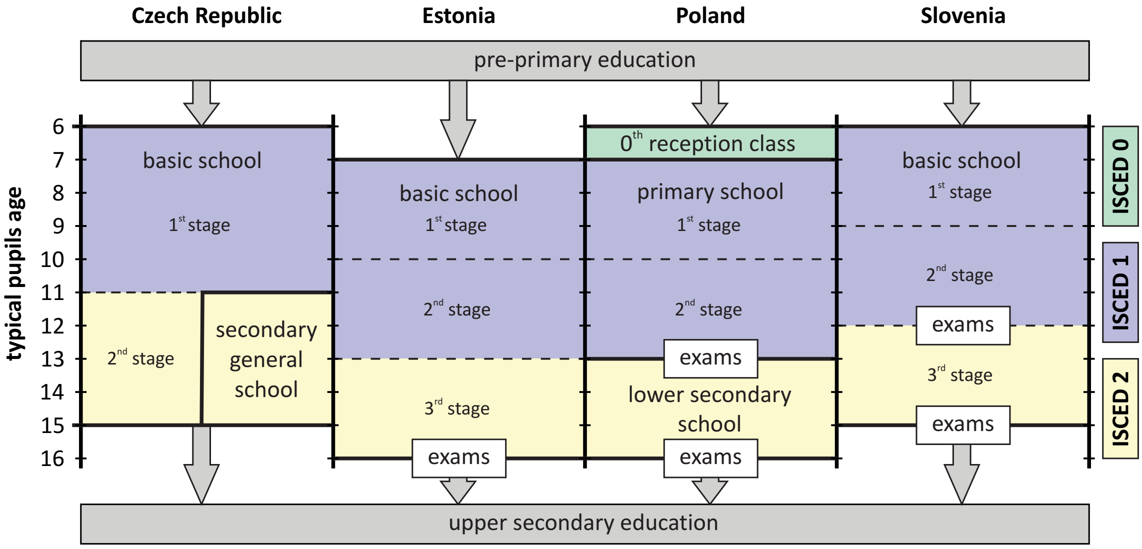

Fig. 4: Full-time compulsory educational system in Czech Republic, Estonia, Poland and Slovenia

In Fig. 4 the full-time compulsory part of educational systems of all four countries are compared. Additionally, in Poland, three years of part-time compulsory education follow up.

Is shown in Fig. 4, the Czech Republic is the only country where pupils at the age of ca. 11 can pass entrance exams to be admitted at elective secondary general school, so called *gymnázium*. On the other hand, if they remain at basic school (most of the population), they are not forced to pass any exams during their whole basic education, while in other countries they have to do so.

In Estonia, to acquire basic education, pupils have to pass a graduation exam in Estonian language, maths and in a subject of their own choice as well as completing a creative assignment (Estonian Ministry of Education and Research, n.d.; Eurydice, n.d.).

Polish pupils leave their primary school passing a national test in Polish language, maths and foreign language. Also the lower secondary school is finished by examination, specifically in humanities, math and science and foreign languages; the results together with the final assessment determine pupils' admission to upper secondary schools (Polish Eurydice Unit, 2015). On the other hand, exams finishing the 2nd and 3rd stage in Slovenia do not influence the marks or have any impact on the educational path of pupils. These examinations are held in math, the native language and a foreign language in 6th grade, and further in math, the native language and a third subject chosen by the ministry in 9th grade (Taštanoska, 2017).

2.4 Curricular documents on lower secondary level

In the Czech Republic, there is a two-level structure for the educational programme — state (The Research Institute of Education, 2017) and school levels. The state level curriculum document, *Framework Education Program for Basic Education* (FEP), specifies among others particular objectives, form and basic curricular content of education, and general conditions for their implementation.[2] In accor-

[2]At some points, the FEP refers to the Czech Education Act and to the Decree no. 48/2005.

dance with the FEP, each school creates its own education programme, which provides the framework for implementing education in particular schools.

The Estonian *National curricula for basic schools* (Estonian Ministry of Education and Research, 2014) consists of a general part and appendixes. The general part forms the national standard for basic education and the appendixes include subject field syllabuses, optional subject syllabuses and descriptions of cross-curricular topics. Similarly as in the Czech Republic, each school creates its own education programme based on the national curricula.

The *National curriculum* in Poland (Polish Ministry of National Education, 2012) establishes the standard for education in all school levels. It specifies teaching objectives for each subject. All teachers have to integrate the national curriculum into their own subject-specific syllabus or to choose a commercial syllabus.

The structure of education in Slovenia is set forth in the *White Paper* revised in 2011 (Krek & Metljak, 2011). The White Paper deals with individual areas of the educational system, describes common learning objectives and discusses education of pupils with special needs, gifted pupils, national minorities or adult education. Syllabuses of individual subjects are described in separate documents on the website of the Ministry of Education, Science and Sport (Ministry of Education, Science and Sport, n.d.).

In the following text we proceed from information obtained in these documents without repeated citations unless otherwise specified.

3 Comparison of prescribed physics curricula

On the basis of documents described in the subchapter 2.4, we will now compare all four countries in fundamental aspects we find important for physics education.

3.1 Physics in the context of the national curricula

In Czech lower secondary schools, *Physics* is (together with *Chemistry*, *Natural Sciences* and *Geography*) a part of educational area *Humans and Nature*, which build on primary school educational area *Humans and their world*. The minimum time allotment for the whole lower secondary area is 21 lessons per week (lpw) for the whole four years (grades 6–9); at their discretion, school directors can increase this number using some of 18 lpw disposable. For *Physics*, specific time allotment depends on each particular school.

Estonian pupils are learning *Science* since they enter the school — in grades 1–7 with total 12 lpw. In grades 8 and 9, the separate *Physics*, which should deepen the knowledge gained in *Science*, appears with total allotment 4 lpw. Additionally, there are also 4 lpw disposable to support selected subjects in the 3rd stage.

In Poland, *Physics* is a separate subject at lower secondary schools following the primary school educational area *Natural Science*. The curriculum allocates for *Physics* minimally 130 compulsory lessons, which corresponds to 4 lpw during the whole three-year period (Francuz-Ornat & Kulawik, 2009).

Slovenian curriculum contains *Science* taught in grades 4–7 (with total allotment 11 lpw) which is — similarly as in Estonia — in grades 8 and 9 replaced by more specialized subjects, among others by *Physics* with 2 lpw in both grades.

3.2 Teaching content and learning outcomes

The core of all above mentioned curricular documents is created by the variously detailed list of prescribed learning outcomes which should be reached by pupils — in other words, what pupils should learn or manage.

Polish curriculum is based only on these outcomes and does not contain any list of prescribed teaching content (concepts or laws required). In Estonia and Slovenia, learning outcomes are explicitly associated with related physics content and both are obligatory for teachers. The Czech curriculum uses a different philosophy, because the teaching content is not obligatory while the learning outcomes are; this leads to the slightly paradoxical situation, when some physics topics in the FEP lack the relevant related outcome and vice versa.

To get an idea of how the structure of particular curricular documents looks like, we choose the topic *"lenses"* on which we would like to illustrate the approach and the degree of detail applied in each country. Tab. 1 shows the verbatim excerpts from curricular documents related to this topic.

At first sight it is obvious that the Estonian national curriculum is much more extensive and detailed in comparison with the other countries — this applies in almost all physics topics. On the other hand, the Czech learning outcomes are formulated rather vaguely avoiding optical concepts related to lenses.

Besides the way how the outcomes are formulated, we also focused on the breadth of the topics being taught. In Tab. 2, we summarize what physics topics are prescribed by curricular documents in compared countries at lower secondary school level.[3] Tab. 2 does not take into account, how deeply are different topics dealt with, as well as what time is allocated for them — it only shows what particular physics topics are present in the curricular documents.

From Tab. 2 a few interesting findings could be extracted:

- In Estonia and Slovenia, some topics are contained in the curriculum of *Science*, so they are no more mentioned as a part of physics lessons.
- Estonia is the only country dealing also with micro-world physics at lower secondary level. On the other hand, Polish curriculum completely resigned from topics of modern physics and astronomy, which is also explicitly written there.
- Czech pupils should learn — unlike their foreign peers — about semiconductors or alternating voltage; however, they can completely miss topics about oscillations and waves.
- In Slovenia, some topics could be incorporated in physics lessons optionally — an example is electromagnetic induction or semiconductors, but also the 3rd Newton's law (while 1st and 2nd law are obligatory).

However, all these findings are made on the basis of prescribed curriculum analysis, they do not have to reflect what is really happening during the instruction.

[3] As we mentioned above, the teaching content is not obligatory in the Czech Republic, but we used both the content and outcomes to fill in Tab. 2. The reason is that many learning outcomes are formulated very vaguely or focused too narrowly. On the other hand, it is illogical to proceed from teaching content only, because it lacks some topics which evidently must be taught to meet learning outcomes. For example, a semiconductor diode is not mentioned in the list of teaching content, but there exists a learning outcome "the pupil connects a semiconductor diode correctly".

Tab. 1: The comparison of what the curricular documents contain related to the topic *lenses*

	teaching content	learning outcomes
Czech Republic	Refraction by thin converging and diverging lenses (qualitative).	*Pupils will decide, based on their knowledge of the speed of light in two different media, whether light will be refracted towards the normal or away from it, and use this fact in analysing the path of light through a set of lenses.*
Estonia	Non-flat lens. Concave lens. Focal length of lens. Optical strength of lens.	*Pupils:* • *describe the important features of the following concepts: angle of refraction, focus, real representation and apparent representation;* • *explain the meaning of focal length and optical lens strength and ways of measuring them and know the measuring unit used;* • *explain the patterns of the refraction of light (i.e. when light is transmitted from one environment to another it refracts depending on the speed of light in substances either towards the perpendicular line of the surface or away from it) and explain the meaning of the formula* $D = 1/f$ *and use this formula in solving problems;* • *describe the function of non-flat lens, concave lens, glasses and light filters and give examples of their use;* • *conduct an experiment measuring the focal length of a non-flat lens or creating an enlarged or decreased representation of an object with a non-flat lens, know how to describe the representation created, construct a drawing of the experimental instrument to which they add the distances between the object, the lens and the screen and process the data of the experiment.*
Poland	—	*Pupils:* • *describe the way of rays passing through the converging and diverging lenses (running parallel to the optical axis), using the terms focus and focal length;* • *by constructing find the image created by lenses, distinguish between real/apparent, upright/inverted and enlarged/reduced images.*
Slovenia	Lens properties. Image formation by converging lens.	*Pupils:* • *adopt the concept of the focal point and the focal length of the converging lens;* • *try to explore the law of the image formation by converging lens and analyse the flow of rays through the collecting lens (experimentally).*

Tab. 2: List of physics topics prescribed by curricular documents in compared countries. Legend: $\surd$ = taught in *Physics*, $\surd$S = taught in *Science*, $\times$ = not taught at lower secondary school level

topic and subtopics		Czech Republic	Estonia	Poland	Slovenia
units and their measurement		$\surd$	$\surd$S	$\times$	$\surd$
mechanics	movements	$\surd$	$\surd$, $\surd$S	$\surd$	$\surd$
	forces, Newton's laws	$\surd$	$\surd$	$\surd$	$\surd$
	work and power, energy	$\surd$	$\surd$	$\surd$	$\surd$
	pressure in fluids, Archimedes' principle	$\surd$	$\surd$	$\surd$	$\surd$
	atmospheric phenomena and weather	$\times$	partly	$\times$	optionally
electricity and magnetism	electrostatics	$\times$	$\surd$	$\surd$	$\surd$
	electric circuits, Ohm's law	$\surd$	$\surd$	$\surd$	$\surd$
	magnets and their properties	$\times$	$\surd$	$\surd$	$\surd$
	magnetic fields due to electric currents	$\surd$	$\surd$	$\surd$	$\surd$
	electromagnetic induction	$\surd$	$\times$	$\times$	optionally
	alternating current/voltage	$\surd$	$\times$	$\times$	$\times$
	generation of electricity, power plants	$\surd$	$\times$	$\times$	$\surd$S
	semiconductors	$\surd$	$\times$	$\times$	optionally
	Earth's magnetic field	$\times$	$\surd$	$\times$	optionally
thermal physics	temperature and heat	$\surd$	$\surd$	$\surd$	$\surd$
	calculation of heat	$\surd$	$\surd$	$\surd$	$\surd$
	changes of states	$\surd$	$\surd$	$\surd$	$\surd$
oscillations and waves	oscillations	$\times$	$\surd$	$\surd$	$\surd$S
	waves	$\times$	$\surd$	$\surd$	$\surd$S
	acoustics	$\surd$	$\surd$	$\surd$	$\surd$S
optics	reflection and refraction of light	$\surd$	$\surd$	$\surd$	$\surd$
	mirrors	$\surd$	$\surd$	$\surd$	$\surd$
	lenses	$\surd$	$\surd$	$\surd$	$\surd$
	principle of eye	$\times$	$\surd$	$\times$	$\surd$
	lights and colours	$\times$	$\surd$	$\times$	$\surd$S
space	Solar System	$\surd$	$\surd$	$\times$	$\surd$
	movement of Earth, Moon phases	$\surd$	partly	$\times$	$\surd$
	stars	$\surd$	$\times$	$\times$	$\surd$
	creation/development of the universe	$\times$	$\times$	$\times$	$\surd$
micro world	structure of atoms	$\times$	$\surd$S	$\times$	$\times$
	radioactivity	$\times$	$\surd$	$\times$	$\times$
	nuclear energy	$\surd$	$\surd$	$\times$	$\times$

3.3 Interdisciplinary and cross-curricular topics

Interdisciplinary and cross-curricular topics are not mentioned in Polish curriculum, so we left it from this chapter.

3.3.1 Interdisciplinary topics

In all other curriculums (except for Poland) physics is viewed as a part of other science subjects and connection between *Physics* (or *Science*) and *Mathematics* is emphasized. In Estonian curriculum, connection between *Science* and other subjects is described in detail. For example connection between *Science* and *Art*: "The shaping of art competence is supported by formulation of research results, making presentations, going to exhibitions, valuing the beauty of nature in study trips etc."

3.3.2 Cross-curricular topics

In the Czech Republic, there are six cross-curricular topics:

- personal and social education;
- democratic citizenship;
- education towards thinking in European and global contexts;
- multicultural education;
- environmental education;
- media education.

These topics are mandatory in basic education, but it is the school's responsibility to implement them. They could be used as an integrated part of the educational content of some subjects or as a special subject, projects, seminars etc. Each cross-curricular topic has a few thematic areas and example, how the topic is related with other subjects and educational areas. For example, the thematic areas in the topic *Environmental education* are:

- ecosystems;
- fundamental conditions for life;
- human activities and environmental problems;
- humankind's relationship to the environment.

In the Estonian curriculum, there are eight cross-curricular topics:

- environment and sustainable development;
- lifelong learning and career planning;
- citizens' initiative and entrepreneurship;
- cultural identity;
- information environment;
- technology and innovation;
- health and safety;
- values and morality.

There are some options, how to implement these topics into science. For example, about Information environment: "While studying natural sciences, students gather information from different sources of information, evaluate and use this information critically."

In Slovenian (and Polish) documents, the cross-curricular topics are not mentioned.

3.4 Methods

In all other curriculums except for the Czech one, active learning methods are emphasized. For example, in Estonia:

> Significant attention is paid to shaping the studying motivation of students, and in order to achieve this various interactive study methods are used: problem-based and research-based studying, project work, discussions, brainstorming, role plays, study outside of the classroom, study visits etc.

Active methods are recommended in Poland too (experiments, problem-solving and work with different materials should be the main activities during lessons), group work is said to be equally as important. Similarly, according to the Slovenian curriculum, the learning should be based on pupils' activity, their observation and experiments.

All three curriculums (except Czech) mention some example of experiments pupils should do. In Estonia, each topic has a part called "practical work and use of ICT" where several laboratory works are described. The Polish curriculum mentions 14 experiments which should be done during lessons (at least half of them in groups, the rest as demonstrative). In Slovenia, there are chosen learning outcomes which should be reached by doing experiments.

In the Czech curriculum, the methods are mentioned only generally in the beginning of the educational area *Humans and Nature*. There is mentioned that *Physics*, *Chemistry*, *Biology* and *Geography* have explorational character. In these subjects, pupils develop some important skills as observing, experimenting and measuring, making hypothesis etc. There are not mentioned any active methods in *Physics*, any recommended experiments, but there are a few learning outcomes which suppose active work of pupils (for example "pupils measure some physical quantities using suitably chosen meters").

3.5 Assessment

The Czech FEP refers to Czech Education Act and to Decree no. 48/2005. According to them, the assessment should be written in school rules where the criteria of assessment should be specified together with "principles and methods of assessment and self-evaluation results of education and behaviour of pupils including how evidences of assessment are gained". What should be assessed and how to assess in *Physics* or in *Science* is not mentioned.

In Estonia, it is specified how to assess in *Science*:

> The aim of assessment is primarily to support the development and studying motivation of the students. In evaluating written assignments, primarily the content of the work is evaluated, but grammar mistakes are also corrected, which are not taken into account in assessment. The forms of checking learning outcomes must be diverse and in accordance with learning outcomes. The students must know what is being evaluated and when, what forms of assessment are being used and what the criteria of assessment are.

In Poland, the assessment is not mentioned in the curriculum.

The Slovenian curriculum has specified how to assess in *Physics*:

> The knowledge is checked with oral and written evaluating, checking experimental work, project work etc. Written assessment is not obligatory; if tests are implemented, they should be assembled in such way that more than half of the points can be achieved with non-calculating tasks.

3.6 Competences

In the sense of the Czech, Estonian and Slovenian national curricula, competences are defined as combination of knowledge, skills, abilities and attitudes important to the personal development in a particular field. In the Polish national curriculum, the word *competency* is not defined, but this document describes the most significant skills, which pupils should develop during their education. After their detailed analysis, it is evident they can also be understood as competences in terms of the definition mentioned above.

3.6.1 Czech Republic

In Czech educational system, together six groups of competences are defined for basic education:

- learning competences;
- problem-solving competences;
- communication competences;
- social and personal competences;
- civil competences;
- working competences.

These competences are formed and developed in all educational areas and contain detailed description of objectives that the pupil is expected to master at the end of basic education. Instructions how to gain these objectives are stated in every educational area (not in particular subjects such as *Physics*) — here is an example for area *Humans and Nature*:

Pupils are guided towards:

- Testing natural phenomena and their interconnections through the use of various empirical fact-finding methods (observation, measurement, experimentation) as well as various forms of rational thinking.
- The need to ask themselves questions regarding the form and causes of various natural processes, to properly formulate these questions and to seek satisfactory answers to them.
- ...

3.6.2 Estonia

Estonian national curriculum distinguishes between seven general competences, subject field competences and competences expected in stages of study. General competences below are described in great detail and developed through all subjects:

- social and citizen competence;
- self-management competence;
- learning to learn competence;
- communication competence;
- mathematics, natural sciences and technology competence;
- entrepreneurship competence;
- digital competence.

The subject field competences in natural science refer to the capability to:

- observe and explain phenomena and processes that exist in the natural, technological and social environment;
- analyse the environment as a system;
- identify science-related problems occurring in the environment and use natural science methods to solve them;
- make decisions on socio-scientific issues.

These competences are completed with the so-called "competences in stages of study" — general objectives saying what basic school graduates are expected to be able to do. In Physics, these objectives are:

- show an interest in physics and other natural sciences and understand their importance in the development of everyday life and society;
- acquire physics-related knowledge and process skills necessary for functioning in everyday life and lifelong learning;
- know how to apply the scientific method when solving problems;
- ...

3.6.3 Poland

Polish national curriculum states eight competences that the pupil should gain during his or her lower secondary education:

- reading competence;
- mathematical thinking;
- scientific thinking;
- teamwork competence;
- ability to search, select and critically analyse information;
- ability to effectively use modern information and communication technologies;
- learning to learn competence;
- communication in mother tongue and foreign languages.

One of the most important goals of the lower secondary education is seen in continuation of learning communication in mother tongue, including enriching the pupils' vocabulary. The emphasis is also put on digital competences. For the educational field *Physics*, no specific competences are stated.

3.6.4 Slovenia

In Slovenia, specific competences are addressed in syllabuses of individual school subjects. This section deals with competences stated in the *Physics* syllabus, but similar ones could be found in the syllabus of *Science*:

- critical thinking;
- problem solving;
- creativity;
- initiative;
- decision making;
- risk assessment.

However, realization of many components of following competences is also enabled:

- mathematical competence;
- communication in mother tongue;
- communication in foreign languages;
- digital competence and literacy;
- learning to learn competence;
- social competence.

All these items contain specific suggestions how to develop them. For instance: "Competence of the digital literacy is based on the use of information technologies (IT), especially simulations, interactive animations and measuring with sensors."

4 Discussion

After detailed analysis, we can state that Czech curricular documents are much less binding and strict in comparison with Estonia, Poland and Slovenia. The Czech FEP gives schools a quite strong autonomy in deciding how the learning process will look like. From the perspective of this document, Czech teachers have more freedom when constructing their lessons, both in selecting specific learning topics and methods; this finding is valid not only in *Physics*, but also generally. Also Czech pupils experience considerable freedom, because they are (unlike their foreign peers) not subjected to any obligatory centrally prescribed examinations or tests at lower secondary level. Among compared countries, the Czech educational system is also unique in that pupils can (typically after grade 5) change to elective schools, which however have to follow the same curricular documents as common basic schools.

The wide autonomy of Czech lower secondary schools is also manifested by time allotment dedicated to physics. While Poland and Slovenia have a fixed number of physics lessons and in Estonia, the guaranteed number of lessons could be increased by disposable ones, the Czech curriculum allocates time only for the whole educational area *Humans and Nature* — because of that, the time allotment for physics may significantly vary at different schools.

For this reason it is impossible to generalize in which grade Czech pupils start with *Physics*; their Polish peers do this in grade 7 and in both Estonia and Slovenia, pupils meet *Physics* only in grades 8 and 9, when it follows up on *Science*.

If we focus on what physics topics are taught (see Tab. 2), in traditional branches like mechanics, electricity, thermal physics or optics we have not found any fundamental differences between the countries. Interestingly, Polish curriculum explicitly avoids all topics from modern physics; on the other hand, Estonian documents deal also with micro-world physics at lower secondary level.

The degree of knowledge which should pupils gain is in all countries expressed by a list of learning outcomes — in other words, what should pupils know and be able to do. In this field, the Estonian curriculum excels due to its punctuality, when some outcomes include even explicitly stated mathematical formulas. In contrast, Czech learning outcomes are the least numerous and the shortest, poor in concrete physics concepts.

Estonian, Polish and Slovenian curricular documents deal also with methods, which could be used by teachers — in all three countries, emphasis is placed on active methods, student-centred and inquiry-based learning. The Czech FEP does not contain any similar recommendation concerning teaching methods.

In Estonia and Slovenia, the curricular documents also mention the aim, subject and way of assessment in *Physics* or *Science*. We have not found any similar instructions in Polish and Czech documents; as in many other cases, in the Czech Republic the responsibility for assessment is left to schools.

As far as competences are concerned, all four countries included them into their curriculum in different forms. However, it seems that in Estonia, Poland and Slovenia the general, not subject-specific, competences ideologically come from key competences for lifelong learning (European Communities, 2007) defined by the European Parliament. Czech key competences are formulated in a different way. Except for general competencies, Estonia and Slovenia define specific competencies for *Physics*; Slovenian curriculum also mentions examples of their implementation in teaching.

In general, Estonian and Slovenian curriculum are in many aspects quite close and have in common especially much more detailed structure of teaching content and learning outcomes in comparison with Czech Republic and Poland.

5 Conclusions

On previous pages, we compared physics curricula of four post-communist countries from different perspectives — e.g. physics teaching content, learning outcomes required from students, teaching methods etc. The overall impression we got shows, that in the Czech Republic, curricular documents offer both schools and teachers high level of autonomy to adapt the lessons according to their ideas. This considerable freedom is enabled and simultaneously redeemed by brevity and superficiality of the main Czech curricular document, Framework Educational Programme. The remaining three countries are characteristic by more rigid and detailed rules, which determine what the learning process looks like.

However, it is hard to say, if and how the nature of curricular documents contributes to quality of instruction. At first, PISA survey, which we took as a starting point of this paper, certainly cannot be a single indicator of this quality. Furthermore, we have no idea how the curricular documents are really implemented in schools and how particular teachers work with them. Finally, it was beyond the scope of this article to analyse the system of future teachers' preparation in compared countries, but that is something that is essential for the results of every educational system of the world. Despite that, we hope this study could serve as an inspiration for possible curriculum changes planning in the Czech FEP in the near future.

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Petr Kácovský, petr.kacovsky@mff.cuni.cz
Věra Koudelková, vera.koudelkova@mff.cuni.cz
Marie Snětinová, marie.snetinova@mff.cuni.cz
Charles University, Faculty of Mathematics and Physics
Department of Physics Education
V Holešovičkách 2, 180 00 Prague, Czech Republic

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A Comparative Analysis of the Chemistry Curricula for Lower Secondary Education in the Czech Republic, Poland, Slovenia and Estonia

Eva Stratilová Urválková, Milada Teplá, Svatava Janoušková

Abstract

This article presents an analysis based on the principles of (international) comparative pedagogy focusing on the study of the similarities and differences in subject-specific competences, educational content, and teaching strategies and methods. The analysis focuses on the field of chemistry, specifically the intended curriculum of the abovementioned countries for the level of lower secondary education. Three parameters were monitored and compared: the number of hours allocated for the teaching of chemistry, of all science subjects from the 6^{th} to 9^{th} grades, the educational content of the subject of chemistry and the teaching strategies discussed and/or recommended for the teaching of natural sciences. Analysis has shown that chemistry is taught for the same length of time, but chemistry topics in Slovenia and Estonia are also taught within the subject Natural Sciences in the 7^{th} grade. The expected outcomes are comparable in all countries, but Czech outcomes are grouped into broad topic areas with few outcomes. The expected outcomes from other countries are specified in much more detail. The recommended teaching methods are most closely described in the Slovenian curriculum, which also contains extensive didactic recommendations for individual subjects.

Key words: chemistry curriculum, comparative analysis, instruction time, learning outcomes, teaching strategies.

Srovnávací analýza vzdělávacího oboru chemie pro základní školy v rámci českého, polského, slovinského a estonského vzdělávacího programu

Abstrakt

Cílem článku je představení analýzy vycházející z principů (mezinárodní) srovnávací pedagogiky se zaměřením na zkoumání shod a rozdílů oborově specifických kompetencí, vzdělávacího obsahu (hodinová dotace, rozsah a zaměření učiva) a metod a postupů ve výuce (zařazení hands on aktivity, badatelsky orientované výuky apod.). Analýza se zaměřuje na vzdělávací obor chemie, konkrétně na zamýšlená kurikula shora uvedených zemí pro úroveň nižšího sekundárního vzdělávání. Byly sledovány a porovnávány tři parametry: počet hodin alokovaných pro výuku chemie, popř. všech přírodovědných předmětů od 6. do 9. třídy, vzdělávací obsah předmětu chemie a vyučovací metody diskutované a/nebo doporučované pro výuku přírodních věd. Analýza ukázala, že chemie je vyučována stejně dlouhou dobu, ovšem přírodní vědy jsou ve Slovinsku a Estonsku vyučovány v rámci přírodovědy už v 6. třídě, přičemž chemická témata jsou součástí kurikula 7. třídy. Očekávané výstupy jsou porovnatelné ve všech zemích, ovšem české výstupy jsou sdružovány do širokých celků s menším počtem výstupů. Očekávané výstupy ostatních zemí jsou mnohem více specifikovány. Doporučované vyučovací metody nejblíže popisuje slovinské kurikulum, které obsahuje také rozsáhlá didaktická doporučení pro jednotlivé předměty.

Klíčová slova: chemické kurikulum, srovnávací analýza, časová dotace, očekávané výstupy, výukové metody.

The national educational system and corresponding documents, especially the national curriculum, have a major influence on the process of education. It is necessary to pay attention to curriculum changes and revisions as they can have far-reaching social, political, economic and mostly educational process consequences. The curriculum is continuously updated by minor changes, but major ones have to be prepared thoroughly in their conception as well as in their content so that the consequences for society will be positive. The way of preparing and implementing the updates partly determines the result at schools. The Czech national curricula are called the Framework Educational Programmes (FEP) and after fifteen years of them being in force, revisions for preschools, lower secondary education, general higher secondary and vocational education shall be prepared. The aim is to set a common basis for the individual development of each student by clearly setting the scope and content of education. These changes should provide sufficient time to consolidate the knowledge and skills necessary to achieve the required learning outcomes as well as to develop individual creativity (NÚV, 2018). In the process of revision, other educational systems and curricula can be inspiring and useful. From comparison and analysis of the documents results can be drawn that support the preparation and implementation of curricula in the Czech Republic and thus make the process more transparent. Another important aspect is that the updates/revisions of curricula should keep to a similar framework to that which is being implemented in other European countries.

The presented research focuses on chemistry education, for which Polish, Slovenian and Estonian curricula for lower secondary education (ISCED2) were chosen. The choice of the countries was determined intentionally. The intention was to compare the documents of countries that: (1) are successful in international surveys, such as the Programme for International Student Assessment (PISA), and (2) have a similar historical background. From all countries, there are these three (Poland, Estonia and Slovenia) that did better than the Czech Republic in the 2015 PISA testing (OECD, 2016: p. 44). Furthermore, these countries used to be part of the Eastern Bloc of states and/or are Slavic countries. Additionally, Estonia and Poland are countries in which the differences in science literacy results between the schools in the country are under the OECD average, while in the Czech Republic the differences are above the average. Educational systems creating different tracks through the system and allowing students to switch among them tend to have larger differences in between-school performance scores and show an impact of social background on learning outcomes (Blažek & Příhodová, 2015: p. 33; OECD, 2016:

p. 225–226). This means that secondary education in the Czech Republic might be found to be selective and students do not have the same opportunity to achieve the same education since it depends on the school the individuals attend. Another assessed aspect in PISA 2015 testing was collaborative problem solving, where out of the European countries, Estonia (followed by Finland) was the one with the highest score, significantly above the OECD average, while the performance of students from the Czech Republic and Slovenia was not significantly different from this average (OECD, 2016: p. 41).

Theoretical framework

The PISA and also other (inter)national assessment results reflect many aspects of education, that can be additionally more or less analysed. This study is focused on curricula with respect to the ongoing Czech curriculum revisions. Therefore, we aim our attention on aspects that could improve the Czech curriculum, so that it is more relevant for the students' achievement and the teachers' smoother implementation of the content and/or changes into school practice.

One of the most obvious parameters to be compared are learning outcomes and learning content, because "what" is taught constitutes the core of the education. For such comparison qualitative comparative analysis (see, e.g., Mayring, 2000) is mostly used. National curricula, as crucial documents that have an impact on almost everyone, are often under analysis. Therefore, many studies are devoted to curricula, moreover, there are journals that focus on curricula research, such as the *Journal of Curriculum Studies*, the *Curriculum Journal*, *Transnational Curriculum Inquiry* and *Curriculum Inquiry.*

A variable that could have an effect on students' achievement is instructional time, but it seems not to be independent variable. The results in the Trends in International Mathematics and Science Study (TIMSS) show that one cannot deduce the students' achievement from instructional time spent on education. There are countries that are high performers in science (grade 8) and spend above average instructional time, such as Slovenia, the Russian Federation, Hungary and Lithuania (Martin et al, 2016a, b). On the other hand, there are countries that spend a great deal of time on instruction, but their students perform relatively poorly, under average; these are Malta, Lebanon and Georgia. On the other hand, there are also countries that report an under average number of hours on science instruction, but achieve high results: for example Singapore, England, Ireland and Sweden (Martin et al., 2016a, b). International studies are also ambiguous: Pattal, Cooper and Allen (2010) reviewed this kind of research and concluded there is a small positive or neutral effect in extended school time on the students' achievements. This can be supported by a later three-month experiment done by Meyer and van Klaveren (2013) carried out in seven Dutch elementary schools. On the other hand, there are recent studies confirming the positive effect of instruction time on achievements, such as in mathematics (Jensen, 2013), or a decrease in grade repetition in Indonesian schools (Parinduri, 2014). Andersen, Humlum amd Nandrup (2016) argue that most of the previous studies were performed on small-scale samples and with weak designs, while their study is large-scale and randomised. Their results show a positive impact of increasing instruction time and compare that extra time with no formal requirements on content is at least as efficient as extra time with a detailed teaching programme. Andersen also confirmed previous studies (Duckworth & Seligman, 2006; Baumeister, 2007) in which extending the school day may cause behavioural problems (students become more aggressive and hyperactive; have trouble managing their emotions), mainly in boys who tend to have less capacity for self-control than girls. However, another large-scale study (about 11 500 students) performed in Switzerland (Cattaneo, Oggenfuss & Wolter, 2017) confirmed a small increase in students' PISA achievements, but the study discusses the effectiveness of this with respect to the high cost that each extra hour brings. Instruction time is important for us, the authors of this article, because it shows how much chemistry education is comparable and whether students have similar time to embrace the required knowledge.

Beside "what" and "how much", there is a crucial question of "how" chemistry content is implemented into chemistry education. The unpopularity of natural sciences is a constant problem that was discussed even at the beginning of the 20^{th} century (Mead, 1906). There are authors that consider the youngsters' interest as a key to successful acceptance of the learning content. Hidi and Renninger (2006) proposed a four-phase model for interest development (triggered situational interest, maintained situational interest, emerging individual interest and well-developed individual interest). They suggested that group work, puzzles, and computers implemented by project-based learning, cooperative group work and tutoring trigger situational interest, and opportunities for intersection and challenges lead to well-developed individual interest. Some research discovered that teachers using methods that are responsive, supportive and flexible, are optimal for interest development (Durik & Harackiewicz, 2007; Reeve, 2002). Teaching methods that are the most preferred by Finnish students in grade 9 and thus may most develop the students' interest, were studied on a sample of 3 500 students (Juuti et al., 2010). Boys seemed to be more satisfied with current science teaching, while girls preferred more interactive teaching methods. The structure of the division of teaching methods served as a tool for determining teaching methods in curricula comparison.

The archetypal "how much", "what" and "how" were transformed into research questions for this study:

a) What is the number of hours allocated for chemistry education for each country?
b) What are the topic areas of chemistry learning content in particular national curricula? How do the learning outcomes and content differ?
c) What are recommended teaching methods for chemistry education?

Methodology

Based on the principles of comparative education, a comparative analysis of national curricula was chosen as a basic research method. Our approach was qualitative and focused on the comparison of the content (numbers, words, sentences or larger units), not on the quantity of monitored codes. Specifically, the analysis is focused on the educational field of chemistry for lower secondary education (ISCED2). The analysis was performed with official documents, so the explicit (formal) curricula of countries were compared to the Czech national curriculum, the Framework Educational Programme for Elementary Education (FEP EE). Regarding Slovenia and Estonia, the current valid curricula were used for analysis, while for the Polish national curriculum the former valid curriculum, which is related to success in international assessments, was used.

The list of analysed parameters of national curricula in the educational field of chemistry is below:

a) The number of lessons allocated for chemistry education
b) Topic areas of chemistry learning content
c) Methods and procedures used in chemistry education.

During the analysis of all four curricula, the parts of texts related to parameters a, b and c were coded. Parameter a, the total number of lessons of chemistry (chapter 4.1) is discussed in detail as the total number of lessons for natural science subjects, but our team also put an emphasis on the information of whether there is time allocated for practical laboratory lessons. As a key for coding methods and procedures (parameter c) was used a study by Juuti et al. (2009) which was focused on teaching methods preferences of grade 9 students in Finland. This part of the curriculum analysis uses the same groups of teaching methods as the Finnish study.

The key for coding the topic areas (parameter b) was derived deductively (Mayring, 2000) from the FEP EE. The Czech topic areas, expected learning outcomes and learning content were the independent variables to which other national curricula were compared. In the Czech curriculum, learning content is not compulsory, just recommended, although the key words of learning content were used as a tool for more precise assignment of the Polish, the Slovenian and the Estonian curricula to the Czech document, the FEP EE. The Czech FEP EE is processed too generally and some parts of learning content are involved implicitly in expected outcomes. Therefore, using learning content for valid mutual comparisons of topic areas was a must. All of the ambiguities were discussed in an expert panel of this article's authors so that the objectivity of coding the topic areas would be guaranteed. The table of the reciprocal assignment of the topic areas to each other is part of this article. The nuances and the details of the assignment of the codes are discussed in the next analytical part of this article.

Description of research sample

Before the comparative analysis of the national curricula will be described, the countries are briefly presented, mainly with a focus on an overview of their educational systems and the valid documents.

Czechia, the Czech Republic, is a small advanced country (population 10.6 million, January 2017) located in the heart of Europe with a long industrial tradition. The education is organised in kindergartens, basic schools, general and vocational upper secondary schools and institutions of higher education. School attendance starts at the age of 6 and is compulsory for 9 years (additionally, the last year of pre-primary education is compulsory from September 2017). Regarding basic education, primary and lower secondary education is organised mostly within a single-structure system in nine-year basic schools which are divided into the first (1^{st}–5^{th} grades) and second stage (6^{th}–9^{th} grades). Lower secondary education is also provided by six- or eight-year general secondary schools and eight-year music and dance conservatoires. Compulsory school attendance, organisation, goals, assessment, etc. are set out in the Act on Pre-Primary, Primary, Secondary, Tertiary Professional and Other Education (the Education Act) (MŠMT, 2004). The national curriculum for basic education is called the Framework Educational Programme for Elementary Education (FEP EE) (VÚP, 2007) which defines the general obligatory framework for all fields of study. Each school elaborates its own School Educational Programme based on the FEP EE where all the content and process details of the educational programme are determined. The Education Act and FEP EE are also available in English.

Poland, the Republic of Poland, with its 38.5 million inhabitants is located in Central Europe and is the ninth largest country (by land area) in Europe. In September 2017, a new educational reform began to be implemented. One of its goals is to transform the primary and secondary educational structure into a single-structure system where the model 6+3 years turns into a model of an 8-year basic school. Since the results in the PISA reflect the former educational system, we focus on the structure and documents valid until September 2017. The Polish former educational structure consisted of four stages, corresponding to basic education, and was partly compulsory until students were 18 years of age. Stages I and II, related to primary education ("szkoła podstawowa" 1^{st}–3^{rd} grades and 4^{th}–6^{th} grades), was followed by stage III organised in junior high school corresponding to lower secondary education (7^{th}–9^{th} grades, in Polish: "gymnazijm"). The last, stage IV, higher secondary education, took two to four years according to the type of school (Eurydice, 2018a). The former educational system is officially defined in the School Education Act; Polish national curricula are elaborated in special documents that are available on the webpages of the Ministry of National Education. The curriculum for the III and IV stages of education, valid until the 2016/2017 academic year, is available, in Polish (MEN, 2007).

Slovenia, the Republic of Slovenia, is a small country (roughly 2 million inhabitants) located in the south of Central Europe. Compulsory basic education is organised in a single-structure nine-year basic school ("osnovna šola") which has three stages, each for three years. After the second and the third stages (grades 6 and 9 respectively), students write a national assessment in three subjects. The assessments should improve the quality of teaching and learning and they do not influence the annual certificate (Eurydice, 2018b). The organisation of education, the scope, competences, procedure and responsible bodies are determined in the Elementary School Act (MIZS, 2016). The national curriculum is called the "Education Programme" and is available in Slovenian on the webpages of the Ministry of Education and Sport (MIZS, 2018a). In addition to the aims, the programme and the national assessment, there are also curricula for each subject, from which we focused on chemistry (MIZS, 2011a, 2011b). All basic schools provide not just a compulsory, but also an extended basic school programme, including after-school classes, morning care, remedial lessons, supplementary lessons, extracurricular activities, as well as non-compulsory optional subjects (Eurydice, 2018b).

Estonia, the Republic of Estonia, is a small country in Northern Europe, with approximately 1.5 million inhabitants (January 2017). Basic education is also organised in a single-structure system with 9 compulsory grades of basic school ("põhikool"). The primary education has two stages (grades 1–3 and grades 4–6) and children start to go to school at the age of 7 (Eurydice, 2018c). Estonian education is legally determined in the following documents: the different levels of education, including basic education, the principles of management and organisation of the educational system, and compulsory school attendance are defined in the Education Act (HTM, 2018a). The basis of the organisation of study, the principles, the rights and responsibilities of students, parents and school staff and other aspects are described in the Basic Schools and Upper Secondary Schools Act (HTM, 2018b). Finally, the national curriculum for basic schools, from 2011, establishes the values and aims of education, the assessment principles and the syllabi of the subject areas (Government of Estonia, 2011). All of the documents are available in English.

Results and discussion

Time allocated for chemistry education

Czech basic education is mostly organised within a single-structure system in nine-year basic schools. The schools are divided into two stages which correspond to primary and lower secondary education. The second stage, lower secondary education, takes up four grades, from 6$^{\text{th}}$ to 9$^{\text{th}}$ (ages 11–15). The Framework Educational Programme for Elementary Education defines the minimum time allotment for educational areas or educational fields (FEP EE: p. 106). Physics, chemistry, biology (nature) and geography are all included in the educational area called Man and Nature and the minimum time allotment per week for these subjects all together and for all four grades is 21 lessons. This means there is no official regulation for a subject nor a grade on time allotment, the only rule is to fulfil the total time allotment in four years. Each school defines in its School Educational Programme how the time allotment will be distributed for natural science subjects (or an integrated subject). The usual practice is chemistry is taught in the 8$^{\text{th}}$ and 9$^{\text{th}}$ grades, in both cases 2 lessons per week. In Table 1 is this is the time allotment for Czech Republic marked as a summary of week lessons for all grades and subjects as it is in the Framework Educational Programme.

Tab. 1: Time allotment per week for natural science subjects

	Czech Rep.				Poland				Slovenia				Estonia			
Grade	*6*	*7*	*8*	*9*	*6*	*7*	*8*	*9*	*6*	*7*	*8*	*9*	*6*	*7*	*8*	*9*
Physics	$\sum 21$				–	$\sum 4$			–	–	2	2	–	–	$\sum 4$	
Chemistry					–	$\sum 4$			–	–	2	2	–	–	$\sum 4$	
Biology					–	$\sum 4$			–	–	1.5	2	–	$\sum 5$		
Geography					–	$\sum 4$			1	2	1.5	2	–	$\sum 5$		
Science	–	–	–	–	3	–	–	–	2	3	–	–	3	2	–	–
Total	21				3 + 16 = 19				5 + 18 = 23				5 + 18 = 23			
ISCED level	2	2	2	2	1	2	2	2	1	2	2	2	1	2	2	2
Chemistry			2	2		1	2	1			2	2			2	2
Laboratory work	Not defined				Not defined				Not defined				Not defined			

Tab. 1 above compares the time allotment for science subjects to the Czech time allotment. The Czech curriculum defines for the educational area Man and Nature 21 hours per week for the whole second stage (grade 6–9, ISCED2). The analysed documents were: the Czech FEP EE (VÚP, 2007: p. 106), the Polish *Poradniky dla dyrektora* (Kapcia et al.: p. 40, 44–50; Domerecka et al.: p. 30, 32–34), the Slovenian *Predmetnik osnovne šole* (MIZS, 2018b) and the Estonian *National Curriculum for Basic Schools* and *Natural Science* curriculum (Government of Estonia, 2011: p. 12; Pevkur, 2011: p. 2).

Lower secondary education in Poland, Slovenia and Estonia takes three years (7$^{\text{th}}$–9$^{\text{th}}$ grades). If we wish to compare the time spent on natural science in these countries to the Czech curriculum, we have to compare the time spent on studying natural science over four years, from grade 6 to grade 9. This means we have to consider also the science subject taught in the 6$^{\text{th}}$ grade (primary education) in Poland, Slovenia and Estonia. In Poland, the subject Science is studied in the 6$^{\text{th}}$ grade 3 lessons per week; in Slovenia and Estonia Science is taught in the 6$^{\text{th}}$ and also the 7$^{\text{th}}$ grade, parallel to geography and this gives 5 more lessons of natural science (see Tab. 1 above).

The total number for natural science subjects (physics, chemistry, biology, geography and science) is similar despite some differences between the studied countries. In Poland, students spend 19 lessons per week in grades 6–9 on studying natural science in total, while students in Slovenia and Estonia spend 23 lessons. The Czech Republic with its 21 lessons allocated for natural sciences over the four years is in the middle. Although students in Poland have 17% less time for natural sciences than students in Slovenia and Estonia, the PISA results do not reflect this.

Regarding chemistry, students in all of the compared countries spend the same amount of time on this subject. In the Czech Republic, the time for the subject chemistry is not specified, but mostly, chemistry is taught two lessons per week for the last two years, in the 8th and 9th grades, which means 4 lessons in chemistry per week per second stage. In Poland, the total number for each subject in each stage of education is defined, which means for chemistry 4 lessons. In Polish schools, chemistry is taught all three years, mostly in the scheme of 1–2–1 lessons. In Slovenia the time schedule for subjects for the whole of basic education is defined; chemistry is studied two lessons per week in the 8th and 9th grades. Lastly, in the Estonian curriculum for Natural Science, it is stated that chemistry, and physics, are studied from the 8th grade for a total of 4 lessons per week, which mostly means the scheme of 2–2 lessons in the 8th and 9th grades.

None of the compared curricula specifies the time allocated for laboratory practice. In the Czech Republic, laboratory practice during lower secondary education is often performed mostly during chemistry lessons or in two lessons of laboratory practice that are held irregularly or every two weeks.

Chemistry curriculum analysis

The educational content of chemistry as a school subject is divided into 7 topic areas in the Czech FEP EE. These areas will be first briefly presented and compared to the areas in other countries using a qualitative analysis approach. The table below summarises the topic areas and gives an overview where the intersections of all curricula can be found. The number of expected learning outcomes illustrates how detailed the chemistry curriculum is for each studied country. Moreover, there is a ratio representing how many outcomes out of the total of each compared curricula matches with the Czech curriculum.

The first topic area, **Observation, experiment and chemical safety**, is devoted to basic laboratory practice, therefore the expected outcomes focus on safe laboratory practice and handling emergency situations. The outcomes are generally described, without any particular suggestions for experiments as it is expected that teachers are continuously applying practical methods. The only explicitly mentioned activities are separation techniques within the second topic *Mixtures* and pH measurement within the fifth topic *Inorganic compounds*. Nevertheless, none of the compared countries isolates the practical work in a special topic area. When discussing the Estonian curriculum: three out of six outcomes from the first topic *What does chemistry involve?* can be assigned to the Czech *Observation, experimentation and safety*. These subcategories generally regard laboratory practice: properties of substances, safety regulations and laboratory instruments. Moreover, each Estonian topic area has a part describing practical work and use of ICT containing specific experiments or suggestions for other practical (student-centred) activities. However, there is no suggested laboratory work for the topic areas *Atomic structure and periodic table* and *Amount of substance – mole calculations*. Similarly, the Polish chemistry curriculum suggests practical work among the outcomes of each topic area, except for the area *Internal structure of matter* and *Carbon and hydrocarbons*. The Slovenian list of learning outcomes consists of two parts, the first of which focuses on content knowledge while the other focuses on the process of receiving the knowledge and suggesting methods and activities for fulfilling operational objectives. In this part, there are suggestions for an experimental approach for each topic, in some cases followed by suggested laboratory activities. The only exception is the topic area *Amount of substance* in which students learn theoretical counting. In the Slovenian chemistry curriculum, safe laboratory practice is among the outcomes of the first topic area *Chemistry is a world of substances*.

In the second topic area, **Mixtures**, students are expected to understand basic separation techniques and their theoretical background (solubility, mixtures, mass fraction); air, water and water pollution are also involved. The Czech curriculum is the only one in which the topic of mixtures is separated from the others. In the Polish chemistry curriculum, a concept of mixtures and separation techniques can be found within the topic area *Substances and their properties*. Unlike the Czech curriculum, the Polish one puts more emphasis on *Water and water solutions*: it is a special topic area, but the outcomes deal with water as a solvent rather than from the environmental point of view, although the two outcomes (water management and solution saturation) are very similar to Czech outcomes. The Estonian learning outcomes for chemistry education do not contain mixtures and separation techniques. The only outcome regarding solutions and colloids is contained in the first Estonian topic area *What does chemistry involve?* which correlates with the outcome for *Mixtures* in the Czech curriculum. Students get to know the concept of the structure of substances and bodies, mixtures and separation techniques in the subject Science which can be found in the Estonian curriculum from the first to the seventh grades. The seventh grade is a part of the third stage of study (ISCED2) and it introduces four topic areas which focus on basic physical, chemical and biological phenomena, as well as technologies and scientific experimental approaches as a part the school subject – Science (Pevkur, 2011). Similarly, the Slovenian chemistry curriculum is lacking the topic of *Mixtures* because it is a part of another subject, Natural Sciences, taught in the 7$^{\text{th}}$ grade. Its first topic area, called *Substances*, is comprised of topics on chemical elements, mixtures and pure substances, solutions, separation techniques and physical and chemical properties of substances, where students also learn the concept of atomic structure and the periodic table (MIZS, 2011a).

The third topic area, **The particulate composition of substances and chemical elements**, seems to be the most prevalent in the curricula of all of the compared countries. Three Czech learning outcomes contain these topics: (1) atoms and molecules, (2) chemical elements and chemical compounds, (3) metals vs nonmetals and the periodic table of elements respectively. There are more specific concepts in the learning content. However, the learning content is only a set of recommendations, and therefore it is not obligatory for school practice.

These concepts comprise the structure of the atom (nucleus, electron shell, electrons in reaction), molecules, elements (periodic table, properties, atomic number) and compounds, nomenclature and the essential concept of a chemical bond. The Polish curriculum presents elements vs compound and metal vs non-metal outcomes in the first introductory topic area, while the *Internal structure of the atom* focuses on the structure of the atom and bonds between atoms in detail. Eight out of fourteen Polish outcomes also match the Czech curriculum. The Slovenian chemistry curriculum contains more information so we can find the concepts of atom-molecule and elements-compounds in the first topic area *Chemistry is a world of substances*.

Three outcomes devoted to the history of knowing the structure of the atom and its relations with the periodic table of elements are included in the topic area *The Atom and the periodic system of elements.* The Slovenian chemistry curriculum defines a separate topic area *Chemical bonds*, where two outcomes match with the Czech topic area. Additionally, the other outcomes are too specific to claim that they correspond with the Czech curriculum. Three other outcomes regarding properties of elements reflecting the position in the periodic system and characteristics of metals can be found in the fifth Slovenian topic area *Elements in the periodic table.* Finally, the Estonian curriculum: the second topic area *Atomic structure and the periodic table: composition of substances* corresponds to five outcomes regarding the structure of the atom and two regarding chemical bonds (covalent vs ionic). In the Estonian curriculum, metals are defined in the wide, separate topic – *Best known metals.* As the Czech curriculum is very brief in its description of metals ("recognize selected metals and non-metals and estimate their possible properties", FEP EE: p. 54), we can assume that just two of the Estonian specific learning outcomes about metals meet the content of the Czech curriculum. We also have to state that unlike the others, the Czech curriculum does not contain a concept of isotopes or ions.

Chemical reactions, the fourth topic area, presents outcomes related to the nature of chemical reactions (reactants vs products, classification of chemical reactions, chemical equations), the factors influencing the process of chemical reaction and basic calculations (amount of substance, molar mass; the law of conservation of mass). The Polish topic area *Chemical reactions* is very similar to its Czech version, with the exception of chemical kinetics which is missing and an indwelling difference between physical phenomenon and chemical reaction which are not included in the Czech curriculum. The Slovenian topic area *Chemical reactions* is also similar to the Czech (and the Polish) as five out of six outcomes match. However, chemical kinetics is not included and the calculations are specified in the last topic *Amount of substance.* On the other hand, Slovenian students learn the first concepts of chemical reactions also during the subject Natural Sciences in the 7^{th} grade. The Estonian curriculum classifies chemical reactions within the curriculum of the subject Science, in the 7^{th} grade, where students learn the difference between physical and chemical phenomena and where they also study chemical reactions known from their everyday lives. Chemical kinetics is mentioned among the outcomes of the fifth topic area *Best known metals*, whereas the calculations of moles and molar mass are involved in the seventh topic area *Amount of substance: mole calculations.*

The fifth Czech topic area, **Inorganic compounds**, is framed in three outcomes devoted to: (i) comparing the properties and uses of selected oxides, acids, hydroxides and salts important in practice, (ii) the concept of pH (scale, measuring pH, neutralisation) and (iii) acid rain. The Polish chemistry curriculum does not include inorganic compounds as an isolated topic. The analysis showed that six out of nine outcomes from the topic *Acids and bases* correspond to the Czech acid and base outcome. The topic area *Salts* is defined in six outcomes, but just two out of them match with the Czech curriculum. The Slovenian curriculum defines the topic area *Acids, bases and salts* where five out of eleven outcomes match with the Czech curriculum – the concept of pH, neutralisation and the importance of acids, bases and salts in everyday life. Lastly, the Estonian curriculum has a topic area called *Main classes of inorganic substances*, but only two outcomes referring to the description of important compounds and chemical pollution match with the Czech curriculum, the other outcomes in the topic refer to chemical reactions of inorganic compounds, solubility and calculations. Other outcomes corresponding to the Czech topic *Inorganic compounds* can be found in the topic area *Oxygen and hydrogen*, where two outcomes relate to oxides (nomenclature). And the fourth Estonian topic area, *Acids and bases*, matches five out of eight outcomes with the Czech outcomes regarding acids and bases.

Organic compounds, which is the sixth topic area, consists of six outcomes regarding properties and applications of hydrocarbons, hydrocarbon derivatives[1], fossil fuels, photosynthesis and biomolecules (proteins, lipids, carbohydrates; vitamins). The content of the following outcomes specifies that students learn about representatives of significant alkanes, alkenes, alkynes and aromatic hydrocarbons as well as significant alcohols and carboxylic acids as examples of hydrocarbon derivatives. The Polish curriculum divides organic compounds into two topic areas: *Carbon and hydrocarbons* and *Hydrocarbon derivatives.* The first topic corresponds to the Czech curriculum in four out of nine outcomes, and these outcomes refer to the classification and properties of hydrocarbons. The topic *Hydrocarbon derivatives* matches with the Czech curriculum in nomenclature and properties of alcohols and well-known organic acids, properties of lipids, protein composition and carbohydrate composition. This means eight matches out of seventeen learning outcomes. The Slovenian chemistry curriculum discusses organic compounds in three topic areas. The first one, *Hydrocarbons and polymers*, corresponds with the Czech curriculum in five out of fourteen outcomes – fossil fuels, carbon's ability to form compounds, and properties of hydrocarbons. The other two topic areas are *Organic compounds containing oxygen* and *nitrogen atom(s).* Furthermore, four out of thirteen outcomes in the topic area *Organic compounds containing oxygen atom(s)* belong to functional groups, polysaccharides and alcohols. The topic area *Organic compounds containing nitrogen atom(s)* matches with the Czech curriculum in four out of ten outcomes – aminogroup, proteins, and the role of proteins in the life of Man. On the other hand, the Estonian curriculum discusses organic compounds mostly in the topic area *Carbon and carbon compounds* (the structural possibilities of carbon, hydrocarbons in nature, alcohols and carbonic acids). There is only one out of five outcomes, describing carbohydrates, lipids and proteins that is specified in the ninth topic area *The role of carbon compounds in nature and carbon compounds as materials.*

The last, the seventh, topic area, **Chemistry and society**, expects students to orient themselves in the theoretical preparation and application of various substances in practice (plastics, detergents, fertilisers, drugs, . . .); students should also learn the basics of the chemical industry and understand materials in the terms of sustainable development. The Polish curriculum seems not to include these outcomes. The Slovenian outcomes corresponding to the Czech curriculum can be found in the topic area *Hydrocarbons and polymers*: three of fourteen outcomes deal with polymers and derivatives influencing the environment. Regarding the Estonian curriculum there are three out of five learning outcomes included in the topic area *The role of carbon compounds in nature* which match with the Czech curriculum. These outcomes contain the questions of renewable and non-renewable resources, characterisation of best known metals and sustainable living.

[1]The title Hydrocarbon derivates is a routine name used in Czech textbooks for naming the group of hydrocarbon compounds containing other atom(s) beside carbon and hydrogen. It is also a part of the Czech national curriculum, the FEP EE, that was used as a key document for comparison. The Polish curriculum uses the same title – the topic area was originally called Hydrocarbon derivatives (*Pochodne węglowodorów).* This division is not used in English literature, but this text uses the term to keep and reflect the original (Czech) terminology.

Tab. 2: Chemistry curricula – a comparison of topic areas

Czech Republic	No. of outcomes	Poland	Matching /Total No. of outcomes	Slovenia	Matching /Total No. of outcomes	Estonia	Matching /Total No. of outcomes
1. Observation, experimentation and safety	3			1. Chemistry is a world of substances	1/10	1. What does chemistry involve?	3/6
2. Mixtures	6	1. Substances and their properties 5. Water and water solutions	4/8 2/7	Science 7th grade: *1.1 Substances: Mixtures and pure substances* *1.2 Substances: Solutions*		1. What does chemistry involve? Science 7th grade: *2. Variability of substances and bodies*	1/6
3. The particulate composition of substances and chemical elements	3	1. Substances and their properties 2. Internal structure of matter	2/8 8/14	1. Chemistry is a world of substances 2. Atom and periodic system of elements 3. Chemical bond 5. Elements in the periodic system	2/10 3/7 2/8 3/10	2. Atomic structure and the periodic table: composition of substances 5. Best known metals	7/8 2/8
4. Chemical reactions	3	3. Chemical reactions	3/4	4. Chemical reactions 10. Amount of substance Science 7th grade: *1.4 Substances: Physical and chemical changes in the substance*	5/6 3/6	5. Best known metals 7. Amount of substance: mole calculations Science 7th grade: *3. Natural phenomena*	1/8 3/6
5. Inorganic compounds	3	6. Acids and bases 7. Salts	6/9 2/6	6. Acids, bases, salts	5/11	3. Oxygen and hydrogen: the most common compounds 4. Acids and bases: substances of opposing properties 6. Main Classes of Inorganic Substances	2/6 5/8 2/7

Tab. 2: continue

Czech Republic	No. of outcomes	Poland	Matching /Total No. of outcomes	Slovenia	Matching /Total No. of outcomes	Estonia	Matching /Total No. of outcomes
6. Organic compounds	6	8. Carbon and hydrocarbons 9. Hydrocarbon derivatives	4/9 8/17	7. Hydrocarbons and polymers 8. Organic compounds containing oxygen atom(s) 9. Organic compounds containing nitrogen atom(s)	5/14 4/13 4/10	8. Carbon and carbon compounds 9. The role of carbon compounds in nature and carbon compounds as materials	4/8 1/5
7. Chemistry and society	3			7. Hydrocarbons and polymers	4/14	9. The role of carbon compounds in nature and carbon compounds as materials	3/5
Topic areas not corresponding with the Czech curriculum							
		4. Air and other gases		1. Chemistry is a world of substances		1. What does chemistry involve?	
		5. Water and water solutions		3. Chemical bond		3. Oxygen and hydrogen: the most common compounds	
		7. Salts		10. Amount of substance		5. Best known metals	
						7. Amount of substance: mole calculations	

The Czech topic areas, listed in Tab. 2 above, are a basis for comparison with the curricula of the other countries. The table contains columns with topic areas and columns with a number of learning outcomes for each topic area. The compared curricula have a ratio that corresponds to how many learning outcomes match with the Czech topic area. In the second part of the table there are topic areas that do not match with the Czech curriculum, or match it very loosely.

To summarise the table and description above, we can see that the Czech chemistry curriculum is divided into 7 topic areas with 27 expected learning outcomes, which is less than any of the compared documents. Tab. 3 (below) summarizes the number of topic areas and learning outcomes for four studied countries.

Tab. 3: The total number of topic areas and learning outcomes in chemistry curricula

	Czech Republic	Poland	Slovenia	Estonia
Topic areas	7	9	10	9
Learning outcomes	27	84	97 (57 + 40)	62

The Polish curriculum states the outcomes more specifically, therefore there are three times more outcomes. The Slovenian curriculum defines almost four times more outcomes than the Czech one, although the higher number is caused by two parts of outcomes as described above (the content knowledge outcomes and the process knowledge outcomes). There are many topic areas which all four countries include in their curricula. These topic areas are the structure of the atom and the periodic table (topic area 3 in the Czech curriculum), inorganic compounds (topic area 5 in the Czech curriculum), organic compounds (topic area 6 in the Czech curriculum) and partly chemical reactions, even though it is not a separate topic area in the Estonian curriculum. Inorganic compounds in the Czech curriculum correspond to the topic areas acids, bases and salts named in the compared curricula. The Czech topic area organic compounds indicates six outcomes, two of them regarding photosynthesis, which is unique just for the Czech curriculum. The other compared curricula describe biochemical topics dealing with proteins, lipids and carbohydrates apart from photosynthesis. The Polish curriculum defines a special topic area – hydrocarbon derivatives, whereas the Slovenian one contains two topic areas – (i) oxygen and (ii) nitrogen containing hydrocarbon compounds.

Now, we can focus on the differences in detail. The Czech topic area *Mixtures* corresponds with the first Polish topic area *Substances and their properties*, but there is a lack of these topics in the Estonian and the Slovenian chemistry curricula as the topics are included in the Natural Science curricula for 7$^{\text{th}}$ grade. This means Estonian and Slovenian students meet with this concept sooner than Czech students. Moreover, the Estonian curriculum also presents the concept of chemical reaction sooner, in the 7$^{\text{th}}$ grade, as a part of the subject – Natural Sciences. The last topic area in the Czech curriculum, *Chemistry and society*, focusing on secondary materials (e.g., fertilisers, plastics, drugs), sustainable development and the environment matches with the Estonian topic area *The role of carbon compounds in nature and carbon compounds as materials* and partly to polymers in the Slovenian curriculum. We can say that this topic area is the most contextualised in the Czech curriculum. The analysis showed there are other contextualised topic areas in the compared curricula: the Polish topic areas *Air and other gases* and *Water and water solutions* focus on phenomena regarding gases and water respectively. Another example can be found in the Estonian curriculum which earmarks two topic areas: *Oxygen and hydrogen: The Most Common Compounds* and *The best known metals*. These concepts are included in topic areas devoted to inorganic compounds in the curricula of the other countries. The Estonian and the Slovenian curricula also present introductory topic areas (the Estonian *What does chemistry involve* and the Slovenian *Chemistry is a world of substances*) that partly relate to the first Czech topic area (*Observation, experimentation and safety*), but they also point out the significance of chemistry for human life and introductory concepts that students may have met in previous grades. Lastly, one of the most significant differences is that observation and laboratory practice is a separate topic area in the Czech curriculum whereas the other compared countries include these in each topic area.

Teaching methods in chemistry education

In this research, the study by Juuti et al. (2009) was used for analysing the teaching methods. Juuti focuses on teaching methods which are preferred by students in the 9$^{\text{th}}$ grade. The effectiveness of each method was not considered because the focus was on the development of the students' interest. The teaching methods for the Finnish study were chosen on the basis of which approaches or strategies are introduced in the pre-service teacher education programme at the University of Helsinki, Finland.

Tab. 4 below summarises extracts from the compared national curricula that correspond to each teaching method.

Tab. 4: The total number of topic areas and learning outcomes in chemistry curricula

Strategies in teaching natural science subjects	
Teacher-led, large group lecture or dialogue	
Czechia	Not specified
Poland	Not specified
Slovenia	Not specified
Estonia	Not specified
Small group work	
Czechia	Not specified
Poland	The amount of the teaching content creates many opportunities to work using the educational project method (especially of a research nature), chemical experiments or other activating methods (...). (p. 316)
Slovenia	Experimental work should be focused on the individual experimental part of each student (group work, pair work, individual work). (p. 23) 5.1.5 Project collaborative work Students' social skills are also developed in chemistry classes (the ability to work together, agreeing, expressing ideas, taking into account different views and opinions, etc.) with various activities (...). (p. 25)
Estonia	Not specified
Laboratory or practical work	
Czechia	The instruction in this educational area is aimed at forming and developing key competences by guiding the student towards: (1) investigating natural facts and their interconnections while employing various empirical methods of cognition (observation, measurement, experiment) as well as various rational methods. (p. 51)
Poland	The student safely uses simple laboratory equipment and basic chemical reagents; designs and conducts simple chemical experiments. (p. 210)
Slovenia	Experimental work is the basic teaching method of chemistry education. This work can be combined with other methods such as active learning and teaching. (...) The experimental work should be focused on the individual experimental part of each student (group work, pair work, individual work). (p. 23)
Estonia	Through practical work, the students acquire the skills they need for such work: learning how to use safely instruments for experiments and the chemicals necessary in everyday life and assessing the danger of everyday chemicals and materials used in everyday life and technology for human health and the state of the natural environment. (p. 61)
Creative problem solving	
Czechia	A way of thinking which requires the testing of hypotheses on natural phenomena through several independent methods. (p. 51)
Poland	Reasoning and applying the acquired knowledge to solve problems. (p. 210)

Tab. 4: continue

Slovenia	The key characteristics of teaching chemistry is problematic scientific questions and activities that help: students learn about certain concepts, facts, content or solve a problem. (p. 22) Developing experimental skills and a research approach is very important for introducing students to research work as it enables them to systematically refer to: (. . .) the definition of an experimental research problem, the setting up of experimental research questions and the creation of hypotheses or the ability to predict. (p. 23)
Estonia	During study, an inquiry-based approach based on the scientific method is used; solving problems arising from the natural, technological and social environments. The studies develop the skills of a creative approach, logical thinking, understanding causal relations, analysis and generalisation. (p. 61)
Reading and writing to learn	
Czechia	Not specified
Poland	The student acquires and processes information from various sources using information and communication technologies. (p. 210) The amount of the teaching content creates many opportunities to work using the educational project method (especially of a research nature), a chemical experiment method or other activating methods, which will allow students to acquire and process information in various ways and from different sources. (p. 316)
Slovenia	In regards to working with sources, a chemistry teacher teaches students to search, sort, edit, and analyse information, cite sources appropriately, and develop critical thinking; the students will then know how to use, evaluate and present the information they receive properly. (p. 25)
Estonia	The students acquire the ability to understand and compile chemistry-related texts, make sense of and use chemistry-related vocabulary correctly, present chemistry-related information through oral and written presentations using different verbal and visual forms of presentation (verbally, and as diagrams, graphs, models and formulas) and using different sources of information, including electronic ones. (p. 61)
Out-of-school informal learning	
Czechia	Not specified
Poland	During the third stage of education, chemistry teachers should find time to perform experiments, use student-centred methods, create educational projects and provide excursions for students. (p. 316)
Slovenia	The chemistry teacher should include modern findings in chemistry; a source of information can also be excursions to research institutions, etc.
Estonia	The school provides: (. . .) 5) outdoor learning sessions and the students participate in nature and environmental education projects. In the 2^{nd} stage of study the students, at least twice, take part in an environmental centre or science education initiative outside of the school and in the 3^{rd} stage of study in every science subject once during the academic year (in the natural environment, at a museum, in a laboratory). (p. 8)

The Czech FEP EE does not specify any teaching method recommended for natural science education. Nevertheless, each subject or topic area is described at the beginning and the main objectives are listed. In the Czech objectives for the educational area Man and Nature, we can see suggestions for laboratory work and creative problem solving.

The former Polish curriculum lacks a description of each subject. On the other hand, educational goals for each subject are included in the introduction. Chemistry has three goals – one of them being managing practical work. At the end of the document, there are short recommendations for implementation, and for chemistry, experiments, activating methods, educational projects (that often require group work) and excursions are mentioned. The new national curriculum that started to be implemented in September 2017 did not change chemistry content and the expected outcomes a great deal, but a remarkable change was in the description of didactic recommendations – problem-based education is stressed and particular experiments are recommended (MEN, 2018).

Regarding methods, the Slovenian chemistry curriculum is the most descriptive. At the beginning of the document, there is a summary of general objectives comprised of experimental skills and critical thinking. Another supportive tool is defining the process of knowledge within the framework of the expected learning outcomes of each topic area. These outcomes recommend an experimental, practical, research and theoretical (such as models, visualisations) approach and other tips for chemistry education. Moreover, the last chapter of the chemistry curriculum is devoted to didactic recommendations (p. 22–31). The main emphasis is put on experimental and practical student-centred activities that should be the main teaching methods in chemistry education. Additionally, various kinds of information and communication technologies, such as visualisation elements, chemical models, and animations should be used to support chemical literacy and the integration of the macroscopic, submicroscopic and symbolic levels. The use of the internet and ICT is also recommended for students' work with information sources, critical thinking and presentation of a scientific issue (p. 25). Teachers should also speak about current knowledge in chemistry that could be supported by excursions to research institutions.

The Estonian curriculum for natural science is the only one naming specific teaching methods which can be used in education for all natural science subjects in the introduction chapter. Unfortunately, the list given for using active learning methods in classes does not contain any suggestions on how to implement the methods in education. A physical learning environment is also specified in the general introductory part, including out-of-school learning (p. 8). Other teaching methods can be found in the description of chemistry (p. 61–62): students learn basic laboratory practice, solve problems by logical thinking, and learn analysis and generalisation and the understanding of chemistry-related texts which they can interpret and present with the proper terminology.

If we compare the four curricula, the Czech and the Polish ones are very brief regarding teaching methods, although the methods can be implicitly derived from the descriptions. The same is implicitly provided in the description in the other (Slovenian and Estonian) curricula, although the Slovenian one is the most elaborated and suggests tips for teaching within each topic area.

Conclusion

The Czech national curricula, the Framework Educational Programmes, for different levels of education, have been under revision. The National Institute for Education, with its panel of experts, is working on the preparation of changes that in addition to other changes shall keep a similar framework as the curricula of other countries. A comparison of the national curricula of other countries is therefore an essential part for suggesting relevant changes. For these purposes countries were chosen that have higher achievements in PISA testing and have a similar historical background as the Czech Republic: Poland, Slovenia and Estonia. The curricula were analysed using the comparative analysis method in aspects of instructional time, teaching methods and learning content.

This study is focused on the chemistry curriculum, therefore the analysed documents were the current Czech, Slovenian and Estonian chemistry curriculum as a part of the national curriculum. Regarding Poland, the former national curriculum for the III and IV stages was used because this curriculum is reflected in the PISA results.

Three research questions were studied: (1) What is the number of hours allocated for chemistry education for each country?, (2) What are the topic areas of chemistry learning content in particular national curricula? How do the learning outcomes and content differ?, (3) What are recommended teaching methods for chemistry education?

Our findings show that regarding the instruction time for chemistry education, all four countries are nearly the same: chemistry is taught four hours per week for the entire length of study, which means two lessons in 8^{th} and 9^{th} grade except for Poland where it is often taught in grades 7, 8 and 9 (1–2–1 lessons). The difference was revealed in the total number of hours allocated for science subjects in grades 6 to 9. Slovenian and Estonian students study natural science subjects the most frequent (total number: 23 hours), while Czech students study natural science 9% less (total number: 21 hours) and Polish students even 17% less (total number: 19 hours) than in Slovenia and Estonia. The in-depth comparative analysis of national chemistry curricula discovered that there are no radical differences in the chemistry content. The documents differ in the attention to detail that can be seen in a number of learning outcomes stated in each chemistry curriculum. The Czech chemistry curriculum defines 7 big topic areas, whereas Poland and Estonia define 9 and Slovenia 10 topic areas. The most obvious differences are then the numbers of learning outcomes: Czech chemistry content is defined in 27 outcomes, Estonian in 62 (2.3 times more), Polish in 84 (3.1 times more) and Slovenian chemistry content is stated in 57 content knowledge and 40 process knowledge outcomes (together, 3.6 times more). A closer qualitative analysis of the documents showed that the Czech learning outcomes are extensive, but also vague at the same time. The learning content that in the Czech curriculum is only recommended had to be considered for precise assignment in other countries' learning outcomes. Often, more learning outcomes of foreign curriculum were assigned to Czech corresponding outcomes – in other words Polish, Slovenian and Estonian learning outcomes are more elaborated and specific which can lead to easier implementation of particular topics into chemistry education.

The last analysed parameter was teaching methods recommended in the chemistry curricula. The least accompanying information is provided by the Polish curriculum even though there are passing references to some methods. The Czech curriculum introduces the educational area Man and Nature and provides information on goals and methods, but not in detail. The Estonian chemistry curriculum is more descriptive, but the most elaborated curriculum regarding the information on implementation of the chemistry curriculum is the Slovenian one. For each topic area there are stated learning outcomes focused on methods and approaches that can be used, moreover there is a detailed chapter on didactic recommendations that describes the conditions for laboratory courses, use of information and communication technologies and detailed cross-curricular links.

Our comparative analysis focused on four chemistry curricula, Czech, Polish, Slovenian and Estonian. The results show that the time for chemistry lessons is comparable in all four countries. Chemistry content corresponds, with no principal differences, but Polish, Slovenian and Estonian learning outcomes are defined in much more detail. Finally, the Estonian, and mainly the Slovenian, chemistry curricula, offer more details for chemistry education, especially the Slovenian didactic recommendations. We can conclude the PISA results may not reflect chemistry content, which is almost the same for all four compared countries. The difference is apparently in the implementation of the chemistry curriculum in practice, which cannot be analysed from the official documents. But, at least it seems, a more elaborated chemistry curriculum can be a more useful and more powerful tool for chemistry teachers who will know also "how" and not just "what" is to be taught in chemistry lessons.

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Eva Stratilová Urválková, urvalkov@natur.cuni.cz
Milada Teplá, milada.tepla@natur.cuni.cz
Svatava Janoušková, svatava.janouskova@natur.cuni.cz
Charles University, Faculty of Science
Department of Teaching and Didactics of Chemistry
Albertov 3, 128 43 Prague 2, Czech Republic

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Geology at the Lower Secondary Educational Level (ISCED 2): Comparison of the Czech Republic, Estonia, Slovenia and Poland

Tereza Jedličková, Andrea Svobodová, Václav Kachlík

Abstract

Geology is a science with a highly interdisciplinary character. Thus, in education it is ideal to provide education in a form integrated with the other branches of natural sciences under the subject of Science or Natural Sciences. However, most European countries prefer separate teaching of the individual educational fields and subsume geology within one of them, most frequently biology or geography. The submitted study discusses the potential advantages and disadvantages of various strategies of allocation of geological topics in education. A comparative method is used to evaluate and analyse curricular documents in the Czech Republic, Estonia, Slovenia and Poland at the lower secondary educational level. The comparison is focused on the scope and incorporation of selected educational content of geology into individual educational subjects, and on the recommended teaching methods suitable for interpreting geological subject matter. On the basis of this knowledge from abroad, individual subjects are selected for the "best practice" and subsequently proposed for implementation under the conditions in the Czech Republic. This seeks to make geology more familiar and attractive for students at the lower secondary level of education.

Key words: geology education, educational content of geology, curricular documents, lower secondary education, comparative study.

Výuka geologie v rámci nižšího sekundárního stupně vzdělávání (ISCED 2): Komparace České republiky, Estonska, Slovinska a Polska

Abstrakt

Geologie je věda vysoce interdisciplinárního charakteru. Ve vzdělávání by se tedy ideálně nabízelo vyučovat ji integrovaně s ostatními přírodovědnými obory v rámci předmětu Science, resp. Přírodní vědy. Většina evropských států však preferuje separovanou výuku jednotlivých oborů a geologické učivo přiřazuje k jednomu z nich, nejčastěji biologii nebo geografii. Předložená studie diskutuje možné výhody a nevýhody různých strategií zařazení učiva geologie do výuky. Komparativní metodou hodnotí a analyzuje kurikulární dokumenty České republiky, Estonska, Slovinska a Polska na úrovni nižšího sekundárního vzdělávání. Předmětem komparace jsou kromě rozdílných strategií zařazení geologického učiva do výuky také rozsah a začlenění vybraného vzdělávacího obsahu z oblasti geologie do jednotlivých vyučovacích předmětů a doporučené výukové metody vhodné pro interpretaci geologického učiva. Na základě těchto zahraničních poznatků jsou vybrány konkrétní náměty „nejlepší praxe" a následně navrženy pro implementaci do podmínek České republiky se záměrem přiblížit a zatraktivnit geologii žákům druhého stupně základních škol.

Klíčová slova: výuka geologie, geologické učivo, kurikulární dokumenty, nižší sekundární vzdělávání, komparativní studie.

1 Inclusion of geological subject matter in education

The natural sciences traditionally include the fields of Biology, Chemistry, Physics, Geography and Geology. While the first four have a traditional position in teaching at the elementary and secondary levels in the Czech Republic, in the past Geology did not generally have such a fixed position as the other above-named fields (Jeníková, 2017). Conditions are similar in most of the countries of Europe and Geology is not taught as a separate subject in secondary education (Fermeli et al., 2011). Nonetheless, geology is widely considered to be an important part of general education and its practical importance for the development of human society dates back to ancient times. The significance of the geological sciences has been increasingly emphasised since the 18^{th} century, especially as a result of the demand for raw materials (coal and iron, later petroleum and gas), and continues at the present time because of the related negative impact on the natural environment. Study of natural archives can substantially contribute to reducing the risk connected with natural and anthropogenic hazards in the future.

In the absence of fundamental knowledge about the functioning of the Earth as a planet, human society cannot live for long in equilibrium with the natural environment. Consequently, teaching of geology is essential at all levels of education, in close connection with the other fields of the natural sciences. Geology is a very interdisciplinary science, where the synergic effect of interconnected teaching of the natural sciences can greatly contribute to understanding geological processes. Simultaneously, the physical and chemical nature of these processes can contribute to practical teaching in the other fields of the natural sciences.

The inclusion of Geology in educational programs for primary and secondary education must be considered to be the first step towards improving teaching of the natural sciences (Pluskalová, 2004). The secondary role assigned to geology leads to global concern in the geological community is based on the substantial reduction in the geological syllabi. This fact is leading to a decrease in number of students of geology at universities (Fermeli et al., 2011). In addition, international surveys suggest that students are frequently not capable of adequately understanding the basic facts and concepts of the natural sciences, including understanding geological processes in a broader context (Meléndez et al., 2007).

Three basic approaches are generally used for teaching geology at the lower secondary educational level in the countries of Europe. The most frequent curriculum involves the inclusion of geological content in the subjects of Biology and Geography. Selected geological topics can also be taught in the context of subjects such as Chemistry or Physics; nonetheless, this does not generally entail a comprehensive explication of the geological subject matter. Geology education can also take place within the integrated subject of Science. Higher secondary education further offers a third form of teaching Geology, as an independent subject (this model is not very widespread in the Czech Republic). In most European countries, a comprehensive conception of teaching the Earth Sciences is frequently completely lacking or is incorporated to a limited degree into other related disciplines. The inclusion of geology into other conceptually related subjects assigns geology to an inferior position. Chapters on geology are frequently ignored or explained only vaguely (Meléndez et al., 2007; Fermeli et al., 2011). Surveys carried out in England and Wales have shown that educators teaching the Earth Sciences are usually biologists, chemists or physicists (King, 2004). Information obtained from teachers has revealed that their basic geological knowledge is, in general, poor and inadequate. Most teachers stated that they would require greater educational support in this area (King, 2001).

It is anticipated that an integrated approach will lead to greater student motivation and greater interconnection of the subject matter with everyday life (Wake, 2008). From an organisational point of view, integrated teaching should lead to saving time, as it would avoid undesirable duplication of the educational content (Hejnová, 2011). However, Pluskalová (2004) points out that the integration of subjects at the level of complex fields of education (e.g. Biology with Geology) is a very demanding process. A basic requirement for implementation of integrated teaching is a teacher who is fully trained in the subjects to be integrated. It follows from an analysis performed by Hejnová (2011) that the introduction of integrated teaching of the natural sciences in Czech schools is prevented particularly by pre-school teacher training. This unfortunate situation is intensified by the lack of a long-term tradition of an integrated approach to teaching and the related lack of confidence of Czech professionals, teachers and the general public towards this form of education.

Although there are a great many theoretical arguments supporting either integrated teaching or teaching the natural sciences as individual subjects, only very little empirical evidence has been presented for their effect on the study results of students (Czerniak, 2014; Lederman & Niess, 1997). The Czech Republic, Estonia, Slovenia and Poland are countries where the natural sciences at the lower secondary educational level are divided into individual subjects. These are countries of the former eastern bloc that have undergone relatively fundamental reform of their educational systems in the last few years. At the present time, Estonia, Slovenia and Poland have achieved better results in PISA tests of natural science knowledge than the Czech Republic (OECD, 2018). The educational strategy forming a basis for curricular documents could play a key role in this success. The introduction of Geology as an independent teaching subject is lacking in all these countries; nonetheless, the approach to inclusion of geology and the scope of educational content differs in the individual countries. Can the selected tactics of these countries be applied to the Czech educational system? Specifically, which particular approach could contribute to making the teaching of geology more effective and attractive?

2 Objectives and methodology

This study concentrates on the structure and content of curricular documents in relation to geology (inclusion of geological content, the scope of the subject matter, recommended teaching methods, etc.). Its goal was to perform an extensive analysis and subsequent comparison of selected curricular documents for lower secondary education, ISCED level 2 (UNESCO, 2012), according to which the current educational system is implemented in the Czech Republic, Estonia, Slovenia and Poland. On the basis of this comparison of curricular documents, individual subjects are selected for the "best practice" and subsequently proposed for implementation under the conditions in the Czech Republic.

The *Framework Educational Programme for Basic Education* (Jeřábek et al., 2017) is the fundamental document for the analysis of geology education in the Czech Republic. The *National Curriculum for Basic Schools* and its Appendix 4 (Ministry of Education and Research, 2014) constituted the basic analysed document for the Estonian educational system. The *White Paper on Education in the Republic of Slovenia* (Ministry of Education and Sport, 2011) and the relevant annexes were the documents analysed for Slovenia. The *Core Curriculum for Pre-school and General Education* (Ministry of National Education, 2002) was selected for Poland. While this document was replaced by a newer version in the 2017/2018 school year, the current form of Polish schooling is still affected by the original version, which was used for the analysis.

2.1 Research and comparison of selected curricular documents in relation to geology

The curricular documents of selected countries were first individually subjected to research with emphasis on the teaching and manner of inclusion of a geology content in the relevant country. Further, the scope of the educational content of geology, i.e. the subject matter and expected outcomes, were monitored. The research was also concerned with the means of interpretation of the recommended teaching methods and requirements on the development of specific skills in the field and interconnection of the stipulated learning content with everyday life.

Content analysis was employed for comparing the above-mentioned curricular documents. Selection of the required concepts followed from this research. The study compares the educational content of geology and the organisational aspect of teaching, i.e. the inclusion of geological subject matter, the range of geology content in elementary schools, recommended teaching methods and equipment.

The text of curricular documents was divided up into smaller parts. These were condensed and labelled by formulating codes. Then these codes were grouped into categories (Erlingsson & Brysiewicz, 2017). The occurrence of two main groups of categories was recorded — specific subject matter and teaching methods (see Tab. 1, 2). The category of specific subject matter comprises expected outcomes and otherwise formulated requirements on students that refer to knowledge of the relevant geological content. The category of teaching methods comprises specific activities characteristic for the individual teaching methods.

Tab. 1: List of categories for analysis of the occurrence of geological content in the curricular documents of selected countries and examples of their interpretation in the text of the relevant documents

Categories — subject matter	Examples of interpretation of a particular category
The Universe	Solar system, Earth, Moon, stars
The Earth as a geological body	formation of the Earth, geospheres, the Earth's crust and mantle
Mineralogy	minerals: formation, subdivision of the processes of formation of minerals, practical importance and use, properties, identifying samples
Petrology	rocks: formation, formation conditions, classification (magmatic, sedimentary, metamorphosed), practical importance and use, properties, identifying samples
Endogenic geological processes	magmatic process, deformation of the lithosphere, causes and consequences of endogenic processes, formation of the Earth's surface, lithospheric plates, continental and oceanic lithospheric/plates, earthquakes, environment of the formation of magmatic rocks
Exogenic geological processes	weathering, transport, sedimentation, exogenic factors, causes and consequences of exogenic processes, shaping of the Earth's surface, sedimentary basins
Soils	formation, composition, properties, development, danger of devastation
Geological history of the Earth	geological development, paleontological development, emergence of life, occurrence of typical organisms, stratigraphy, geological eras, evolution of organisms, geological age determination
Geological development and structure of territories	for the Czech Republic, e.g. the Bohemian Massif, Western Carpathians
Interactions between nature and society	extraordinary events caused by natural forces, natural risks and catastrophes, causes of occurrence, measures and protection against natural disasters, basic classification — geological (earthquakes, volcanic hazards, slope movements), climatic (tornadoes, hurricanes, etc.), oceanographic (e.g. tsunamis)

2.2 Data interpretation

The first section describes the curricular documents of selected countries individually using a unified structure — a brief introduction into the educational system in each country, the relevant syllabus of geology (focused on lower secondary education) and recommended teaching methods. The following section compares these documents with each other in terms of the aforementioned aspects (inclusion of geology in education, educational content of geology, recommended teaching methods). Specific individual examples of the "best practice" are discussed in the last section and are proposed for implementation under the conditions in the Czech Republic.

Tab. 2: List of categories for the occurrence of selected teaching methods in curricular documents of the described countries

Categories — teaching method	Examples of interpretation of a particular code
Critical thinking	Critical thinking, assessing information, logical thinking, argumentation, ability to pose questions
Research activities	Teaching oriented towards research, activity teaching, activation of students
Experimenting	Experimenting and measuring, observation, formulation and verification of hypotheses, analysis of results, drawing conclusions
Work with information	Searching for information, critical assessment of the relevance of information, work with various sources of information
Individualisation	Differentiation of teaching, individual approach
Group work	Work in groups, cooperative teaching, cooperation
Digital technology	Use of modern technology, use of ICT, use of digital technology, safe work with the internet

3 Inclusion of geological content in education in selected European countries

Basic education lasts 9 years in all the evaluated countries (Czech Republic, Estonia, Poland, and Slovenia). The national curriculum of basic education has a central role that overlaps in all the mentioned countries. In a nutshell, it should provide equal support for the mental, physical, social, moral and emotional development of students. The school should contribute to instilling in youth a creative, diverse personality that is capable of self-realisation in a fully-fledged manner in different roles, especially at work, in the family and in public life (Eurydice, 2011). All the described curricula define the expected level of knowledge set for all students at each level of education and differentiate competences which are the aggregates of the relevant knowledge, skills and attitudes. However, the manner of anchoring the subject of Geology in the curriculum differs amongst these countries.

3.1 National Curriculum of the Czech Republic

Compulsory school attendance in the Czech Republic is divided into two levels: primary school (grades 1–5, ISCED level 1) and lower secondary school (grades 6–9, ISCED level 2). The Framework Educational Programme for Basic Education delimits the compulsory framework for elementary education and defines the general requirements on the organisation of elementary education. It further sets forth the goals of elementary education, i.e. the creation and gradual development of key competences and provision of a reliable basis for general education. The school level corresponds to school education programs that the schools create themselves and according to which education is provided at the individual schools.

The educational content is divided into nine educational areas. These are formed of one or more fields of education with similar contents. Their educational content is represented by the subject matter and expected outcomes (the compulsory level for formulating outputs in the teaching curriculum in a school educational programme).

Syllabus of Geology

The subject matter of Geology and the corresponding expected outcomes permeate both educational levels of primary education. At the primary school level, they occur especially in the educational area of Humans and their World, especially in the units of "The place where we live" and "Diversity of nature" (Jeřábek et al., 2017). From the first level, students should gain basic knowledge related to non-living nature, which should be deepened and expanded at the second level.

At the lower secondary school level, the Czech curriculum assigns geological content to the educational area of Humans and Nature, specifically to the educational field of the Natural Sciences (hereinafter Biology). This encompasses direct definition of the educational content of Non-living Nature, which includes topics such as the Formation and Structure of the Earth, Minerals and Rocks, Internal and External Geological Processes, Soils, Development of the Earth's Crust and Organisms on the Earth, Geological Development and Structure of the Territory of the Czech Republic, Weather and Climate and Extraordinary Events caused by Natural Effects (Jeřábek et al., 2017: p. 75). The other educational fields in the educational area of Humans and Nature are also more or less related to geological subjects. In geography, this applies, e.g., to the subjects of The Earth as a Body in Space, the Landscape Sphere, Training Exercises and Observation in the Terrain of the Local Landscape and Protection of Humans in case of Danger to Health and Life. The teaching field of Chemistry includes subject matter on the Elements, where Inorganic Chemistry encompasses compounds and fuels. The subject unit of the Universe, more precisely the Solar System and the Stars, constitutes learning content that, in the Czech curriculum, permeates three fields of the natural sciences — biology, geography and physics.

On the basis of the expected outcomes of Non-living Nature, after completing level 2, students should be able, e.g.

> to explain the effect of the individual spheres of the Earth on the formation and continued existence of life, based on their characteristic properties, identify selected minerals and rocks using identification equipment, differentiate among the consequences of internal and external geological processes, including the geological cycle of rocks and the cycle of water, compare the importance of soil-forming agents for the formation of soil, differentiate amongst the main types of soil and kinds of soil in Czech nature (Jeřábek et al., 2017: p. 75).

Recommended teaching methods

Recommended teaching methods are defined in general in the framework of the characteristics of the educational area. The student should gain a comprehensive view of the relationship between humans and nature. The characteristics of this area can lead to the development of critical and logical thinking amongst students. It provides the basis for teaching to progress through activities and by scientific research methods. Through this study, students should learn to use specific recognition methods to acquire skills, such as observation, experimenting and measurement, formulation and verification of hypotheses, analysis of results and drawing the relevant conclusions. The individual fields of education are limited only by their educational content and suitable teaching methods are not defined at this level in the national curriculum.

3.2 National curriculum of Estonia

In Estonia, compulsory education is divided into three stages: grades 1–3, grades 4–6 (both ISCED level 1) and grades 7–9 (ISCED level 2). The national curriculum defines the results and goals of education for the individual subjects but emphasises mainly the need for development of general competences and abilities that are also applicable outside the field. The schools prepare a school curriculum in accordance with the national curriculum. This consists of a general part and syllabuses for the individual subjects. The choice of teaching methods and materials is left to the schools and individual teachers.

The national curriculum consists of a general part and appendixes. The appendixes set forth subject field syllabuses, optional subject syllabuses and descriptions of cross-curricular topics. The study of geology is part of the compulsory subject field of Natural Science. It is intended to develop competences associated with critical and creative thinking. Science studies should also ensure motivation towards study and shape the student's interest in science and science-related careers. The following subjects comprise the natural science domain: Science (studied from grades 1 to 7), Biology, Geography (both studied from grade 7), Physics and Chemistry (both studied from grade 8).

Syllabus of Geology

In the Estonian curriculum, a relatively large part of the subject of Geology is assigned to the 2nd stage of study. Specifically, it is included under the subject of Science, which is intended to form a basis for future study of the individual natural sciences. From the viewpoint of geology, after completing grade 6, students should be acquainted with the basic facts under the subjects of Space, Planet Earth (continents and oceans, natural disasters), Rivers (parts of rivers, water currents), Lakes and Water as a Substance, Landforms and their Shaping, Soils (formation and development) and the Natural Resources of Estonia (minerals, mining and use).

In the 3rd stage, the subject matter of Geology is included in the subject of Geography. The educational content includes the Internal Structure of the Earth, Tectonic Plates and their Movement, Earthquakes, Volcanic Activity, Seismic and Volcanic Areas, Rocks and their Formation. In addition to the subject matter, the expected outcomes are defined very specifically; they correspond to the required educational content with specified geological concepts. For example: The students:

> describe tectonic plates according to drawings and maps as well as the geological processes taking place on the edges of tectonic plates: volcanism, earthquakes and the formation and transformation of landforms and rocks; know the reasons for the occurrence of earthquakes and volcanic eruptions, show on a map the main areas where they occur, give examples of their consequences and know how to act in case of danger; explain the erosion of rocks, movement and sedimentation of erosion-related material and formation of sedimentary and igneous rocks (Ministry of Education and Research, 2014: p. 42).

"Landforms" are another area of geography, which is concerned with geological content. Here, students are acquainted with various shapes of the Earth's surface (mountain ranges and highlands, plains, lowlands, relief of the ocean floor) and also with the progress of evolution of the Earth's surface over time. The separate area

"Bodies of Water" is devoted to teaching about water as a geological agent. The latter two areas of geography are once more included in the syllabus of this subject in the context of European and Estonian Geographic Location. The content is devoted to regional areas that are identical with the "general" areas, but concentrate on local specific features of the particular phenomena. For example, Estonian Geological Structure and Natural Resources, the Activity of Continental Glaciers in Shaping Landforms in Europe, Problems Related to Groundwater in Estonia, etc.

Recommended teaching methods

Recommended teaching methods are first defined in the characteristics of the educational field of Natural Science. The main goal of teaching geography is to provide students with an overview of processes taking place in nature and society. The material studied should be presented as far as possible in a problem-oriented way and in connection with the students' everyday lives and home areas. The individual specificities of the students should be taken into account. Significant attention is paid to shaping the study motivation of students and various interactive study methods are recommended: problem-based and research-based study, project work, discussions, brainstorming, studies outside the classroom, study visits, etc. Digital technologies and ICT should be used in all the stages of study.

For the individual teaching areas of geography, proposals are made for specific student activities and the use of ICT. In the context of geology, this consists in

> describing and comparing rocks (sandstone, limestone, oil shale, coal and granite) and sediments (sand, gravel and clay), compiling an overview or, on the basis of sources of information, presentation of one geological phenomena (earthquake or volcano) or describing an area from a geological angle, studying the erosive and accumulative activities of flowing water in a given river in different sections according to drawings, photos (including satellite photos) and maps (Ministry of Education and Research, 2014: p. 43–45).

Moreover, the introduction to the area of the Natural Science delimits the Options for Integrating Natural Science Subjects and Options for Implementing Cross Curricular Topics.

3.3 National curriculum of Slovenia

In Slovenia, nine years of basic education is divided into three-year cycles: grades 1–3, grades 4–6 and grades 7–9. Slovenia employs a system with a multi-level curriculum. At the national level, it is regulated by the document *White Paper on Education in the Republic of Slovenia* (Ministry of Education and Sport, 2011), hereinafter the *White Paper*. This document stipulates compulsory and optional subjects. At the school level, teachers have a certain degree of freedom to adjust the educational content of the subject according to the specific conditions of teaching at the given school. The compulsory subjects set forth in the White Paper must also be part of the curriculum of the school and new teaching subjects cannot be created from them.

Syllabus of Geology

In the Slovenian national curriculum, a certain geology content is already included in the integrated subject of Environmental Education (taught in grades 1–3). This consists in basic knowledge about the Universe and Forming of the Earth's Surface.

The educational content of geology is included in the single field of study Geography (taught in grades 6–9). Geology matter is spread out through all the grades and does not have its own separate teaching area. The curriculum defines a number of operational goals for grade 6. Some of them are concerned with the development of practical skills (e.g. searching for and processing information, assessing its relevance, the use of various means of communication, work in the field, etc.). Another area of operational goals is directly connected to a geological content — students are capable of differentiating the continents, their geographical position and the relationships among them, and they are able to understand the basic laws governing the movement of the Earth in the Universe (Ministry of Education and Sport, 2011: p. 8). The educational content for the 6^{th} grade consists in the size and shape of the Earth, the position of the Earth in the Universe, the oceans and continents, the aquatic environment and surface of the land, movements of the Earth and their consequences.

The remaining geological subjects are taught in the context of the regional geography of the individual continents. In practice, this means, e.g., that teaching about Southern Europe in grade 7 includes the subject of the regional occurrence of earthquakes and volcanic activity and the related operational goals. Amongst these, for example, the student explains the tectonic causes of the occurrence of earthquakes and explains the course of volcanic activity and describes the consequences of volcanic activity and earthquakes for human life (Ministry of Education and Sport, 2011: p. 11). Similarly, teaching in the thematic unit of the Alps or Northern Europe includes glaciers and their impact in forming the surface of the Earth — rivers, river valleys, etc. Teaching in grade 9 is concerned with the region of Slovenia. From a geological standpoint, students are required to explain the main phases in the formation of the present-day relief of Slovenia and the main factors that affected this process (Ministry of Education and Sport, 2011: p. 17).

Recommended teaching methods

Didactic recommendations are generally given for all the compulsory subjects. They provide suggestions for conception of the work of teachers with students. Emphasis is placed on the process of teaching and development of students' skills, their active participation in the educational process and the development of critical thinking. Primarily, teaching methods are emphasised that take into account the individual potential of the student. The Slovenian curriculum brings into equilibrium teaching and other forms of student activities. This part of the syllabus of the subject explains in detail the concept and organisation of geographic excursions.

The White Paper directly contains information on interdisciplinary relationships. These emphasise both the area of the personal development of students (e.g., communication, work with information, reading literacy) and development of their professional skills (e.g. reading graphs, work with modern technologies, ability to defend one's own opinion).

3.4 National Curriculum of Poland

According to the educational system until 2017, compulsory school attendance in Poland included six years of elementary education divided into two stages (szkola podstawowa) and three years at lower secondary school (gimnazjum). The main goal of Polish elementary education, in addition to development of reading and mathematical literacy, also encompasses perfecting the scientific thinking of students. This skill includes the ability to formulate conclusions about nature and society based on observation. The curriculum is also directed towards preparing students for life in a digital society.

The *Core Curriculum for Pre-school and General Education* stipulates the expected outcomes for the individual subjects. The detailed subject matter is not specified in the Polish curriculum.

Syllabus of Geology

Teaching progresses in an integrated manner in the first stage of primary education (grades 1–3). The subject matter also includes some geological topics. Geology is taught, e.g. in the educational area of the "Closest Surroundings" (water sources, kinds of surface water, identifying local rocks, soils), the area of Poland and Europe (morphology of the Polish Landscape: high mountains, limestone uplands, lowlands, lakes, ocean), the Earth from Space, Continents and Oceans.

The teaching should grow and expand in a spiral, i.e. in each higher year, information and skills should be repeated, deepened and subsequently expanded. The teaching units and the expected outcomes defined for the separate subject of Nature in the second stage (grades 4–6) correspond to this idea. A number of general goals and the expected outcomes are defined for the subject of Nature. They include, e.g. interest in nature (the student poses questions about phenomena occurring in nature and searches for answers), formulating hypotheses and their verification (the student predicts the course of some phenomena and natural processes, carries out observation and experiments according to instructions), observation measurements and experiments (the student utilises various sources of information and performs measurements, documents and presents the results of observations, uses information and communication technology). These general objectives are identical with the requirements laid down for the related third teaching stage, "gimnazjum". Here, for example, the ability to identify relationships and dependences and explain phenomena and processes, or to formulate of one's own opinions and attitudes are further expanded.

From the viewpoint of teaching geology, Geography is a key subject at secondary schools. The definition of the educational content of this subject more or less corresponds to the teaching units of the subject of Nature (mineralogy, petrology, soils, interaction between humans and nature — see above). However, the expected outcomes are extended to include further subject matter and are at a higher cognitive level than the previous stages. Newly included topics are primarily endogenic and exogenic geology:

> the student gives the main characteristics of the lithospheric plates, describes the relationship between the movement of lithospheric plates and the occurrence of volcanic phenomena and earthquakes, understands the effect of wind, erosion, flowing water, ocean waves and glaciers in forming the Earth's surface (Ministry of National Education, 2002: p. 106).

A newly included subject unit is the "Natural environment in Poland", including important events in the geological history of Poland (the formation of black coal, mountain areas, land flooding events, glaciation, etc.).

Recommended teaching methods

For the subject Nature, the Polish curriculum recommends a choice of activities that would strengthen a scientific approach to the natural sciences and increase interest in nature. Teaching should have an interdisciplinary character and individual subject areas can be taught by teachers in various fields (physics, chemistry, biology, geography).

In teaching geography, it is recommended that the extent of encyclopaedic knowledge be limited in favour of forming the student's ability to use and analyse various kinds of information sources. The concept of requirements in the third stage of education is based on the predominance of regional geography, where students learn general information (including geological subjects) on the basis of study of selected regions. Teaching should be partly practical and implemented with substantial support from experiments, observation, activities in the field and excursions.

4 Comparison of curricular documents of selected countries from the viewpoint of teaching geology

4.1 Inclusion of geology in education

In general, it can be stated in the context of elementary education in all the selected countries that geology is part of both educational levels (ISCED level 1, ISCED level 2). However, it is assumed that the subject matter discussed at the first level consists only of a brief acquaintance with a selected subject area and that this will be developed further at the second level. All the analysed countries approach the teaching of the natural sciences in an integrated manner in the context of primary education. At the second level, natural science fields are divided into independent subjects. Geology is not set aside as an independent subject in any of the described curricular documents.

In the Czech Republic, most of the geological subject matter at the second level of elementary schools is included in the subject of Biology, Non-living Nature. Selected topics are also mentioned in other subjects, such as Geography, Chemistry and Physics, where these topics are mostly duplicated — thus they are included both in Biology and, e.g. in Geography. In practice, this means that some topics are taught twice at the second level, in a different subject each time or in a different grade.

Estonia, Slovenia and Poland assign most of the subject matter of geology to the subject of Geography. The specific approach to inclusion of geological subject matter differs in the individual countries. In the Estonian curriculum, some topics (e.g. the Universe) are included in the integrated subject of Science and subsequently are not dealt with in Geography. An independent subject block in the context of Geography, with detailed description of expected outcomes, encompasses the topics of endogenic and exogenic geology. The remaining topics (e.g. rivers, lakes, landscapes) are first discussed from a general viewpoint and then in the regional context of the landscapes of Estonia and Europe. Students are able to verify selected general knowledge on the basis of "local" examples. The Polish curriculum has a similar system of ordering of geological subject matter. The individual topics and related expected outcomes are first oriented towards general knowledge. Subsequently, the topics of the natural environment of Poland once again provides the students with scope to connect this theoretical knowledge in practice with local examples (the geological past of Poland, the formation of the Earth's surface, local minerals and rocks). The Slovenian curriculum employs greater inclusion of geological subject matter in Geography. It utilises direct connection of theoretical knowledge with regional examples. For example, endogenic and exogenic geological processes are not taught as independent topics but are discussed in the context of the specific geographic areas with which the relevant process is connected (e.g. the Alps — glacial activity, Southern Europe – volcanic activity and earthquakes). Students receive complex information about the relevant geographic area and acquire general geological knowledge on the basis of specific examples.

4.2 Educational content of Geology

The educational content of the curriculum in the Czech Republic consists of both subject matter and expected outcomes. The subject matter is divided according to the individual topics, which are further specified. This consists basically of a list of concepts that the students should learn during completion of the particular unit. The expected outcomes are related directly to the specific subject matter and are defined rather generally. They concentrate mainly on the knowledge gained by the student rather than on the development of the practical skills of the individual, critical thinking, etc. Although the expected outcomes are compulsory for the individual schools in the Czech Republic, the manner of their formulation leads to knowledge of delimited concepts and does not further expand requirements on the skills of students. As a consequence, emphasis is placed mainly on learning terminology and classification and less on the development of practical skills by students and their ability to think critically, create working hypotheses and evaluate them.

In contrast, the Estonian curriculum delimits the educational content very specifically. For each subject, it sets forth not only the subject matter, but also the related concepts. Learning outcomes are defined quite specifically and in detail. In addition to knowledge of delimited concepts, students are required to have further skills and more complicated cognitive operations following from study of the given subject matter. Compulsory subjects in the Slovenian curriculum have a certain structure, which is maintained for all the subjects. The subject matter is not defined in terms of a list of concepts. The curriculum mentions only individual topics that are related to the general and operational goals of the specific subject. Schools do not have practically any freedom related to assignment of the educational content to the individual subjects; even the names of the individual subjects are specified. Thus integration of the natural science subjects cannot be even considered. The Polish curriculum does not in any way deal with delimitation of specific subject matter. For each subject, general goals are given for the subsequently anticipated outcomes for the individual subject topics. These are rather extensive and are formulated in detail.

4.2.1 Expected outcomes

The expected outcomes are a unit that occur in various forms in all the analysed curricular documents. Tab. 3 gives a comparison of formulation of the expected outcomes for the individual countries. Endogenic geology was selected as a model topic that is contained in all the analysed curricular documents. It is apparent from Tab. 3 that Estonia has the most specific approach to defining the expected outcomes. Poland and Slovenia are at the same level in this respect. All three countries concentrate on processes taking place in the lithosphere and their consequences in terms of volcanic activity and earthquakes. Earthquakes and volcanism are dynamic processes that are most attractive for students but, however, do not encompass further processes at lithospheric plate boundaries. The Czech curriculum mentions only the anticipated output from this topics, which is formulated very generally and briefly. It does not delve into the core of the given subject topics and maintains a definition at the level of "headings". In fact, it doesn't even include the above-mentioned volcanism and earthquakes.

Tab. 3: Comparison of the expected outcomes as defined by selected countries for the model subject of endogenic geology

Expected outcomes for the subject of ENDOGENIC GEOLOGY	
Czech Republic	Students: • differentiate the consequences of internal and external geological processes, including the rock cycle and hydrological cycle
Estonia	Students: • describe lithospheric plates according to drawings and maps as well as the geological processes taking place on the boundaries of lithospheric plates: volcanism, earthquakes and the formation and transformation of landforms and rocks; • know the reasons for the occurrence of earthquakes and volcanic eruptions, show on a map the main areas where they occur, give examples of their consequences and know how to act in case of danger;
Slovenia	Students: • explain the tectonic causes of the occurrence of earthquakes and explain the progress of volcanic activity • describe the consequences of volcanic activity and earthquakes on human lives
Poland	Students: • state the main characteristics of lithospheric plates • describe the relationship between lithospheric plates and the occurrence of volcanic activity and earthquakes

The expected outcomes are formulated to different degrees and in various ways; nonetheless, all the countries exhibit little interconnection between the subjects and lack a description of the interconnections among the individual phenomena. For example, the Estonian curriculum speaks about the erosion and accumulation properties of flowing water, but does not mention various means of transporting material. Simultaneously, this is an important factor affecting the roundness, shape and size of grains. Extending this subject to include transport would create scope for interconnection of geology with, e.g. physics. Similarly, in the specification of soil, the Czech curriculum does not mention topics such as the origin of soil, soil-forming agents, etc. The relationship between the substrate, pedogenic processes, soil forming agents and the resultant soil is not described.

4.2.2 Selection of geological subject matter

The scope of the educational content was assessed, on the basis not only of the defined subject matter, but also of the requirements on students following from the expected outcomes. The Slovenian and Polish curricula do not even rely on the subject matter in the sense of defined concepts. Tab. 4 compares the assignment of selected geological topics at the lower secondary school level.

Tab. 4: Comparison of the scope of the educational content of geology and inclusion of selected geological topics in the individual subjects at the lower secondary school level in selected countries
Bi – Biology, Gg – Geography, Sci – Science, Ph – Physics; $\surd$ – the curriculum contains this subject matter, × – the curriculum does not contain this subject matter

geology subject matter	Czech Republic	Estonia	Slovenia	Poland
The Universe + formation of the Earth	$\surd$ Bi, Ph, Gg	$\surd$ Sci	$\surd$ Gg	$\surd$ Gg, Ph
The Earth as a geological body	$\surd$ Bi, Gg	$\surd$ Gg	$\surd$ Gg	$\surd$ Gg
Mineralogy	$\surd$ Bi	$\surd$ Sci, Gg	×	$\surd$ Sci, Gg
Petrology	$\surd$ Bi	$\surd$ Gg	×	$\surd$ Sci, Gg
Endogenic geological processes	$\surd$ Bi, Gg	$\surd$ Sci, Gg	$\surd$ Gg	$\surd$ Gg
Exogenic geological processes	$\surd$ Bi	$\surd$ Sci, Gg	$\surd$ Gg	$\surd$ Gg
Soils	$\surd$ Bi	$\surd$ Sci	×	$\surd$ Sci, Gg
Geological history of the Earth	$\surd$ Bi	×	×	×
Geological development and structure of territories	$\surd$ Bi	$\surd$ Gg	×	$\surd$ Gg
Interactions between nature and society	$\surd$ Bi, Gg	$\surd$ Sci, Gg	$\surd$ Gg	$\surd$ Sci, Gg

Compared to the other countries, the Czech curriculum includes more geological topics. The entire content of non-living nature is assigned to a single subject, making geology teaching comprehensive in the context of lower secondary education. The scope of geological subject matter in the Czech Republic is most similar to that in

Estonia. In addition, the individual subjects are defined very specifically in terms of the learning content and concepts. The Polish curriculum corresponds to the Estonian curriculum in terms of the number of geological topics but it has less specific content. Slovenia includes geology only sporadically in its curriculum and only in connection with regionally focussed physical geography.

In some cases, it was rather difficult to assess whether the curriculum is actually devoted to this topic. This is especially true of the subject of the Geological History of the Earth, which is contained only in the curriculum of the Czech Republic. Nonetheless, e.g., the Estonian curriculum is related to this area in the integrated subject of Science, where it includes the learning content Development of Life on Earth. Poland encompasses this subject in more detail at the higher level of secondary education. Similarly, a certain part of mineralogy could related to the subject of Chemistry (e.g. in the Czech curriculum). While this is teaching about minerals, it follows from the expected outcome that this subject matter is expounded in terms of chemical properties and not from a geological standpoint (thus the subject of chemistry is not mentioned in the table).

4.3 Recommended teaching methods

The teaching requirements are more or less the same in all the EU countries. There is a unifying concept in an attempt to develop knowledge and skills that can be used in the everyday lives of students. Requirements on the use of specific teaching methods directed towards attaining this goal are contained to various degrees in the curricular documents of the individual countries. It can be anticipated that teachers will take into consideration especially that part of the curriculum devoted to their teaching field. The presence of requirements on implementation of specific teaching methods was thus assessed at the level of the educational area or the specific field or subject and not on the basis of the characteristics of the curriculum as a whole. In relation to the teaching of geology, there are three ways in which recommended teaching methods could be implemented, i.e. directly in the context of geology, in the context of the characteristics of the subject into which the geology subject matter is included or as the general characteristics of the educational area within which geology is included (see Tab. 5).

The Czech curriculum defines teaching methods only in the framework of the characteristics of the educational area. This is primarily a requirement on the development of critical thinking and managing teaching in an experimental and scientific manner. There is also a brief mention of work with information. The Estonian curriculum requires all the selected methods to be used in teaching (see Tab. 5). Recommended teaching methods are defined both in the characteristics of the educational field of Natural Science and also specifically for the subject of Geography. For the individual areas of teaching, suggestions are given for specific student activities and the use of ICT. The teaching methods employed for the individual subjects in the Slovenian curriculum are partly concerned with teaching standards. The greatest emphasis in the methods is devoted to didactic recommendations for the subject of Geography. They contain suggestions for the use of all the selected teaching methods (see Tab. 5) and also substantiate these working methods in the context of teaching Geography. The Polish curriculum lists basic recommendations for the subject of Geography in the introductory characteristics of the subject. The independent chapter on the Recommended Conditions and Implementation then formulates the main requirements on teaching the individual subjects, including Geography.

Tab. 5: Comparison of inclusion of recommended methods of geology education, including the place of introduction of the given method

$\surd$ – the curriculum mentions this teaching method, $\times$ – the curriculum does not mention this teaching method; Geology – the method is mentioned directly in the context of geology, Subject – the method is mentioned in the context of the characteristics of the subject (within which geology is included), Field – the method is mentioned in the context of the characteristics of the educational area (within which geology is included)

Teaching method	Czech Republic		Estonia		Slovenia		Poland	
Critical thinking	$\surd$	Field	$\surd$	Field, Subject	$\surd$	Subject	$\surd$	Subject
Research activities	$\surd$	Field	$\surd$	Field, Subject	$\surd$	Subject	$\surd$	Subject
Experimenting	$\surd$	Field	$\surd$	Field, Geology	$\surd$	Subject	$\surd$	Subject
Work with information	$\surd$	Field	$\surd$	Field, Subject	$\surd$	Subject	$\surd$	Subject
Individualisation	$\times$	$\times$	$\surd$	Field, Subject	$\surd$	Subject	$\times$	$\times$
Group work	$\times$	$\times$	$\surd$	Field	$\surd$	Subject	$\times$	$\times$
Digital technology	$\times$	$\times$	$\surd$	Field, Subject, Geology	$\surd$	Subject	$\surd$	Subject

5 Discussion

Contemporary society is becoming increasingly aware of the interdisciplinary character of the fields in the natural sciences (e.g. Wake, 2008; Škoda & Doulík, 2009). Geology as a science is a highly interdisciplinary field and the interpretation of geological information is directly dependent on other fields of science, especially physics, chemistry, astronomy, geography, mathematics and geoinformation systems. It is thus not surprising that allocation of the subject matter at the level of lower and higher elementary schools is the subject of numerous discussions (e.g. Fermeli et al., 2011; King, 2004; Pluskalová, 2004). Various countries have different approaches to teaching geology; however, geology is not taught as an independent subject almost anywhere. Integrated teaching of the natural sciences is not very common in the context of secondary education in Europe, including the Czech Republic, and the individual fields are taught as independent subjects. An integrated approach to teaching the natural sciences requires different professional and didactic preparation of future teachers (see e.g. Hejnová, 2011; Pluskalová, 2004). Thus, in the countries of Europe, geology is most frequently included in the subjects of Biology or Geography. Comparison of the curricular documents of selected countries with a similar level of economic development, following many years of a centralised schooling system with different trends in international evaluation, should reveal the positive and negative features of approaches towards natural science education. Simultaneously, it should provide subjects and recommendations for improving and increasing the attractiveness of teaching the natural sciences, especially geology in the Czech Republic.

5.1 Comparison of curricular documents

It follows from comparison of the curricular documents that the volume of the required subject matter is above average in the Czech Republic compared to the other analysed countries (see Tab. 4 as an example). A somewhat negative effect of a large amount of subject matter very frequently occurs in practice in duplication of teaching of some geological subjects at the lower secondary school level, where the same subject matter is discussed in various subjects or grades (e.g. the universe, formation and structure of the Earth). On the other hand, the flexibility of the Czech system is a favourable factor. It enables schools to move subject matter between the individual subjects and, where appropriate, to create new teaching subjects and integrate subject matter into them (including the possibility, e.g. of creating the separate subject of Geology) (Jeřábek et al., 2005). Nonetheless, this potential is insufficiently exploited and most school educational programmes exactly copy the assignment of subject matter set forth in the national curriculum. The possibility of freely assigning subject matter to the individual subjects in the framework of school educational programmes is based, amongst other things, on the mutual cooperation of teachers, interconnection of suitable subject areas and strengthening of the interdisciplinary approach to education. However, teachers often have no concept of the subject matter in other fields of the natural sciences. This attitude is completely contrary to the idea of an interdisciplinary approach to teaching (Wake, 2000, 2008), which should be reinforced.

The scope of geological subject matter in the Czech Republic is most similar to that in Estonia. The Polish curriculum corresponds to the Estonian curriculum in terms of the number of geological topics but the specific content is less. The Slovenian curriculum includes geology only sporadically. Slovenia and Poland approach the inclusion of geology in teaching through its integration into physical geography. The choice of educational content is quite logically completely determined by the local geology, but is not systematic. On the one hand, students are better able to remember examples and they are more illustrative for them but, on the other hand, the local emphasis prevents discussion of some important geological subjects or they are considered only marginally. The inclusion of geological content in the context of the Estonian curriculum is a sort of compromise between the explication of theoretical geological knowledge and specific examples of geological phenomena relating to the region of Estonia or Europe. Geological topics are first considered in general (this corresponds to the subject matter of Geology in the Czech curriculum); then the subject matter returns to the geological phenomena that correspond to the local geology (in parallel with the Polish and Slovenian curricula). The concept of the Estonian curriculum gives students the opportunity to connect their general knowledge with illustrative examples.

A great many surveys came to the conclusion that the low or decreasing interest of students in science is partly a consequence of its presentation as a collection of separated, out-of-context facts with little value, which are not related to everyday life and the personal experience of students (Aikenhead, 2005; Osborne, Simon & Collins, 2003; Sjøberg, 2002). Thus, from the viewpoint of its illustrative capability, the Estonian exposition of geological subject matter and the simultaneous provision of comprehensive information seem most suitable. The volume of educational content is not reduced as a consequence of the local focus and theoretical information is simultaneously connected with what students can observe in the immediate surroundings.

5.2 Educational content of Geology and expected outcomes

All the curricular documents of the analysed countries have a general inadequacy in the incompleteness of the coverage of the key geological topics and, in some places, excessive vagueness in their definition. Specification of the educational content corresponds to classical teaching divided into the individual subjects with emphasis on learning the terminology, description of natural processes and classification of minerals, rocks and raw materials. The individual educational topics should be defined in relation to the most important geological processes, their physical or chemical nature and their mutual relationship. This is the only way that greater integration of knowledge can be achieved and skills acquired in the various disciplines. More general subjects should be supplemented by practical examples, where possible in areas familiar to students. Formulation of the outcomes should emphasise the ability to carry out simple analysis of phenomena and processes, where the student is capable of using the acquired knowledge to perform specific tasks. Outcomes should also encompass practical skills that the student can utilise in everyday life or his/her future employment, as well as theoretical observations which form his/her relationship to nature and the environment.

5.3 Recommended teaching methods

A contemporary trend in education in the natural sciences and elsewhere is to introduce teaching methods based on critical thinking, independent work and individual observations, where the student develops his/her abilities irrespective of his/her natural talents. Teaching methods such as project teaching, experimentally oriented teaching and problem-based or complex tasks are generally conceived to maximise the individual development of each student within the framework of his/her abilities. This is motivating for the student and these methods are intended to make the content of the not-very-popular natural sciences accessible for students (Rocard et al., 2007). Wake (2008) based his work on a similar idea, according to which a student who is interested in a particular field can make a greater contribution to this field if (s)he is capable of properly employing the literature and technology, and of applying ideas and opinions.

However, the analysed countries have different approaches to requirements on the use of the above-mentioned teaching methods. While the Czech curriculum defines all the requirements only at the level of the educational area, Estonia, Slovenia and Poland recommend selected methods at the level of the specific teaching subjects. The Polish curriculum even contains a separate chapter dealing with the manner of implementation of methods suitable for teaching Geography. In addition, Estonia and Slovenia define the spheres of applied teaching. In this respect, the Czech curriculum is the briefest and tends to under-evaluate the recommendation of teaching methods suitable for education in the natural sciences. It would undoubtedly be more binding for teachers if the required teaching methods were fixed in the curriculum directly in connection with the subject they taught. Similarly, suggestions for implementation of these methods in teaching would simplify work for teachers, motivate them and help in achieving the defined expected outcomes.

5.4 Incorporation of geology — recommendations for Czech education

The current inclusion of Geology with Biology in teaching the Natural Sciences (Biology) in the Czech Republic would seem to be obsolete in the present day. There is very little interpenetration of geological topics with biological topics. The connection of Geology with Physical Geography would undoubtedly be useful and would eliminate unnecessary duplicity; in addition Physical Geography directly describes and explains the shapes of the Earth, which are a consequence of endogenic or exogenic geological processes, and connects them with the environment, anthropogenic effects on the natural environment, non-renewable and renewable natural resources, agriculture, territorial planning and other disciplines. It thus has a far greater overlap with Geology than Biology. The fact that Geology is traditionally connected with Biology in the subject of Natural Science follows from the tradition of describing the connection between the development of non-living and living nature and probably also from the fact that Geography has a long tradition of teaching as a separate subject. The introduction of study programs for teaching geography together with geology in elementary schools would undoubtedly be facilitated by resolution of this problem. This combination is not yet available at universities in the Czech Republic. This is similar only to the combination of Natural Science with Environmental Studies. A similar connection would be useful at the level of education of teachers for secondary schools, where it is theoretically possible to study Geology together with Geography at Masaryk University in Brno, but this is not utilised very often.

6 Conclusion

Geology is not a very popular branch of science in the Czech Republic (e.g. Bicanová, 2013; Pařízková, 2015) and other European countries (Fermeli et al., 2011). It is a frequent complaint that there is too much theory and little connection to everyday life. While an above-average amount of information is provided to students according to the Czech curriculum, there is a lack of interconnection of the individual subject areas and scientific fields. The traditional combination of the geological sciences with biology does not facilitate such a close interconnection; these fields interpenetrate only in the area of palaeontology and related stratigraphy, the development of life, its evolution and the development of the relationship between non-living and living nature in the past. However, most geological processes tend rather to be controlled by the laws of physics and chemistry, whose exposition is lacking in the current explication of geology. In the Czech Republic, this problem already arises from the university preparation of pre-service teachers, which practically does not offer the possibility of studying the combined fields of geology and geography; this would seem to be a better approach to the preparation of teachers for the subject of Geology. Similarly, at the level of secondary education, the interconnection of these two subjects would undoubtedly contribute to better understanding of the connections between geological processes and their consequences, as studied by the geographic sciences. This change would probably lead to more effective and more attractive teaching. The modifications in the appearance of the curriculum in the Czech Republic should include expected outcomes encompassing, amongst other things, requirements on practical skills that the student can use in everyday life or his/her future employment. The learning content could be made more attractive by including the requirement on the use of modern teaching methods, ideally supplemented by specific suggestions for implementation of these methods.

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Tereza Jedličková, tereza.jedlickova@natur.cuni.cz
Andrea Svobodová
Václav Kachlík
Charles University, Faculty of Science
Institute of Geology and Paleontology
Albertov 6, 128 43 Prague, Czech Republic

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A Comparative Analysis of the Biological Parts of the National Curricula in Lower Secondary Education in the Czech Republic and Selected Post-Communist Countries

Jana Poupová, Vanda Janštová, Radim Kuba, Jan Mourek

Abstract

In the Czech Republic, a revision of the national curricular documents for primary and secondary education is being prepared and intensively discussed. The aim of this paper is therefore to contribute to the ongoing professional discussion and to select the key aspects of foreign curricular documents that may be inspiring for the Czech curricular reform.

In our study, we compare the concept of the biological part of the valid national curricular documents for lower secondary education (from the 6^{th} to the 9^{th} grades), the second stage of basic school in the Czech Republic, with five selected post-communist European countries, namely Estonia, Hungary, Poland, Slovakia and Slovenia. We focused on the following key aspects: a) the major characteristics of biology as a school subject (or the biological part of the subject "science"); b) specification and arrangement of subject matter; c) biology as a scientific discipline; d) didactic recommendations and requirements; e) the way of treating crucial biological disciplines; f) other criteria, such as emphasis on local regions or public engagement.

We consider the Estonian and Slovenian educational programmes to be the most inspiring ones, since they elaborate general educational objectives to the level of particular learning content and standards of knowledge. We also find the links to practical work and ICT and connections between biology and general competences very useful when using the documents in classroom practice. The Slovenian document offers an inspiring holistic approach to teaching of biological issues. The Estonian curriculum is a good example of incorporating local aspects, such as typical local ecosystems. The national curricula of both countries recognise biological knowledge and scientific literacy as being very important for the lives of the individual as well as for society.

Key words: biology, curriculum, curricular reform, lower secondary education, science.

Srovnávací analýza biologické části národního kurikula na 2. stupni základních škol České republice a ve vybraných postkomunistických zemích

Abstrakt

V České republice v současné době probíhá revize národních kurikulárních dokumentů pro základní a střední školy, kterou doprovází intenzivní odborná diskuse. Naším cílem je proto vybrat klíčové aspekty zahraničních kurikulárních dokumentů, které by mohly pro českou kurikulární reformu posloužit jako inspirace.

V naší studii porovnáváme koncepci biologické části platných národních kurikulárních dokumentů pro druhý stupeň základní školy (a odpovídající stupně nižšího sekundárního vzdělávání v zahraničí) v České republice a v pěti vybraných evropských postkomunistických zemích (Estonsku, Maďarsku, Polsku, Slovensku a Slovinsku). Zaměřili jsme se na následující klíčové aspekty: a) hlavní charakteristiky biologie jako školního předmětu (respektive biologické části předmětu „přírodní vědy"); b) specifika a uspořádání vzdělávacího obsahu; c) pojetí biologie jako vědní disciplíny; d) didaktická doporučení a požadavky; e) pojetí jednotlivých klíčových biologických disciplín; f) další kritéria, jako například důraz na lokální aspekty nebo občanskou angažovanost.

Za velmi inspirativní považujeme vzdělávací programy Estonska a Slovinska, ve kterých jsou obecné vzdělávací cíle velmi dobře rozpracované na úroveň konkrétního vzdělávacího obsahu a požadovaných standardů znalostí. Pro jednotlivá témata poskytují náměty na praktickou činnost žáků a využití ICT ve výuce. Slovinské kurikulum uplatňuje ve výuce biologických témat holistický přístup. Estonské kurikulum poskytuje dobrý příklad začlenění místních aspektů, jako jsou typické místní ekosystémy. Kurikula obou těchto států zdůrazňují, že biologické znalosti a přírodovědná gramotnost mají zásadní význam pro život jednotlivce i společnosti.

Klíčová slova: biologie, kurikulum, kurikulární reforma, 2. stupeň základní školy, přírodní vědy.

In the Czech Republic, a revision of national curricular documents for primary and secondary education, the Framework Educational Programmes, is being prepared and intensively discussed. Our aim is therefore to contribute to the ongoing professional discussion and to select the key aspects of foreign curriculum documents that can be inspiring for the Czech Republic.

We compare the concept of the biological part of the science curricula for lower secondary education, the second stage of basic school (from the 6^{th} to the 9^{th} grades) in the Czech Republic and for corresponding school grades in five other European countries, namely Estonia, Hungary, Poland, Slovakia and Slovenia, and evaluate their strengths and weaknesses in the light of current pedagogical literature. These post-communist countries joined the European Union a few years after the millennium and subsequently performed their curricular reforms according to EU-legislation. Hungary, Poland and Slovakia were selected as our nearest post-communist neighbours, sharing a similar history after World War II. Estonia and Slovenia were added to our comparison, because they scored above the OECD average in PISA (OECD, 2016) and their curricula might thus provide a desired inspiration for our planned curricular reform. We were methodologically inspired by Pawilen and Sumida (2005), who compared the educational programmes of the Philippines and Japan. In our comparison, we focused on the major characteristics of the school subject biology, subject matter, biology as a scientific discipline, didactics of biology, and the ways of teaching biological disciplines.

1 Theoretical Background

There are numerous studies describing the decline of pupils' interest in science and science subjects both in the Czech Republic and abroad (Bílek, 2008; Dawson, 2000; Osborne, Simon & Collins, 2003; White Wolf Consulting, 2009). The attitude toward science is declining as well (Abrahams, 2007; Haste, 2004). The most frequently mentioned reasons are that science subjects are not relevant and are isolated from pupils' everyday lives (Rennie, Goodrum & Hackling, 2001) and therefore are perceived as difficult (Lyons, 2006; Shirazi, 2017) and boring (Ebenezer & Zoller, 1993; Goodrum, Rennie & Hackling, 2001). In contrast, some studies revealed that lessons in some science disciplines (especially biology) are relatively popular among pupils (Prokop, Prokop & Tunnicliffe, 2007) and biological topics, such as human health, are more interesting for the pupils than technological science (da Silva et al., 2018). Also, the difficulty perceived by the pupils strongly differs between particular topics (Cimer, 2012).

Another problem is the huge amount of knowledge which is required, rather than problem solving, literacy and creativity (Hong, Shim & Chang, 1998; Koul & Fisher, 2002; Lindahl, 2003; Osborne & Collins, 2001; Šorgo, 2012). Therefore, it is crucial to re-evaluate what and how to teach (Škoda & Doulík, 2009; Vařejka, 2006). When looking for an answer to the question of how to teach, we can find some possible solutions in published research studies. Hands-on and minds-on teaching forms and methods have the potential to improve pupils' attitudes toward science (Šorgo & Špernjak, 2009; Uitto & Kärnä, 2014) and increase their motivation and interest (Grant, Malloy & Hollowell, 2013; Holstermann, Grube & Bögeholz, 2010; Janštová, 2017). The teaching content has to be relevant to the students (Hassan, 2011; Lindahl, 2003; Lindner, 2014). Pupils should have the opportunity to be active and discuss freely (Freeman et al., 2014; Lyons, 2006). Dealing with living organisms is advisable when learning biology (Randler, Hummel & Prokop, 2012), as well as learning outdoors, e.g., during field trips (Žoldošová & Prokop, 2006). Practical indoor courses can be also effective if taught properly (Stohr-Hunt, 1996; van den Berg, 2013). Inquiry is recognised as an advisable method as well as it includes scientific principles as described, e.g., by Papáček (2010) or Bogner and Sotiriou (2014). Although the abovementioned principles are widely accepted, the reality at Czech schools is often different. More and more teachers recognise the term "inquiry" or "inquiry-based science education", although Radvanová, Čížková and Martinková (2018) pointed out that the terms are quite often misunderstood by Czech teachers. This is in concordance with the fact revealed by PISA (OECD, 2016) that Czech pupils have only limited chances to carry out experiments and use inquiry at school. Science literacy has been tested on a regular basis by PISA. The latest results (2015 testing) show that pupils from Poland, Estonia and Slovenia scored above the OECD average and did not perform worse than in 2012. In contrast, pupils from the Czech Republic scored significantly worse in the 2015 testing compared to three and nine years before. In general, Czech pupils have better content knowledge than procedural knowledge (OECD, 2016).

Since the late 1990s until the school year 2006/2007, Czech schools had to choose between two alternative state educational programmes for the second stage of basic school (lower secondary education) – the more widespread "Základní škola" (MŠMT ČR, 2003) and the less common "Národní škola" (MŠMT ČR, 1997), with more or less fixed structuring of subject matter into particular study grades. Since the school year 2007/2008, the original educational programmes were replaced by the Framework Educational Programme for Basic Education, which has been gradually updated (MŠMT ČR, 2017). This principal curricular reform followed EU legislation, gave the schools more freedom in arrangement of teaching content and aimed to incorporate the abovementioned modern educational trends in the Czech school system.

Recent studies indicate that the curricular reform in Czech schools was adopted only formally, the teachers have not accepted it and therefore there is no great impact on everyday teaching (Dvořák, Starý & Urbánek, 2015; Janík et al., 2010; Janík, 2013; Štech, 2013). The reason is probably underestimating the need for a broader discussion and agreement among teachers, teacher trainers and the professional public, together with missing methodology that would support the reform (Straková, 2013). Another problem was that the teachers were required to prepare themselves and their school for the reform after their ordinary teaching hours, virtually in their free time (Kuřina, 2014). Currently, a revision of the Czech Framework Education Programme (MŠMT ČR, 2017) is being prepared. This offers a great opportunity to search for inspiration in other studies focused on curricular documents or in the documents themselves.

Many studies focus on comparing science education in different countries. Most of them can be divided into the following five groups according to their predominant perspective:

a) Studies concentrating on how a particular topic is dealt with in countries with different national curricula (Erdoğan, Kostova & Marcinkowski, 2009; Poupová, 2018; Zembylas, 2002);

b) Studies comparing different school educational programmes based on the same national curriculum (Hayes & Deyhle, 2001);

c) Studies comparing textbooks (Park, Park & Lee, 2009);

d) Studies describing differences monitored directly during science lessons at schools (Su, Su & Goldstein, 1994, 1995);

e) Studies comparing pupils' results in connection with the type of their school curriculum (Kim, Lavonen & Ogawa, 2009; Russell & Weaver, 2011; Schmidt et al., 1996);

f) Studies describing the development of curricula or comparing selected aspects of curricula of different school subjects in particular countries (Ayas, Çlepni & Akdeni, 1993; Šorgo & Špernjak, 2012).

In contrast, studies providing detailed and complex comparative analysis of the entire science/biology part of national curricula of several countries are rather scarce (Grajkowski, Ostrowska & Poziomek, 2014; Pawilen & Sumida, 2005). We believe this type of study is urgently needed and therefore we have chosen this approach for our study. Our results may provide important arguments and inspiration for the ongoing professional discussions about the new form of the Czech national curriculum.

2 Methods

The national curricular documents (educational programmes for basic schools) that were used in our study are stated in the References. We studied their latest available online editions. The Czech (MŠMT ČR, 2017), Slovakian (ŠPÚ, 2015), Slovenian (MIZS, 2011a, 2011b, 2011c; MIZS, 2014) and Polish (MNE, 2018) documents were studied in their original languages. The Estonian (Government of the Republic of Estonia, 2014a, 2014b) and Hungarian (The Government of Hungary, 2014) documents were studied in their official English translations.

We formulated the following categories for a qualitative content analysis. In the comparison, we used criteria stated in Appendix I. We focused on the following categories:

a) The major characteristics of biology as a school subject: These comprise, e.g., whether biology is taught as a separate subject or as a part of an integrated science subject, what its aims are and its prescribed time allocation (see nos. 2, 3, 4 and 9 in Appendix I.).

b) Subject matter: its specification, arrangement, etc. (see nos. 5, 6, 7, 8, 10 and 11 in Appendix I.).

c) Biology as a scientific discipline: its specifics, history, relationship to society and to other disciplines and adoption of scientific methodology (see nos. 15, 16, 18, 19, 21 and 25 in Appendix I.).

d) Didactic recommendations and requirements for biology lessons: These comprise the required equipment of classrooms, number of practical lessons, recommended teaching methods or forms of assessment (see nos. 20, 23, 24, 26 and 27 in Appendix I.).

e) Way of treating crucial biological disciplines: taxonomy, evolutionary biology, cell biology and ecology (see nos. 11, 12, 13, and 14 in Appendix I.)

f) Other criteria: such as emphasis on local regions or public engagement that did not appear in all documents (see nos. 17 and 22 in Appendix I.).

3 Results

3.1 Stage of school

In this chapter, we compare biological parts of the intended national curricula in the Czech Republic (CZ), Estonia (EST), Hungary (HG), Poland (PL), Slovakia (SK) and Slovenia (SLO). We focus on lower secondary education, represented by the second stage of Czech basic schools (6^{th} to 9^{th} grades). This corresponds approximately to the Slovakian, Polish and Hungarian second stages (5^{th} to 9^{th} grades in Slovakia, 5^{th} to 8^{th} grades in Hungary, 4^{th} to 8^{th} grades in Poland), Estonian and Slovenian second (4^{th} to 6^{th} grades) and third stages (7^{th} to 9^{th} grades). In Slovenia, the second stage (4^{th} to 6^{th} grades) is considered as a part of primary education (see Šorgo & Špernjak, 2012), but we included it into our study for the sake of better context.

3.2 Integrated science or separate biology

In the above-mentioned stages of basic school, biology can be taught either as an independent subject or as a part of an integrated subject called "science". Biology as a separate subject is taught in Poland and Slovakia, Czech schools can decide which way they prefer (either biology or science). In Estonia, science is taught in lower grades (till 7^{th} grade) whereas biology is taught in higher grades (from 7^{th} grade on). Similarly, in Slovenia, science is taught in the 6^{th} and 7^{th} grades, with about two thirds of time allocation devoted to biological topics. Biology is taught as a separate subject in the 8^{th} and 9^{th} grades. Moreover, in Slovenia, pupils in the 8^{th} and 9^{th} grades can choose among a variety of optional subjects, including those focused on biological, environmental, agricultural and health related topics (MIZS, undated). Optional subjects (electives) are not included in our study. In Hungary, the integrated science subject for the whole second stage is planned.

3.3 Prescribed time allocation

In some countries the time allocation for biology or science is specified by the proper educational programme (see Appendix, row No. 4). It is stated either as the number of hours per week or per school year (CZ, EST, SK, SLO), or as the percentage of time (HG) devoted to that particular educational subject. The time allocation can be either minimal (CZ, HG) or obligatory (EST, SLO). Only in Estonia and Slovenia is the time allocation prescribed for biology as a separate subject. The exact number of hours is not stated in the Polish document.

3.4 Objectives and expected outcomes

All of the countries studied (CZ, EST, HG, PL, SK, SLO) have similar objectives for science (or biology) in basic schools. In accordance with the Estonian document we can divide these objectives into: a) scientific knowledge, b) inquiry skills and c) values and attitudes. All of the countries studied formulate key competences in a similar manner. These competences are usually common to all science subjects, thus not only to biology, but to physics, chemistry and geography as well, but in the Slovenian document for the 8^{th} and 9^{th} grades, the key competences are elaborated also specifically for biology. One of the main aims of the science subjects is to promote scientific literacy by gaining appropriate methodological competences: Pupils should formulate questions, observe natural phenomena, solve problems, do experiments, analyse data, draw conclusions from them, use different information sources and present their results. Pupils also should understand the relationship between nature and society, feel responsible for the environment and make competent decisions in everyday life. Pupils should also have positive attitudes to nature and value natural sciences. In the Slovenian documents, the demands on the pupils' inquiry skills are elaborated for each study grade and are gradually increasing from 6th to 9th grades and a positive attitude towards science is accented.

3.5 Distribution of subject matter into grades

In some countries (PL, SK, SLO), the educational programme describes how to sketch out the subject matter into particular grades, but these recommendations need not be compulsory (PL). In other countries (CZ, EST, HG), the educational programme just states that the subject matter should be taught in the second stage (in EST either in the second or third) and schools themselves decide how to distribute the subject matter into the particular grades. In Hungary, the educational programme makes a difference between pairs of grades, 5th and 6th on one hand and 7th and 8th on the other, and describes the subject content for each of these pairs.

3.6 Structuring of subject matter

In some countries (CZ, HG, PL) where the schools themselves decide what to teach in which grade, the subject matter in the educational programme is structured into biological disciplines (botany, zoology, human biology, genetics, ecology, etc.). The situation is different when the order of topics is obligatory (SK, SLO) and it is even more complicated in Estonia where the educational programme determines the stage (2nd or 3rd) and also the type of subject (science or biology). Both Slovakia and Estonia start with an ecological view of nature (in 5th and 6th grades in SK, and in 2nd stage science in EST) and focus on life in various ecosystems or near human settlements. In higher grades, the attention moves to various groups of organisms (plants, mushrooms, microorganisms, invertebrates, vertebrates), human biology, genetics, ecology and environmental protection. The Slovenian documents apply a holistic approach to biological teaching content. They clearly follow three hierarchical levels – cell, organism and ecosystem, which are continuously present from the 6th to the 9th grades and also the links between them are clearly defined (MISZ, 2011a: scheme on p. 30). The Slovenian 6th grade focuses mainly on the biology of plants; 7th grade on the biology of bacteria, fungi, animals and ecosystems; 8th grade on cell biology and human biology. The Slovenian 9th grade is devoted to more general, synthesizing and applied topics, such as evolution, genetics, biotechnologies, biodiversity, and biology and human society.

3.7 Depth of learning content

The learning content in the majority of the countries studied (CZ, HG, PL, SK) is not specified in detail. It is described briefly, and only in outline records the structure of that particular topic. It cannot be understood as a list of terms and theories pupils should learn. The Estonian and Slovenian documents distinguish between biological concepts and learning content. Formulations such as "pupils give examples" or "determine the most important species" are used without explicit specification of those examples and species. In zoology, the following taxa are mentioned: cnidarians, coelenterates, molluscs, arthropods, worms, fish, amphibians, reptiles, birds and mammals. In botany, the Czech and Slovenian educational programmes are the most detailed – they mention algae, mosses, sporogenous plants, conifers, monocotyledonous and dicotyledonous angiosperms, which the other countries do not specify. In human biology, the compared educational programmes state the same topics ordered in the same way (bones and muscles, circulatory, respiratory, digestive and excretory tract, nervous system, reproduction and ontogenesis of man). The Slovenian document puts a strong emphasis on the pupils' understanding of the relation between the anatomy of organs, their physiological function and human health (e.g., "pupils understand the connection between the structure and the function of the eye (the appearance of the image), they correlate this with errors and corrections of vision, risks of injury, prevention and first aid,"; MIZS, 2011a: p. 12, paragraph D8-2).

3.8 Incorporation of geology

All of the countries include at least some geological topics in the subjects science or biology. In some of them (CZ, SK), the whole of geology is covered by the topic "Inanimate nature", and "The history of Earth", while in the others just certain topics are included (EST, SLO). Geology can also be part of geography (PL, SLO, in CZ it can be so as well, depending on the particular school's educational programme). In Hungary, geology is incorporated especially in two subject areas – "The earth – our environment" and "Man and nature" encompassing science, biology, geography, chemistry and environmental science in general. In Slovenia, geological content is briefly covered by the teaching content "Rocks and soil" in the 6^{th} grade.

3.9 Educational and practical aims

The expected outcomes are many practical skills that can be used in everyday life. In all of the countries studied, they are connected with human biology and a healthy lifestyle. We can give the following examples of expected outcomes: giving first aid, behaving safely in nature, following hygienic rules and rules preventing one from diseases, behaving in an environmentally-friendly manner, maintaining a healthy lifestyle (healthy eating habits, avoiding drug abuse), behaving in a sensible way during ecological disasters and behaving in a sexually responsible way. Topics connected with agriculture and food processing are also valuable from a practical point of view. For example, the Slovakian document states such topics as types of vegetable, fish farming and beekeeping. Slovakian and also Czech pupils should, among others, learn how to differentiate between poisonous and edible mushrooms. Estonian pupils should be able to make compost. The Hungarian document states several times that pupils should gain a critical approach to pseudoscientific, anti-scientific and anti-technological assertions. In Hungary, Estonia and Slovenia, the ability to operate with new technologies and ICT is accented.

3.10 Opportunity for pupils and teachers to influence what is taught

In Estonia, there is a passing reference that it is important to plan investigation-based assignments that follow the pupils' interests and experiences. In Slovenia, teachers are allowed to use up to 20% of the overall time allocation for biology in the 8^{th} and 9^{th} grades for more detailed teaching of topics according to the pupils' abilities and interests, current issues and/or the local situation. In the other countries, the opportunity for pupils to influence what they learn is not mentioned at all.

3.11 Taxonomic demands

Classification of organisms is a relatively marginal part of the biology curricula in the countries studied. Their expected outcomes usually state that pupils should classify organisms into appropriate taxa (on the level of main classes of vertebrates and phyla of invertebrates and plants). Moreover, the Czech Republic, Hungary, Poland and Slovenia require knowledge of taxonomic principles. Slovenian pupils of the 9^{th} grade shall understand basic principles of phylogenetic systematics. A list of definite species of organisms that pupils should learn about is not stated in any country. Especially in Estonia, Slovenia and Slovakia, botany and zoology are not treated in a systematic manner, but rather a comparison of the physiology (reproduction, etc.) of various groups of organisms is required.

3.12 Incorporation of evolution

In some countries (EST, PL, SLO), evolution is set as a separate chapter. Estonian and Polish documents state a few expected outcomes connected with evolution – such as explaining principles of biological evolution, comparing humans and other vertebrates, etc. In Slovenia, "Evolution" is one of the crucial themes of the 9^{th} grade and is recognised as a central one. The chapter is relatively comprehensive, with 18 well elaborated expected outcomes which put rather high demands on the cognitive abilities of pupils and a fundamental knowledge of genetics (e.g., "pupils recognize that evolution is a gradual process in which the new complex properties of an organism arise through many generations; mutations are random in the sense that they are not aimed at improving the organism; natural selection is not accidental", MIZS, 2011a: p: 17, paragraph J1-5). In the Czech Republic, evolution is included in three different chapters: Introduction to biology, Phylogenesis of man, and Inanimate nature. In Slovakia, it is a short part of the chapter History of the Earth and human evolution is not mentioned at all. However, in Slovakia, evolution is also a part of other topics, such as biocenosis (in the 5th grade), diversity of vertebrates (in the 7^{th} grade) and ecological factors (in the 9^{th} grade). The Hungarian document speaks about evolution in various places in the subject area "Man and nature", especially in the biology subject. This section contains several references to the evolution, e.g., regarding the topic of History of science and Constancy and Diversity of the living world. Except for Hungary, evolutionary principles are not involved in other topics. In the Hungarian document an evolutionary approach is, among others, used in geography for analysing the geographical distribution of plant and animal species.

3.13 Treating ecology

Lower grades in some countries (EST, HG, SK) present an ecological view of nature. This is especially true for Estonian second stage science. Organisms and their life processes are dealt with in connection with their environment (wild animals and their ecosystems or domestic animals and organisms living in human settlements). The Estonian document focuses a great deal on Estonian and Baltic wildlife. In higher grades in Estonia and Slovakia, environmental protection and ecology is incorporated as a separate discipline. In the Czech Republic and Poland, ecology and environmental protection are dealt with as separate chapters but we must be aware of the fact that the schools do not have to follow strictly the structuring of the learning content stated in educational programmes. In Slovenia, ecological topics start in the 6th grade with the roles of plants in ecosystems; continue with the ecological roles of animals, bacteria and fungi and with the structure and functioning of ecosystems, and ends in the 9th grade with biomes, the biosphere and biodiversity.

3.14 Treating cell biology

In some countries (EST, SK), cell biology is not described as a separated chapter and specific characteristics of bacterial, plant and animal cells are mentioned when the group of organisms is being discussed. Details about the nucleus are incorporated into genetics. The structure of the cell is taught before the cell functioning. In other countries (CZ, PL), cell biology is a part of the introduction to biology. (But as has been stated above, the Czech document does not demand the following of the prescribed order of topics.). In Hungary, some information about cells are in a separate topic (Life processes at the cell level, Types of plant and animal tissues), and other information is mentioned elsewhere. The Slovenian curriculum, in contrast, puts a strong emphasis on cell biology from the 6th up to the 9th grades – starting with plant cells, continuing with animal, bacterial and fungal cells and graduating with general topics such as cell physiology and genetics.

3.15 Incorporation of history of science

The history of science seems to be a relatively marginal part of the studied curricula as it is not systematically incorporated in any of them. Marginal remarks that appear in the Hungarian, Czech and Slovenian documents follow: Hungarian pupils should be occupied with the history of science to get to know the nature of science. They should, for example, describe the evolution of models and theories or analyse the advantages and limitations of methods of obtaining knowledge. In the Czech educational programme, there is one reference of peripheral importance about the historical development of biology (or science). Slovenian teachers should present biological facts as the result of the work of many scientists throughout centuries of research. Their pupils should recognise the significance of biological discoveries (e.g., Darwin's Theory of Evolution or the structure of DNA). In EST, PL and SK hardly any remarks about the history of science can be found.

3.16 Relationship between science and society

As far as the relationship between biology and society is concerned, educational programmes in the countries studied concentrate on utilisation (growing plants and breeding animals, forestry), environmental protection (responsibility for the environment, sustainability), medicine and the merits and risks connected with various technologies. Pupils are expected to understand the connections between human activities and the environment as well as between various scientific disciplines; they should also express respect for living beings. Moreover, in Hungary, avoidance of pseudoscientific approaches is mentioned.

3.17 Emphasis on local regions

Preferring topics connected with local regions is especially striking in the Estonian educational programme. Estonian pupils should (especially in the second stage) occupy themselves with environmental problems near their home and focus on wildlife in their homeland or in the Baltic Sea. In the other countries (HG, PL, SK, SLO) the emphasis is not so striking, nonetheless, pupils should also determine common species living near their school, find information about the local region and do experiments (or observations) near their home. Slovenian pupils should understand the reasons for the high biodiversity found in Slovenian nature. Only in the Czech Republic are local regions not accented.

3.18 Interdisciplinary links and their fulfilment

In the introductory part of the educational programmes, the need to promote interdisciplinary links is stated. This is so in all of the countries studied. These links are stated in general without any particular recommendation on how to do so. In Estonia and Slovenia, connections between biology and general competences (cultural and values, social and citizenship, self-awareness, communication, mathematics and entrepreneurial competence) are more elaborated. These pieces of advice are short but usable in practice (e.g., the demand for oral presentations on results from observations to bolster the pupils' communication competence).

3.19 Related educational areas and cross-curriculum subjects

Biological topics are also incorporated in other educational areas and cross-curriculum subjects. In CZ, these are the educational areas Man and health, Man and work (plant growing and breeding, laboratory technique), the cross-curriculum subject Environmental education and the optional educational field Ethical education. In Slovakia, the relevant educational areas are Man and work (plant growing and breeding), Health and movement, the cross-curriculum subject Environmental education, Health and life protection and Sexual education. In Estonia, many biological problems are dealt with in the educational areas Environment and sustainable development and Health and safety, in Hungary, there is an educational area called Way of life and practical skills. Similar trends can be seen in the Slovenian curriculum, especially in the 6^{th} and 7^{th} grades, where the integrated science subject is taught. No related educational areas are mentioned in Poland.

3.20 Recommended teaching methods

Estonia and Slovenia pay the most attention to teaching methods from all of the countries studied. In Estonia, various teaching methods and activities should be used, including homework, pair and group work, extending the study to museums and school surroundings (outdoor learning), role play, discussions, project work, creating a study folder and a research paper, and practical and research related work. In the Slovenian document, didactic recommendations are included as are well elaborated separate chapters, but the teachers are autonomous in choosing from among the methods. In addition to particular teaching methods, they include also general topics, such as remedying the pupils' misconceptions or promoting their interest in biology. In the other countries, less attention is paid to this topic, it is often said that the methods should be varied (HG, PL) and that inquiry-based learning and the pupils' own activity should be preferred (CZ, SK). In the Slovakian document, creating mental maps is mentioned several times. The Polish document strongly recommends using various types of information (pictures, films, texts, animations, internet data, etc.), outdoor learning and field work (examples of suitable experiments are stated in Polish syllabi).

3.21 Specific biological skills

Scientific skills pupils should gain during biology lessons are the following: species identification with the help of identification manuals (HG, CZ, SK), designing experiments and observing animal behaviour (CZ, PL, SK), and using a microscope or magnifying glass for observation (CZ, HG, PL, SK, SLO). In Slovakia and Slovenia, the inquiry skills are interconnected with presentation and communication skills. The Estonian, Hungarian, Polish and Slovenian documents speak more generally about solving scientific problems (choosing appropriate methods, creating models, collecting information, formulating hypotheses, recording data, drawing conclusions and presenting summaries). In Estonia, particular biological skills are incorporated into practical tasks (see below).

3.22 Public engagement

In Slovakia, we can find the requirement that pupils should become involved in raising public awareness of natural scientific issues. The motivation to participate in age-appropriate environmental protection events or activities supporting public health is demanded. To a certain degree, we can find this demand in Estonia and Slovenia, as well; the other countries do not refer to it. Polish pupils should show and share their opinions on current biological topics such as genetic modification, and ecological and nature conservation issues.

3.23 Required practical lessons

In the educational programmes, practical work in a laboratory and field research are mentioned as essential teaching methods. In Hungary, the minimum number of practical lessons is set down. (In the 5^{th} grade, pupils should perform at least two independent experiments per year, present their notes or drawings at least four times per year and prepare one work on a science-related subject. In the 7^{th} and 8^{th} grades they should perform at least two biological experiments or examinations per year and take part in at least one practical activity outside the school.) The Slovenian curriculum for science requires that at least 40% of teaching hours in the 6^{th} and 7^{th} grades be based methods of work, with an emphasis on classroom and field experimental research. In the 8^{th} grade at least 10 and in the 9^{th} grade at least 13 teaching hours of biology (at least 20% of the total time allocation) must be devoted to experimental and fieldwork in smaller groups. In Estonia, tasks for practical work are listed for every topic. (This is called "Practical work and use of ICT" and is comprised of usually 3 to 5 tasks that may involve field research and other activities outside of school: e.g., studying the sprouting of seeds in different environmental conditions, making a model of an organ, going for a study trip to a nature reserve, etc.) The minimum requirement of outdoor learning is also stated in the Estonian document. (In the second stage of study, pupils should visit an environmental centre, museum or laboratory outside of the school at least twice, in the third stage of study in every science subject once during the academic year.) Practical tasks in the other countries (CZ, HG, PL, SK, SLO) are not specified so precisely. They are embodied in expected outcomes: Pupils should, for example, monitor pollution in the school's surroundings (SK) or do an experiment with yeast fermentation (PL). More detailed examples can also be included in the supporting document (PL).

3.24 Requirement of methodological skills

All of the countries' demands on methodological (inquiry) skills are high. As has been written above, pupils should be able to solve scientific problems using appropriate methods (observation, experiment), they should be able to plan their research, formulate hypotheses, collect the information needed, analyse data and draw conclusions from the data. These inquiry skills are described in the general characteristics of scientific education and are embodied in expected outcomes (CZ, HG, PL, SK, SLO), while in Estonia they are addressed also in connection with particular learning content.

3.25 Equipment of laboratories and special classrooms

The equipment needed for laboratory and practical work is also discussed in educational programmes (except for HG). Estonia and Poland explicitly state very concrete demands (classrooms with hot and cold water, sinks, sockets, working desks, microscopes, binoculars, different sensors per class, first aid kit, models of human organs, sets of microscopic sections or technology for a teacher's demonstration). Other countries (CZ, SK, SLO) just state that schools should have special classrooms with appropriate equipment.

3.26 Specification of assessment

There is nothing said about pupils' assessment in the Czech Republic, Hungary, Poland and Slovakia. In contrast, Estonia pays much attention to this issue. It is stated that teachers should use oral assessment and/or numerical grades and that the assessment should be applied to attitudes and pupils' behaviour, too. Estonian teachers should correct grammar mistakes in written assignments (but not take them into account in the assessment), pupils must know the criteria for assessment, and their inquiry skills and active participation in discussions must also be evaluated. In the third stage of study, thinking in the context of the subject should be 80% of the grade (40% being tasks that require the use of lower levels of thinking, 40% being tasks that require the use of higher levels of thinking) and development of research and decision-making skills should make up the other 20% of the grade.

Slovenia has a well elaborated way of general assessment of pupils' achievement of the expected standards of knowledge. Three standards of knowledge are distinguished; standard 1 defines the minimum, and standard 3 is the most advanced knowledge. The Slovenian standards are not based on details of the learning content, but on understanding the principles, ability to use the knowledge in a broader context, proper interpretation of facts and taking a stance on the issue based on relevant arguments.

4 Discussion

4.1 General features of the studied curricula

From the detailed comparative analysis presented above, we can infer the following general characteristics of the biological parts of the six national curricula studied:

The Estonian and Slovenian educational programmes are precise and the general aims are very well elaborated on the level of the particular learning content. In comparison with the other countries they specify practical work and assessment of pupils' performance and outcomes in the most sophisticated way. They also state particular recommendations on how to fulfil its demands (e.g., how to deepen interdisciplinary bonds or which teaching methods to choose). Moreover, the Estonian and Polish educational programmes specify also the required classroom equipment. There is a heavy emphasis on using ICT in Estonia and Slovenia. In Estonia, the education is (especially in the lower grades) centred on the local region and applies an ecologically-oriented approach. This is facilitated by the existence of an integrated subject, science.

The educational programmes of the Czech Republic, Slovakia and Poland are much alike. There is huge freedom for schools: Czech schools can even choose whether to teach biology or science, and Czech and Polish schools can decide on their own what to teach in which grade. None of these countries specify the learning content in much detail. Slovakia differs from the other two countries in the respect that it applies an ecologically-oriented approach in lower grades and that it emphasises the need of the pupils' participation in public educational and environmental activities.

The Hungarian educational programme prefers an ecologically-oriented and interdisciplinary approach. This document is the least detailed; it states a great many general proclamations and lets the schools arrange the education at their own discretion.

4.2 Do the national curricula foster pupils' interest in biology?

In agreement with published studies which point out the need of connecting biology and science education to everyday life in order to make it relevant (Hassan, 2011; Lindahl, 2003; Rennie, Goodrum & Hackling, 2001), all of the analysed curricula mention topics which are useful and needed in everyday life. These are mainly human health, poisonous plants, domestic animals, environmental protection and, very importantly, avoidance of pseudoscientific approaches (HU). Most of these topics are cross-curriculum subjects. The issue of connecting scientific issues and everyday life is raised in several curricula (EST, PL, SK, SLO). Another part of the content being relevant is learning about local regions, which is a very important part of the Estonian curriculum and is also mentioned in other national curricula (HG, PL, SK, SLO) but not in the Czech Republic. Learning about local regions can naturally happen outdoors as many studies recommend (e.g., Žoldošová & Prokop, 2006). Outdoor learning has to be used in Estonia, Poland and Slovenia according to their curricula. Another essential recommendation from literature is to let the pupils find their own way of solving problems, doing inquires and discussing (Freeman et al., 2014; Lyons, 2006; Šorgo & Špernjak, 2009; Papáček, 2010). This is also reflected by the analysed curricula, as in all of the countries studied inquiry or solving scientific problems should be used while teaching biology. Quite naturally, pupils are required to present and communicate their thoughts by some curricula (EST, HU, PL, SLO). Discussion is pointed out in the Estonian curriculum, which is the most detailed among the studied curricula where talking about teaching methods is concerned. Practical courses are also ordered by all of the compared curricula, with the Estonian one being the most detailed and including "Practical work and use of ICT" in every topic and the Slovenian one which requires a high proportion of laboratory and field practical work in small groups. Interestingly, even more importance to practical work compared to biology is given in the chemistry and physics parts of the Slovenian curriculum (Šorgo & Špernjak, 2012). As literature suggests, a hands-on, together with a minds-on approach, is effective (Stohr-Hunt, 1996; van den Berg, 2013). Among other topics, observing animal behaviour is also mentioned in some curricula (CZ, PL, SK), as recommended by Fančovičová and Prokop (2017), Prokop and Fančovičová (2017) and Randler, Hummel and Prokop (2012). In spite of the emphasis on practical activities in the Slovenian curricula, Šorgo (2012) pointed out that little attention is placed on the development of the pupils' creativity.

Regarding structuring the subject matter, an interesting pattern was revealed. While some countries (CZ, HG, PL), where the decision on what to teach in which grade is left up to schools, have the subject matter in the educational programme structured into biological disciplines (botany, zoology, human biology, genetics, ecology, etc.), another situation was found in Estonia and Slovakia. These countries start with ecology (learning about ecosystems and focusing on various groups of organisms later) and continue with human biology, genetics, ecology and environmental protection. The order or even location in a grade is given. A similar case is the Slovenian curriculum, in which the distribution of subject matter within the grades is obligatory and the curriculum is constructed in a holistic way – each of the main groups of organisms are treated on the level of cell, organism (mainly anatomy and function) and ecosystem, with special emphasis on the links between the levels. 8^{th} grade is devoted to human biology and 9^{th} grade to general, synthetic and applied topics (e.g., biological molecules, evolution, human genetics, biotechnologies and environmental problems). This raises an interesting question of whether this pattern can be generalised and why it works better to give more structure to the subject matter in case of an "ecological and evolutionary" approach. One would expect links and interconnection within the subject matter to be crucial in any case, even when structuring biology into disciplines like botany, zoology, etc. Analysing more curricula is needed to answer this question. Structuring the subject matter in a different way does not seem to have a direct influence on science literacy as pupils from both Poland on one side and Estonia and Slovenia on the other scored above the OECD average in 2015 (OECD, 2016).

There are several recommendations from the literature and analysed curricula which can be taken into account for the revision of the Czech curriculum. The main ones are to emphasise outdoor education, links to local place and community, and in general to mention more specific examples such as suitable practical courses, links to ICT, and the connections between biology and general competences. Although the Czech curriculum states experiments and inquiry should be used while teaching biology, PISA results from 2015 indicates that this, in reality, happens quite rarely (OECD, 2016). As experience from the last Czech curricular reform has shown, previous discussion with in-service teachers, teacher trainers and others involved in the educational process and acceptance by the professional public is essential (Straková, 2013).

The results of our study can be related to those stated in a Polish study by Grajkowski, Ostrowska and Poziomek (2014). This study compares core curricula for science subjects in Poland, England, Finland, Estonia, France, and in the Czech Republic. Thus, three of these countries are the same as in our study. The Polish paper lists several points that its authors find missing or insufficiently emphasised in the Polish core curriculum in comparison with the other countries. They use this list to suggest advice on how to improve the Polish educational programme. In the following passage we discuss their points and recommendations with respect to our study (Grajkowski, Ostrowska & Poziomek, 2014: pp. 33–34, 37–38).

The Polish paper recommends combining science subjects, and stresses the need for stronger interdisciplinary links and a cross-curricular nature for Polish education. Having an integrated subject at least in the lower grades is supposed to be a contemporary trend. From our study we can infer that this is true especially in Estonia and Slovenia. Some authors (for example, Folta, 1998) recommend teaching the history of science to help create cross-curricular connections and overcome the traditional specialisation of scientific disciplines. However, as was shown in our study, none of the countries pay enough attention to this topic. The Polish study came to a similar conclusion, with the exception of England, where a tradition of teaching the history of science exists.

As the Polish study states, the need for an interdisciplinary approach is interconnected with problem-based coverage of teaching content. They suppose that a problem-based approach is more adequate for the 21st century than teaching separate topics resulting from the 19th century arrangement of natural sciences. According to our results, especially Estonia employs this approach. Moreover, both our study and the Polish study highlight the emphasis Estonia put on the application of ICT in various topics.

According to Grajkowski, Ostrowska and Poziomek (2014), the creation of a catalogue of skills common for all science subjects is needed. They mention especially those skills that are connected with scientific reasoning and scientific method (experiments and observations). They think such a list could enable moving the emphasis from teaching content to educational aims. Some authors state (e.g., Matthews, 2011) that doing science (or imitating it during school lessons) is one way to come to understand the scientific way of thinking. Learning about science and its nature is at least as important as learning science (Matthews, 2011). According to our study, scientific skills in the chosen countries are described only in general and having such a catalogue of skills could make deciding what to do during practical lessons easier.

The Polish study advises adding a few sections of content. They list ethical and moral issues related to science and the history of science. According to our study ethical and moral issues are partially present in the Slovakian document where the need for public engagement of pupils (their participation in the formation of public consciousness of scientific issues) is mentioned several times. Although Grajkowski, Ostrowska and Poziomek (2014) do not state any argument for teaching the history of science, there are many: History of science is supposed to show the way that scientific knowledge is formed and the nature of science as such. It presents science as a never-ending search for answers and prevents people from regarding today's state of scientific knowledge as an indisputable absolute truth (Horner & Rubba, 1978). Moreover, according to some authors (e.g., Karpenko, 1997), the history of science can serve as a source of ethically interesting situations, thus, teaching the history of science can fulfil this need as well.

The Polish study also states that more attention should be paid to developing pupils' motivation to study science. They demand more concrete suggestions for how to make a pupil interested in science and affect his or her attitude towards the natural world (Grajkowski, Ostrowska & Poziomek, 2014). Forming a positive attitude to science and nature is an educational aim of all curricula in all of countries we studied. To fulfil this requirement, concrete advice would be helpful.

4.3 Limitation of our study

We are obligated to mention that although we explored the national curricula of all of the countries thoroughly and performed in-depth comparisons, it is not possible for our results to give a full picture regarding the educational processes in the selected countries. Moreover, in our study, we did not include an important link between the official national curricula and school reality – the textbooks. As we stated above, the evidence evinces that the reality often differs from the instructions of the national curricula. We also did not take into account issues overlapping into the humanities. Further, as we are not native speakers/citizens of all of the chosen countries (only of the Czech Republic), there is a possibility that we misunderstood some of the information and involuntary misinterpreted them. We tried, however, to reduce this to a minimum.

5 Conclusions

From the analysed curricula, the most inspiring were the Estonian and Slovenian ones, because they precisely elaborate general educational objectives into the level of the particular learning content and standards of knowledge. Moreover, the Slovenian document offers an inspiring holistic approach to the teaching of biological issues. The Estonian curriculum is a good example of incorporating local aspects, such as typical local ecosystems. We also find the content-specific links to practical work and ICT and the connections between biology and general competences in the Estonian curriculum very useful when using the documents in school practice. The national curricula of both countries recognise biological knowledge and scientific literacy as being very important for the individual and society.

This can be a good inspiration for revision of the Czech Framework Education Programme. Regarding this revision, both experience and literature show that public discussion and elaborate support for teachers are essential conditions for successful change.

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Jana Poupová, jana.poupova@natur.cuni.cz
Vanda Janštová, vanda.janstova@natur.cuni.cz
Radim Kuba, radim.kuba@natur.cuni.cz
Jan Mourek, jan.mourek@natur.cuni.cz
Charles University, Faculty of Science
Department of Teaching and Didactics of Biology
Viničná 7, 128 43 Prague 2, Czech Republic

Appendix

Differences between the biological parts of core curricula of selected countries (CZ, EST, HG, PL, SK, SLO)

curricular documents

CZ Rámcový vzdělávací program pro základní vzdělávání (MŠMT ČR, 2017)
EST National Curriculum for Basic Schools (Government of the Republic of Estonia, 2014b) Appendix 4 of Regulation No 2 of the Government of the Republic of 6 January 2011. National Curriculum for Upper Secondary Schools (Last amendment 29 August 2014). Subject Field: Natural Science (Government of the Republic of Estonia, 2014a)
HG National Core Curriculum (The Government of Hungary, 2014)
PL Nowa podstawa programowa (Szkoła podstawowa IV–VIII) (MNE, 2018)
SK Štátny vzdelávací program (ŠPÚ, 2015)
SLO Program osnovna šola. Biologija. Učni načrt. (MISZ, 2011a) Program osnovna šola. Naravoslovje – Učni načrt. (MISZ, 2011b)

1 stage of school

CZ 6^{th} to 9^{th} grades
EST 2^{nd} stage (4^{th} to 6^{th} grades) and 3^{rd} stage (7^{th} to 9^{th} grades)
HG 5^{th} to 8^{th} grades
PL 4^{th} to 8^{th} grades
SK 5^{th} to 9^{th} grades
SLO 2^{nd} stage (4^{th} to 6^{th} grades) and 3^{rd} stage (7^{th} to 9^{th} grades), relevant subjects taught from the 6^{th} to the 9^{th} grades

2 integrated science or separate biology

CZ It depends on the school, both arrangements are possible.
EST From 4^{th} to 7^{th} grades science integrating biology, chemistry, geography and physics is taught. From 7^{th} grade biology is taught.
HG Integrated science is being planned, but in the document separate subjects are dealt with.
PL Biology, science in 4^{th} grade.
SK Biology.
SLO In the 6^{th} and 7^{th} grades science (naravoslovje), integrating biology, chemistry, physics, environmental science and geology; in the 8^{th} and 9^{th} grades separate biology (biologija).

3 prescribed time allocation

CZ For the educational area Man and nature (comprised of biology, chemistry, geography and physics) the time allocation pooled for 6^{th} to 9^{th} grades must be at least 21 lessons per week. This educational area should be incorporated in each grade.
EST In the 2^{nd} stage science should be taught 7 lessons per week, in the 3^{rd} stage (in 7^{th} grade) science should be taught 2 lessons per week and biology 5 lessons per week.
HG Minimum percentage rates for subject areas are set:
a) Man and nature – for 5^{th} and 6^{th} grades 6–10%; for 7^{th} and 8^{th} grades 10–15%.

b) The Earth – our environment – for 5th and 6th grades 6–10%; for 7th and 8th grades 15–20%.

PL It is not specified.

SK It is not specified.

SLO **science:** 6th grade – 2 lessons per week (70 per school year), 7th grade – 3 lessons per week (105 per school year), 175 lessons in total **biology:** 8th grade 1.5 lessons per week (52 per school year), 9th grade – 2 lessons per week (64 per school year), 116 lessons in total.

4 OBJECTIVES AND EXPECTED OUTCOMES

The main aim is to develop scientific literacy. Forming scientific literacy is comprised of gaining methodological skills (exploring, problem solving, dealing with information, discussing), forming a positive attitude to science and wildlife and gaining environmentally-friendly attitudes. Expected outcomes are formulated as verbs that show what ability pupils should obtain.

5 DISTRIBUTION OF SUBJECT MATTER INTO GRADES

CZ Distribution of subject matter into grades is decided on the school level.

EST Subject matter is obligatorily distributed into stages, not into particular grades.

HG Subject matter is divided into two sections: 5th and 6th, and 7th and 8th grades. It is not obligatory.

PL Distribution of subject matter is suggested but is not obligatory.

SK Distribution of subject matter into grades is fixed.

SLO Distribution of subject matter into grades is fixed.

6 STRUCTURING OF SUBJECT MATTER

CZ Structuring of the subject matter is decided on the school level. In the document it is arranged into separate biological disciplines (botany, zoology, . . .).

EST The second stage science follows an ecological approach. The third stage of biology deals with particular taxa (e.g., physiology and reproduction of vertebrates), ecology, human biology, genetics and evolutionary biology. The third stage science is devoted especially to physics and chemistry.

HG An ecological approach to the subject matter is followed.

PL Structuring of the subject matter follows traditional biological disciplines. It is similar to the Czech one.

SK The subject matter in 5th grade follows an ecological approach, then anatomy and physiology of various taxa of organisms is dealt with. In higher grades, human biology, genetics, ecology and geology are taught.

SLO A holistic approach to biological teaching contents, three hierarchical levels – cell, organism and ecosystem, from the 6th to the 9th grades. 6th grade focuses mainly on the biology of plants; 7th grade on the biology of bacteria, fungi, animals and ecosystems; 8th grade on cell biology and human biology. 9th grade on synthesizing and applied topics, such as evolution, genetics, biotechnologies, biodiversity or biology and human society.

7 DEPTH OF LEARNING CONTENT

CZ The particular species pupils should know are not specified. Learning content is described only briefly. Classes of vertebrates, phyla of invertebrates and plants and organ systems are enumerated.

EST Learning content is described briefly, the document enumerates a few concepts and a list of concrete practical tasks (together with the use of ICT) for each topic.
HG Learning content is not described in detail. No taxa are specified.
PL Learning content is short and briefly described. Classes of vertebrates, phyla of invertebrates and plants, organ systems and selected diseases are enumerated.
SK Learning content is short and briefly described. Classes of vertebrates, phyla of invertebrates and plants and organ systems are enumerated.
SLO Subject matter is briefly described. Classes of vertebrates, phyla of invertebrates and plants and organ systems are enumerated. A strong emphasis is put on the pupils' understanding of the relation between different hierarchical levels and between the structure and function, e.g., the anatomy of organs, their physiological function and human health.

8 Incorporation of geology

CZ Yes.
EST There are just a few geological issues in science and biology, the majority of them is incorporated into geography.
HG There are just a few geological issues in the chapter Earth.
PL There are just a few geological issues in biology.
SK Yes.
SLO Briefly covered by the teaching content "Rocks and soil" in the 6^{th} grade.

9 Educational and practical aims

They are related to food, healthy lifestyle, first aid, agriculture, wildlife protection and protection of humans in extraordinary situations.

10 Opportunity to affect what is taught

CZ It is not mentioned at all.
EST There is just one general notion.
HG It is not mentioned at all.
PL It is not mentioned at all.
SK It is not mentioned at all.
SLO Teachers are allowed to use up to 20% of time allocation in the 8^{th} and 9^{th} grades for more detailed teaching of topics according to the pupils' abilities and interests, current issues or the local situation.

11 Taxonomic demands

CZ There are a few remarks on principles of classification.
EST It is not mentioned at all.
HG There are a few remarks on principles of classification.
PL There are a few remarks on principles of classification.
SK There are a few remarks on classifying species into taxa. Botany and zoology is not treated systematically.
SLO Botany and zoology are not treated in a systematic manner, knowledge of taxonomic principles is required.

12 INCORPORATION OF EVOLUTION

CZ Evolutionary biology is not a separate chapter, evolutionary issues are incorporated into other chapters (for example, human evolution is incorporated into human biology).

EST In the 3rd stage there is a separate chapter on evolutionary biology. It does not penetrate other chapters.

HG There are brief and general notions about the necessity of acquainting pupils with the Theory of Evolution.

PL There is a separate chapter about the evolution of life. It includes similarities between humans and apes.

SK Only one topic (the origin of life and its evolution) is mentioned in general. There is no notion about the evolution of humanity.

SLO One of the crucial themes of the 9th grade; treated as a separate chapter. Evolution is recognised as a central principle in biology.

13 TREATING ECOLOGY

CZ Ecology of species is incorporated into systematic chapters dealing with taxa. There is a separate chapter ecology. (Nonetheless, the arrangement of subject matter is not obligatory.)

EST The 2nd stage deals with ecosystems, in the 3rd stage ecology and environmental protection is dealt with in biology.

HG The whole 2nd stage is ecologically-oriented.

PL There are separate chapters ecology and environment.

SK The 5th grade is ecologically oriented. It deals with ecosystems and organisms living with humans and in human settlements. In the 8th grade environmental protection and ecology is dealt with.

SLO Ecological topics start in the 6th grade with the roles of plants in ecosystems; continue in the 7th grade with the ecological roles of animals, bacteria and fungi and with the structure and functioning of ecosystems and ends in the 9th grade with biomes and biosphere and biodiversity.

14 TREATING CELL BIOLOGY

CZ Some topics are included in introduction to biology, the rest is distributed in many other chapters. (Nonetheless, the arrangement of subject matter is not obligatory.)

EST Subject matter concerning the cell is divided into several chapters.

HG Subject matter concerning the cell is divided into several chapters.

PL The majority of cell biology is incorporated into the introductory chapter Organisation and chemistry of life. The rest is divided into other chapters.

SK Subject matter concerning the cell is divided into several chapters. (The sequence of the partial topic is the following: structure of cell, function of cell, specifics of bacterial cell, eukaryotic nucleus.

SLO Cell biology is taught from the 6th up to the 9th grades – starting with plant cells, continuing with animal, bacterial and fungal cells and finishing with general topics such as cell physiology and genetics.

15 INCORPORATION OF HISTORY OF SCIENCE

CZ There is only an isolated notion about important biologists and their discoveries.

EST It is not mentioned at all.

HG It is mentioned just in a general manner.

PL It is not mentioned at all.
SK It is not mentioned at all.
SLO Teachers should present biological facts as the result of the work of many scientists throughout centuries of research. The significance of some biological discoveries is mentioned (e.g., Darwin's Theory of Evolution or the structure of DNA).

16 RELATIONSHIP BETWEEN SCIENCE AND SOCIETY

CZ Specification of the subject matter is comprised of, among others, such points as importance, protection, usage, benefits, risks, advantages and disadvantages.
EST The document stresses the need of responsibility for the environment, a positive relationship to wildlife and understanding of the connections between science and technology.
HG The document stresses the need of responsibility, of being able to distinguish between pseudoscientific and scientific approaches and of understanding the links between science and technology.
PL The document mentions the need of understanding connections between science and everyday life (for example, in medical issues) and between various scientific disciplines. It stresses understanding problems concerning GMO, biodiversity, energy sources, etc.
SK Some chapters deal with agriculture, forestry, medicine and environmental protection.
SLO The document stresses the need of responsibility for the environment, positive relationship to wildlife and understanding of the connections between science and technology.

17 EMPHASIS ON LOCAL REGIONS

CZ It is not mentioned at all.
EST It is accented especially in 2^{nd} stage science which focuses on the school surroundings, Estonia and the Baltic region. Pupils should be occupied with the environmental problems of their home region.
HG Pupils should occupy themselves with the environment in school surroundings and they should know the species living there.
PL Pupils should be acquainted with the species living near their home.
SK The document lists concrete environmental tasks pupils should do in their school surroundings. They focus on the knowledge of local natural specifics.
SLO The pupils should understand the reasons for the high biodiversity of Slovenian nature.

18 INTERDISCIPLINARY LINKS AND THEIR FULFILMENT

CZ Creating interdisciplinary links is required only in general, no concrete advice is given.
EST The connection between biology or science and key competences is briefly mentioned. There are several pieces of advice for teachers on how to create interdisciplinary links in their lessons. This is made easier by the existence of integrated science.
HG The requirement is stated only in general, no concrete advice is given.
PL The requirement is stated only in general, no concrete advice is given.
SK Creating interdisciplinary links is required only in general, no concrete advice is given.
SLO The connection between biology or science and key competences is briefly mentioned. There are several pieces of advice for teachers on how to create interdisciplinary links

in their lessons. This is made easier by the existence of integrated science in the 6th and 7th grades.

19 RELATED EDUCATIONAL AREAS AND CROSS-CURRICULUM SUBJECTS

CZ Man and health, Man and work, Ethical education, Environmental education

EST Environment and sustainable development, Health and safety

HG Way of life – practical skills, Earth – our environment

PL No related educational area is mentioned.

SK Man and work, Health and movement, Environmental education, Protection of life and health, Education for marriage and parenthood.

SLO Human influence on nature and the environment, Biology and society, Chemistry of living systems, Biotechnology, Biomes and the biosphere, Protection of nature and the environment. Interdisciplinary links and links between biology and human health are often mentioned in particular topics.

20 RECOMMENDED TEACHING METHODS

CZ Problem-based learning and the pupils' own activities should be accented. However, no concrete methods are recommended.

EST The document requires the usage of various methods, including homework, work in pairs and groups, role playing, outdoor activities, discussion, project-based education, creating portfolios and research papers and practical lessons. Lessons should be pupil-centred, active, and pupils should occupy themselves with problem-solving. In the 2nd stage, pupils should visit a centre for environmental education at least twice a year, on the 3rd stage they should do field work, go to a museum or to a laboratory at least once in each science subject.

HG It is stated that teaching methods should be various and should involve experiments.

PL It is recommended to present information in various ways (pictures, films, texts, . . .), and to do field work and experiments.

SK The document recommends problem-based education; creating mental maps is mentioned several times.

SLO Didactic recommendations are included as well elaborated separate chapters. Besides particular teaching methods, they include also general topics, such as remedying the pupils' misconceptions or promoting their interest in biology.

21 SPECIFIC BIOLOGICAL SKILLS

CZ Pupils should observe with a magnifying glass, microscope or telescope. They should use various determination materials, create a herbarium and dissect plants and animals.

EST The document describes methodological skills in general; concrete tasks (such as using a microscope, doing field work, . . .) are described in passages. Practical work and use of ICT.

HG Pupils' skills are described only in general. Being able to use a microscope is the only concrete demand.

PL Methodological skills are mentioned in general as is using a microscope, observations and doing field work.

SK Specific biological skills are formulated similarly to the Czech version. Moreover, in the Slovakian document there is mentioned at least one other research activity linked to some presentation skill (making a poster, discussing conclusions, . . .).

SLO Methodological (inquiry) skills are mostly mentioned in general, without links to particular biological topics. Use of a microscope is required in relation to human and animal cells and tissues and the circulatory system (recognition of blood cell types).

22 PUBLIC ENGAGEMENT

CZ It is not mentioned at all.
EST The pupils' public engagement is required but not so strongly as in Slovakia.
HG It is not mentioned at all.
PL Just the understanding of the social aspects of science is mentioned, no pupils' activities in this respect is required.
SK The pupils' public engagement is required in connection with environmental protection, health protection and local regions.
SLO Responsible personal behaviour in relation to the protection of nature and environment and the adoption of principles of sustainable development are required.

23 MINIMUM NUMBER OF REQUIRED PRACTICAL LESSONS

CZ It is not mentioned at all.
EST In each chapter, the practical tasks pupils should do are specified. Among the teaching forms and methods, outdoor activities and field work is required.
HG In the 5th and 6th grades at least 2 experiments or observations and 4 presentations of some results should be made. In the 7th and 8th grades there should be at least 4 experiments, and the creation of 4 protocols, 1 health project and 1 practical work outside school.
PL It is not mentioned at all.
SK It is not mentioned at all.
SLO At least 40% of teaching hours in the 6th and 7th grades must be is based on methods of practical work, with an emphasis on classroom and field experimental research. In the 8th grade at least 10 and in the 9th grade at least 13 teaching hours of biology (20% of the total time allocation) must be devoted to experiments and fieldwork in smaller groups.

24 SPECIFICATION OF PRACTICAL TASKS

CZ It is not mentioned at all.
EST It is specified in each chapter in a part called Practical work and use of ICT.
HG Tasks for practical lessons are not specified.
PL In some chapters it is stated that experiments should be done, however no concrete experiments are mentioned.
SK Practical lessons are not described in detail, but the activities required can be inferred from the expected outcomes.
SLO Tasks for practical lessons are not specified.

25 REQUIREMENT OF METHODOLOGICAL SKILLS

Much attention is paid to this issue. Especially the ability to observe, measure, experiment, create a hypothesis, analyse results, draw conclusions and present them is required.

26 EQUIPMENT OF LABORATORIES AND SPECIAL CLASSROOMS

CZ It is mentioned just in general. (The school should have adequate special classrooms.)
EST More concrete requirements on classroom equipment are stated.
HG It is not mentioned at all.
PL Concrete requirements on classroom equipment as well as on requisites (models of organs, ...) are dealt with.
SK It is mentioned just in general. (The school should have adequate special classrooms.)
SLO Not specified in detail.

27 SPECIFICATION OF ASSESSMENT

CZ It is not mentioned at all.
EST It is specified in detail. The document states, for example, what percentage a particular ability should have in final marks.
HG It is not mentioned at all.
PL It is not mentioned at all.
SK It is not mentioned at all.
SLO Three standards of knowledge are distinguished (standard 1 – minimum level, standard 3 – most advanced level of knowledge). The standards are not based on details of the learning content, but on understanding principles, ability to use knowledge in a broader context, proper interpretation of facts and taking stances on issues based on relevant arguments.

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A Comparative Study of Biology Curricula in England, Scotland and the Czech Republic

Jakub Holec

Abstract

In recent years, both in the Czech Republic and abroad, there has been a debate about the renaissance of educational content and its intended form expressed in national curricula. From the curriculum analyses point of view, it is highly interesting to compare similar curricula created in different contexts, on the one hand, and different curricula created in similar contexts on the other hand. On the basis of the context-curriculum analysis, the curricula of England, Scotland and the Czech Republic were selected. The paper seeks to explore biology education in three National Curriculum Frameworks in the field of primary and lower secondary education. The comparative analysis is a tool for a deeper understanding the intended learning objectives as stated in the curricula. It provides an opportunity to compare different types of curricula and analyse biology content organization and the cognitive demands of the respective disciplinary knowledge, at least judging from the curriculum documents. The paper contributes to comparative curriculum research and provides the knowledge needed for the future process of curriculum review in the Czech Republic. I conclude that, while all these curricula emphasize learning outcomes and experiences, there are distinct differences between them in a stronger emphasis on the disciplinary knowledge or developing transversal competencies. It is reflected in both the learning outcomes formulation and the level of their specificity. This paper offers a contribution to the debate about the way in which particular disciplinary content is organized and taught from the perspective of a specific curriculum policy.

Key words: curriculum, curriculum policy, biology, learning objectives.

Srovnávací studie kurikula biologie v pojetí Anglie, Skotska a České republiky

Abstrakt

V posledních letech se v zahraničí i v českém prostředí mluví o obnovení tematiky obsahu vzdělávání, jehož zamýšlenou podobu vyjadřují kurikulární dokumenty. Z hlediska komparace kurikul je zajímavé zkoumat obdobně pojatá kurikula, která vznikla v odlišných socio-kulturních kontextech a naopak odlišně pojatá kurikula, která vznikla v obdobných kontextech. Na základě analýzy „kontext-kurikulum“ byla vybrána kurikula Anglie, Skotska a České republiky. Příspěvek se zaměřuje na komparaci pojetí biologického vzdělávání ve třech národních kurikulárních rámcích pro oblast primárního a nižšího sekundárního vzdělávání. Srovnávací analýza je nástrojem k hlubšímu porozumění tomu, jak se ve srovnávaných kurikulech přistupuje k formulování zamýšlených cílů vzdělávání. To nabízí příležitost ke komparaci různých typů kurikul a analýzám obsahu oborových znalostí biologie a jejich uspořádání v kurikulu. Příspěvek obohacuje současný diskurz srovnávací pedagogiky a přináší znalostí, ze kterých mohou vycházet budoucí revize kurikula biologie v České republice. Docházím k závěru, že všechna analyzovaná kurikula akcentující vzdělávací výstupy a zkušenosti se v zásadních rysech liší ve formulaci vzdělávacích výstupů i úrovni konkrétnosti jejich rozpracování. Text nabízí příležitost k debatám týkající se způsobu, kterým se z pohledu vybraných vzdělávacích politik přistupuje k formulování a strukturaci předmětového obsahu v kurikulu.

Klíčová slova: kurikulum, vzdělávací politika, biologie, vzdělávací cíle.

In the past two decades, a consensus across the European Union countries has emerged that the science curriculum should be focused mainly on developing key competencies. The tendency stems from adopting the Lisbon Agenda, which underlined the crucial importance of the acquisition of competencies for the wellbeing of citizens, social cohesion, economic development and competitiveness (Council of the European Union, 2000). In consequence of the ongoing social and economic changes brought about by progress in science and technology, people are strongly concerned about how the school curriculum responds and prepares learners to meet the needs of, what Drucker (2004) calls the "knowledge society". These economic and social changes require young people to gain a wide range of knowledge, skills, attitudes, and values in order to prosper in the current ever-changing societies. The European Union has defined eight key competencies to be acquired during compulsory schooling, amongst which is competence in science (Council of the European Union, 2018).

However, whilst there is a general agreement that science education is highly important for all educational systems, there has been little research about its structure and contents (Osborne & Dillon, 2008). As a part of studies on curricula, international comparisons become increasingly helpful for curriculum planning. Even countries achieving excellent educational results (e.g. Finland, Estonia, Canada) are systematically studying the results of international comparisons and are constantly trying to find an optimal solution for improving their own curriculum (Schmidt et al., 2001; Oates, 2011). International comparisons provide a tool for recognizing factors that have a significant effect on educational processes and results. Indeed, the statutory national curriculum has a crucial impact on the way in which teachers plan their school-based curriculum (Schmidt & Prawat, 2006).

Nowadays, the national curriculum review takes place in the Czech Republic. The curriculum revision constitutes a cyclic process that starts with an analysis of the current and desired situation, including context analysis, needs analysis and an exploration of the existing knowledge base (van den Akker, 2004). The paper contributes to the analytical phase of curriculum planning as comparative research about the structure and content of curriculum frameworks that can serve as an inspiration for the national curriculum design.

This study is related to the development of macro-level educational policies and curricular documents, not the actual practice in schools and classrooms. The text is focused on analyzing national curricula for science/biology during compulsory education in England, Scotland and the Czech Republic. The aim of the comparative analyses is to answer the following research questions:

1. How the compared curricula adopt global culture of education and policy borrowing?
2. How the compared curricula differ in the biology content organisation and in cognitive difficulty and progression of the statements of learning outcomes and objectives?

National curriculum documents analysed in the study:

- National Curriculum (NC): England (Department for Education, 2013, 2014)
- Curriculum for Excellence (CfE): Scotland (Scottish Executive, 2004)
- Framework Educational Programme (FEP): the Czech Republic (VÚP, 2007)

Theoretical Framework

The actual discussion refers to two theoretical perspectives, which have a significant influence on current comparative educational research – the theory of new institutionalism and the theory of policy borrowing. New institutionalism (Meyer & Rowan, 2006; Meyer, 2010; Ramirez & Meyer, 2002; Wiseman, Astiz & Baker, 2014) postulates that the spread of the global culture of education dominates reform processes in different parts of the world. Some nations, however, imitate the global models quite superficially. The concept of "loose coupling" explains changes and divergence from an original model, which may happen in a particular country during the adoption and implementation of the reform process. Understanding whether and why there have been identifiable global changes resulting in a putative international core curriculum may reveal which strategies and topics countries have recognized as supporting future skills and knowledge (Stecey et al., 2018).

Linked to the rising influence of international large-scale assessments is "policy borrowing", where countries adopt education reforms and policies that have been successfully implemented in other countries, typically high-performing jurisdictions. The theory of policy borrowing posits, in some cases, that educational reforms are borrowed on the principle of "solutions first". In education, the study of policy borrowing has helped to substantiate and legitimise the field of comparative education. However, learning from comparison does not necessarily mean that policies and practices should be transferred from one context to another. International comparison is not a tool for analysing education out of context and against using comparisons to transplant educational reforms from one country to another. The policy borrowing tends to be a one-way process: the Western/ English speaking nations are typical "lending" countries of policy origin, while post-socialistic and post-colonial countries are borrowing policies. The borrowing process in Central/Eastern European countries may face lack of necessary capacity and resources to emulate Western models (Pritchett, Woolcock & Andrews, 2010; Dvořák & Holec, submitted). The process of policy borrowing always includes policy translation, i.e., local adaptation, modification or re-framing (Steiner-Khamsi, 2014).

These two theoretical perspectives provide enable us to study the process of curriculum development in different local contexts. They offer a deeper understanding of how the compared curricula differ in the aims and objectives of particular learning content. The English National Curriculum, the Scottish Curriculum for Excellence (CfE) and the Czech Framework Educational Programme were selected on the basis of context-curriculum analysis. For the comparative analysis, the similar curricula developed in different sociocultural contexts (CfE, FEP) and different curricula developed in similar local contexts were selected. CfE and PEP are based on very similar principles promoting general key competencies, cross-curricular topics and the key role of teachers as agents of change (Priestley & Humes, 2010; Holec & Dvořák, 2017). Both of them represent a shift from a centrally prescribed curriculum oriented on knowledge transmission to a more progressive curriculum based on principles of constructivism (Walterova, 1994; Hutchinson & Hayward, 2005). Typically, this type of curriculum is predicated around a view of what an autonomous adult should be and a learning process (often dialogical, inquiry-based and experiential) that may serve as the route to achieving these learning objectives.

English NC represents a different model of curriculum. It is acknowledged as a mainly knowledge-oriented curriculum embodying rigor and high standards in the key disciplines and focus on the aims of comprehensive knowledge or skill in a particular subject or activity (Priestley & Humes, 2010; DfE, 2013). In NC, key competencies are not mentioned explicitly. Comprehensive skills and competencies are part of particular learning content (see Tab. 1).

Tab. 1: A comparison of general key competencies in three curriculum frameworks for primary and lower secondary education

National Curriculum (2013, 2014) England	*Curriculum for Excellence (2004) Scotland*	*Framework Education Programme (2007) Czech Republic*
Competencies are not mentioned explicitly. (key skills as part of disciplinary learning content).	Successful learners	Learning Competency
	Confident individuals	Problem-Solving Competency
		Communication Competency
	Responsible citizens	Social and Personal Competency
		Civic Competency
	Effective contributors	Professional Competency

The curriculum consists of a set of content items, most common knowledge, skills and attitudes that should be gain by all pupils in all schools. These items are organized into particular disciplines and further into thematic areas. Disciplinary curriculum position knowledge is organised either horizontally or vertically. Horizontal organisation means the particular learning content splits into a list of thematic areas. On the other hand, the vertical organisation shows the sequencing of particular learning content in different stages of education (Goodlad & Su, 1992).

All the compared curricula use the educational aims set for particular disciplines and educational levels (stages) in terms of learning outcomes. Firstly, learning outcomes in biology can be organised into thematic areas consistent with biology organism classification. This systematic approach uses the Linnaeus system for classifying organisms into plants, animals, minerals, etc. In my opinion, the approach represents a traditional academic view on structuring the biology curriculum. On the other hand, there is an attempt to connect science education to everyday life experience. This approach leads to more practically oriented concepts, such as "Towards a sustainable future" and "What is life?" Science education based on developing these science concepts is focused on the centrality of pupils in the learning process (Škoda & Doulík, 2009). Nowadays, science curricula are structured into key scientific concepts emphasizing the nature of science and its relevance for pupils. It is highly interesting to compare a mainly competence-based curriculum and a mainly subject-based curriculum.

The curricula for the content analyses were not selected in relation to achieved curriculum and educational results. In my study, I am interested in formal curriculum documents that play a limited role in teaching and learning. Despite this fact, I provide a short insight into science education results according to PISA 2015 international survey of scientific literacy for the selected countries. The mean score of English pupils in scientific literacy performance is higher in comparison to Scottish and Czech pupils. Pupils in England scored 512 points – above the OECD average, whilst pupils in Scotland scored 497 points and Czech pupils scored 493 points – both around the OECD average (Blažek & Příhodová, 2016) Mean performance in science has not changed since 2006 for students in England, while it has declined both in Scotland and the Czech Republic remarkably (OECD, 2016).

Methodology

In conducting the analysis, I employed a case study approach, using document content and comparative analysis to examine curriculum policy texts. The purpose of looking to national curriculum frameworks of England, Scotland and the Czech Republic was not specifically to compare the context of these three curricula, but rather to enable a deeper understanding of the way in which they position a biology curriculum. The document analysis approach dealt with actual written texts (Bowen, 2009). The study is aiming at finding out how the biology curriculum of each country differs in a specific disciplinary structure and the nature of knowledge presented by particular learning outcomes. For the text analysis, it is used a qualitative research design.

Firstly, a list of the thematic areas covering biology education in all curricula was selected. Secondly, categories for the analysis were defined beforehand. For this purpose, it is employed a category system defined in the PISA 2015 Assessment and Analytical Framework for Science (OECD, 2016) and the TIMSS 2015 Science Framework (Mullis & Martin, 2014). The frameworks provide us with life science concepts covering both PISA and TIMSS international assessments in the field of science and scientific literacy. From the PISA and TIMSS frameworks, two life science (biology) topics were analysed in each curriculum: food chains, cell and its organisation. For analysing the corresponding learning content of each curriculum, these two PISA and TIMSS assessment topics were used. For this purpose, the analysis is focused on how the particular statement of learning outcomes differs in cognitive demands. For this purpose Bloom's taxonomy of the cognitive domain (Anderson & Krathwohl, 2001) was used. Apart from this analysis, the specific learning outcomes progression in each curriculum was examined with the aim of uncovering how the learning objectives are revisited at a higher-order cognitive level (Bruner, 1960).

The Curriculum Content Analyses

Before the comparison, I first provide a brief overview of the key features and undertake a content analysis of each curriculum. The content analysis is focused on the science curriculum and the position of biology knowledge and scientific skills in the curriculum documents. The text studies how the science content is organised within each curriculum with a focus on biology instruction.

Tab. 2: An example of "working scientifically" topics in the National curriculum (Department of Education 2013, 2014)

Key stage	KS1 (age 5–7)	KS2 (age 7–11)	KS3 (age 11–14)	KS4 (age 14–16)
Learning areas	Science	Science	Biology	Biology
Scientific skills	Working scientifically (Practical scientific methods, processes and skills through the teaching)		Working scientifically (Scientific attitudes, Experimental skills and investigations, Analysis and evaluation, Measurement)	Working scientifically (The development of scientific thinking, Experimental skills and strategies, Analysis and evaluation, Vocabulary, units, symbols and nomenclature)
Thematic areas	Plants (Y1, Y2)	Plants (Y3)	Cells and organisation	Cell biology
	Animals, including humans (Y1, Y2)	Animals, including humans (Y3, Y4, Y5, Y6)	The skeletal and muscular systems	
	Seasonal changes (Y1)		Nutrition and digestion	Transport systems
	Living things and their habitats (Y2)	Living things and their habitats (Y4, Y5, Y6)	Gas exchange systems	Coordination and control
		Earth and space (Y5)	Reproduction	
		Evolution and inheritance (Y6)	Health	Health, disease and the development of medicines
			Photosynthesis	Photosynthesis
			Cellular respiration	
			Relationships in an ecosystem	Ecosystems
			Genetics and evolution	Evolution, inheritance and variation

The National Curriculum Case

In England, primary and secondary education is compulsory between the age of 5 and 16. In 1988, the Education Reform Act introduced in England the compulsory National Curriculum. The majority of the current national curriculum was introduced in September 2014. The curriculum sets out the programmes of study and attainment targets for all subjects at all four key stages. In addition to identifying the main directions of educational processes, including science education, the National Curriculum contains a detailed specification of skills, which students should obtain at specific educational stages. The compulsory state education system in England consists of three stages/levels – Key Stage 1 (KS1), Key Stage 2 (KS2), Key Stage 3 (KS3), Key Stage 4 (KS4). Biology content is a part of Science education during KS1 and KS2, while there is a separate Biology subject from KS3 and KS4 (Department for Education, 2013; Department for Education, 2014).

The national curriculum for science aims to ensure that all pupils develop scientific knowledge and conceptual understanding through the specific scientific disciplines. The curriculum focuses on content knowledge of traditional science disciplines. The learning objectives emphasize the position of traditional subject disciplines with the aim of developing a secure understanding and skills within the disciplinary key concepts. By the end of each key stage, pupils are expected to know, apply and understand the knowledge, skills and processes specified in the relevant programme of study (Department for Education, 2014).

The structure of the curriculum for biology represents a combination of traditional content classification into systematic categories (plants, animals including human, rocks, etc.), along with a classification using crucial biology concepts (cells, genetics and evolution, photosynthesis, etc.). Except for the disciplinary content, the curriculum also emphasizes scientific skills that should be developed across the science disciplines. Tab. 2 shows a list of biology topics in the curriculum through four key stages.

The disciplinary objectives include content knowledge together with procedural knowledge and skills. The learning outcomes set the specific knowledge and skills that pupils should gain further learning progress in the next programme of study. While the primary education highlights basic cognitive educational aims, the lower secondary education underlines the position of knowledge application in order to solve scientific problems (see Tab. 3).

Tab. 3: A vertical structure of learning content representing the National Curriculum (England). The concept of "food chains" was used for the illustration of topic progression (Department of Education 2013, 2014)

Pupils should be taught about:		
Key Stage 1 (age 5–7)	Key Stage 2 (age 7–11)	Key Stage 3 (age 11–14)
Describe how animals obtain their food from plants and other animals, using the idea of a simple food chain, and identify and name different sources of food.	Construct and interpret a variety of food chains, identifying producers, predators and prey.	The interdependence of organisms in an ecosystem, including food webs and insect pollinated crops.

Working scientifically specifies the understanding of the nature, processes and methods of science for each year group. It should not be taught as a separate strand. These types of scientific enquiry should include: observing over time; pattern seeking; identifying, classifying and grouping; comparative testing; and researching using secondary sources. Pupils should seek answers to questions through collecting, analysing and presenting data. Table 4 shows learning objectives related to scientific skills and its subcategories. Apart from "working scientifically", the table also contains learning outcomes for specific disciplinary content: "cells".

Tab. 4: Learning objectives for developing scientific skills and procedural knowledge by 11–14 years pupils (Department of Education 2013, 2014)

Working scientifically	*Through the content across all three disciplines, pupils should be taught to:*
Scientific attitudes	• pay attention to objectivity and concern for accuracy, precision, repeatability and reproducibility • understand that scientific methods and theories develop as earlier explanations are modified to take account of new evidence and ideas, together with the importance of publishing results and peer review • evaluate risks
Experimental skills and investigations	• ask questions and develop a line of enquiry based on observations of the real world, alongside prior knowledge and experience • make predictions using scientific knowledge and understanding • select, plan and carry out the most appropriate types of scientific enquiries to test predictions, including identifying independent, dependent and control variables, where appropriate • use appropriate techniques, apparatus, and materials during fieldwork and laboratory work, paying attention to health and safety • make and record observations and measurements using a range of methods for different investigations; and evaluate the reliability of methods and suggest possible improvements • apply sampling techniques.
Analysis and evaluation	• apply mathematical concepts and calculate results • present observations and data using appropriate methods, including tables and graphs • interpret observations and data, including identifying patterns and using observations, measurements and data to draw conclusions • present reasoned explanations, including explaining data in relation to predictions and hypotheses • evaluate data, showing awareness of potential sources of random and systematic error • identify further questions arising from their results.
Measurement	• understand and use SI units and IUPAC (International Union of Pure and Applied Chemistry) chemical nomenclature • use and derive simple equations and carry out appropriate calculations • undertake basic data analysis including simple statistical techniques.
Disciplinary content – Biology	*Pupils should be taught about:*
Cells and organisation	• cells as the fundamental unit of living organisms, including how to observe, interpret and record cell structure using a light microscope • the functions of the cell wall, cell membrane, cytoplasm, nucleus, vacuole, mitochondria and chloroplasts • the similarities and differences between plant and animal cells • the role of diffusion in the movement of materials in and between cells • the structural adaptations of some unicellular organisms • the hierarchical organisation of multicellular organisms: from cells to tissues to organs to systems to organisms.

The Curriculum for Excellence Case

Curriculum for Excellence is the Scottish national curriculum for learners from the ages 3–15. The Framework containing aims and principles of the ongoing curriculum reform was published in 2004. The learning outcomes and experiences for specific learning areas including Science were released in 2009 (Scottish Executive, 2007; Holec & Dvořák, 2017). The curriculum is a basis for school-based curriculum development (Priestley & Minty, 2012). During all stages of Scottish compulsory education, the biology curriculum is a part of the Science learning area.

The purpose of the curriculum is to help children and young people to become successful learners, confident individuals, responsible citizens and effective contributors (the four capacities). The framework, therefore, puts the learner at the centre of the curriculum. The curriculum areas are the organisers for setting out the experiences and outcomes. In drawing up the experiences and outcomes, learning in each curriculum area emphasizes the contributions it can make to developing the four capacities. Priestley (2010) argues that the shift to learning outcomes represents a move from subject-specific to generic curriculum criteria. The experiences and outcomes have been structured using the following categories: expressive arts; health and wellbeing; languages; mathematics; religious and moral education; science; social studies; and technologies (Scottish Government, 2008). The experiences and outcomes under each learning area are written at four levels for compulsory education. The science key concepts have been structured using five categories: Planet Earth; Forces, electricity and waves; Biological systems; Materials; and Topical science. The thematic categories remains the same for all educational levels. The science curriculum specifies that scientific skills should be developed by the pupils and disciplinary content is expressed as the experiences and outcomes (see Tab. 5).

Tab. 5: List of key science topics in Curriculum for Excellence focusing on scientific skills and biology learning content (Scottish Executive, 2004)

Level	Early (age 3–5)	First (age 5–8)	Second (age 8–11)	Third, Fourth (age 11–14)
Learning area	Science			
Scientific skills	Inquiry and investigative skills Scientific analytical thinking skills			
Thematic areas	Biodiversity and interdependence			
	Body systems and cells			
	Inheritance			

CfE formulates learning expectation outcomes in terms of experiences, as well as broad significant outcomes, all of that are designed to reflect the four capacities (Scottish Executive, 2006b). These learning statements put emphasis on practical knowledge and its application. Experiences and outcomes are designed from the learner's point of view, using terms like 'I have. . . ' for experiences and 'I can. . . ' for outcomes' (Scottish Executive, 2006a). The use of the first person in these statements is intended to give centre-stage to the learner and emphasize the importance of personal engagement (Pristley & Humes, 2010). Biesta (2009) refers to this trend as the "learnification" of education. According to Biesta, this tendency reflects an unproblematised acceptance that learning is good and a failure to address educational questions, such as 'what are we learning?' and 'why are we learning it?'.

Tab. 6: A vertical structure of learning content represented in the Curriculum for Excellence (Scotland). The concept of "food chains" was used for the illustration of the topic progression (Scottish Executive, 2004)

P2–4 (First level), age 5–8	P5–7 (Second level), age 8–11	S1–S3 (Third and Fourth level), age 11–14
I can explore examples of food chains and show an appreciation of how animals and plants depend on each other for food.	I can use my knowledge of the interactions and energy flow between plants and animals in ecosystems, food chains and webs. I have contributed to the design or conservation of a wildlife area.	–

Tab. 7: Learning objectives for developing scientific knowledge and procedural knowledge by 11–14 years pupils (Scottish Executive, 2004)

Scientific skills	
Inquiry and investigative skills	*Through experimenting and carrying out practical scientific investigations and other research to solve problems and challenges, children and young people:* • ask questions or hypothesise • plan and design procedures and experiments • select appropriate samples, equipment and other resources • carry out experiments • use practical analytical techniques • observe, collect, measure and record evidence, taking account of safety and controlling risk and hazards • present, analyse and interpret data to draw conclusions • review and evaluate results to identify limitations and improvements • present and report on findings
Scientific analytical thinking skills	*Children and young people develop a range of analytical thinking skills in order to make sense of scientific evidence and concepts. This involves them:* • being open to new ideas and linking and applying learning • thinking creatively and critically • developing skills of reasoning to provide explanations and evaluations supported by evidence or justifications • making predictions, generalisations and deductions • drawing conclusions based on reliable scientific evidence
Disciplinary content – Biology	
Body systems and cells	• I can explain how biological actions which take place in response to external and internal changes work to maintain stable body conditions. • Through investigation, I can explain how changes in learned behaviour due to internal and external stimuli are of benefit to the survival of species. • By researching cell division, I can explain its role in growth and repair and can discuss how some cells can be used therapeutically. • I have taken part in practical activities its impact on the curriculumvolve the use of enzymes and microorganisms to develop my understanding of their properties and their use in industries. • I can debate the moral and ethical issues associated with some controversial biological procedures.

The Framework Educational Programme Case

Compulsory education in the Czech Republic covers students aged 6 to 15. The basis for teaching in the Czech education system is the Framework Education Programme for Elementary Education. The Framework was introduced in 2004. Based on the Framework, schools prepared their own School-Based Curriculum Document from 2005 (Tupý, 2014). In primary education (Grade 1–Grade 5), biology is integrated in the subject "Man and his World" (thematic area "Diversity of Nature"). From 6th to 9th grade, biology is delivered as a subject: Natural Sciences.

The science curriculum includes four educational fields: Physics, Chemistry, Natural Sciences and Geography. The biology thematic areas covered in the FEP are presented in Tab. 8.

Tab. 8: The basic structure of biology instruction divided into Learning areas and thematic fields in the FEP (the Czech Republic) (VÚP, 2007)

Grade	1–3 (age 6–9)	3–5 (age 9–11)	6–9 (age 11–15)
Learning areas	Man and His World	Man and His World	Man and Nature
Thematic areas	Diversity of Nature	Diversity of Nature	General Biology and Genetics
			Fungal Biology
			Plant Biology
			Animal Biology
			Human Biology
			Inanimate Nature
			Essentials of Ecology
			Empirical Exploration of Nature

The learning objectives are recorded by means of learning outcomes. The learning outcomes define general requirements on science instruction and learning content that each pupil should be taught. Science content is recorded by means of operational verbs.

Tab. 9: The learning outcomes defined for the topic of "food chains" across educational stages covering primary and lower secondary education in the Czech Republic (VÚP, 2007)

Grade 1–3 (age 6–9)	Grade 3–5 (age 9–11)	Grade 6–9 (age 11–15)
–	*The pupil:* Study basic communities in selected localities of regions, explain principal mutual relations between organisms, and identify shared and different features in the adaptation of organisms to the environment	*The pupil:* Give examples of the occurrence of organisms in a specific environment and the relations between them. Explain the nature of simple food chains in various ecosystems and evaluate their importance.

Tab. 10: Learning objectives for developing particular biology knowledge (the topic of cell and its structure) and procedural knowledge by 11–14 years pupils (the Czech Republic) (VÚP, 2007)

Disciplinary content – Biology	*The pupil:*
General Biology and Genetics	• recognises the basic manifestations of life and its conditions and becomes familiar with the outline of the evolution of organisms • describes the basic differences between plant, animal and bacterial cells and explains the functions of basic organelles • recognises, compares and explains the functions of basic plant and animal organs (organ systems) • classifies organisms and places selected organisms into kingdoms and lower taxonomic units • explains the basic principles of sexual and asexual reproduction and their importance in terms of heredity • provides examples of heredity from everyday life, as well as examples of environmental influence on the formation of organisms • explains the significance of viruses and bacteria in nature and for Man on examples from everyday life
Empirical exploration of nature	• applies empirical methods of exploring nature • observes the basic safety rules of work and conduct when becoming acquainted with animate and inanimate nature

Findings

Question 1: Regarding the two theory perspectives (new institutionalism and policy borrowing) it is interesting analyse either different national curricula developed in similar contexts or similar national curricula developed in different contexts. During designing curriculum in the Czech Republic, inspiration was sought in foreign curriculum documents, specifically in Scotland, England, Norway, Denmark, Sweden, Hungary, etc. (Tupý, 2014). It is obvious that Scottish CfE and Czech FEP stem from similar ideology and mechanisms for reforming curriculum in schools. Both curricula aim to move away from the centrally prescribed, disciplinary-isolated, and knowledge overloaded curriculum to a model based on constructivist pedagogy, relying on the professionalism of teachers and "soft" key competencies/capacities as a crucial goal of education (Holec & Dvořák, 2017).

Most importantly, the quality of implementation was very different in the compared countries. While the Scottish curriculum is accepted by many teachers the Czech reform is perceived as unsuccessful in school implementation and the readiness of many teachers for the transition from the centrally prescribed, disciplinary-oriented curriculum to curriculum emphasizing key competencies and relying on teachers as agents of curriculum change (Dvořák, Holec & Dvořáková, 2018). These problems are often explained by the low support provided to schools and teachers during the implementation phase of the reform and/or by the attitudes of conservative teachers (Straková, 2013; Dvořák & Holec, v recenzním řízení).

The impact of globalization the science curriculum and its impact on the curriculum is an interesting topic for research but it depends on acquiring comparable data on school curricula from sufficient numbers of countries (Stacey et al. 2018). The globalisation of local educational policies can be partly explained by transnational influence particularly results of TIMSS and PISA studies (Dvořák & Holec, v recenzním řízení). The result of the TIMSS and PISA studies are being a key factor affecting the educational policies significantly as the countries attempt to improve their performance in international point of view Both Scottish and Czech educational policies reacted to decreasing results in PISA by more detailed description of learning outcomes and their standardization. In England, there is a rising interest in defining core knowledge and skills to be delivered in particular academic disciplines (Young, 2007). It is highly important the current National Curriculum in England took place approximately 10 years after the curriculum reforms in Scotland and the Czech Republic. National Curriculum represents a different model to curriculum making focused on developing key knowledge and skills in learning content without defining key skill apart from the disciplines. A further study of the National Curriculum may bring an impulse for innovating the Czech curriculum in reflecting both knowledge and competencies in the revised learning content.

Question 2: As expected, there were significant differences among the analysed curricula, both in organisational approach and thematic areas. First of all, the biology content differs significantly by the way of how biology topics are organised in each curriculum.

CfE defines broad thematic areas of biology instruction – biodiversity and interdependence; body systems and cells; inheritance. These concepts are developed across all levels of Scottish compulsory education. In contrast, NC defines specific thematic areas emphasizing an academic approach to learning science. The thematic areas differ in each level of compulsory education in England. During the early years, there are broad topics relevant mostly to a systematic approach to content organisation in curricula (e.g. animals, including humans; plants, rocks). In lower secondary education, biology topics focus on developing academic disciplinary knowledge. The biology education leads to developing concepts of photosynthesis; cellular respiration; nutrition and digestion etc. Similarly to CfE, Czech FEP prescribes a broad thematic area "diversity of nature" at primary education. In contrast, during lower secondary education, the Czech curriculum employs thematic categories that reflect the systematic approach to classifying organisms (e.g. plant biology, fungal biology, animal biology, human biology). This content organisation is similar to the NC approach in terms of developing academic knowledge.

I compared expected learning outcomes focusing on the topics of food chains and cell and its organisation. In the analysis, I focused on how the statements of outcomes and objectives differ in their cognitive demands. Moreover, I wanted to find out whether these outcomes represent academic disciplinary knowledge or practical everyday knowledge.

Firstly, I analysed the learning objectives intended for primary education. The following examples show the learning outcomes for the topic "food chains". According to Bloom's revisited taxonomy (Bloom & Krathwohl, 2001), the outcomes are intended to develop both understanding the content knowledge and its application:

> *Pupils should be taught to:* construct and interpret a variety of food chains, identifying producers, predators and prey. (NC, Key stage 2 Science)

> *Learning in the sciences will enable me to:* I can use my knowledge of the interactions and energy flow between plants and animals in ecosystems, food chains and webs. I have contributed to the design or conservation of a wildlife area. (CfE, second level Science)
>
> *The pupil:* studies basic communities in selected localities of regions, explains principal mutual relations between organisms, and identifies shared and different features in the adaptation of organisms to the environment. (FEP, Grade 3–5, Man and his world – Diversity of nature)

Secondly, the analysis was focused on statements of objectives referring to lower secondary education. The outcomes cited below focus on developing content knowledge in the topic of cell and its organisation. According to Bloom's taxonomy of cognitive education goals, the outcomes cited below tended to signal emphasis on the most advanced cognitive skills and metacognitive knowledge in the case of NC and CfE. In contrast, the FEP statement of learning objectives focuses on prescriptive knowledge and basic cognitive skills including remembering and understanding content knowledge.

> *Pupils should be taught about:* cells as the fundamental unit of living organisms, including how to observe, interpret and record cell structure using a light microscope. (NC, Key stage 3 Science)
>
> *Learning in the sciences will enable me to:* by researching cell division, I can explain its role in growth and repair and can discuss how some cells can be used therapeutically. (CfE, third and fourth level Science)
>
> *The pupil:* describes the basic differences between plant, animal and bacterial cells and explains the functions of basic organelles. (FEP, Grade 6–9, Man and Nature – Natural Sciences)

I can, therefore, conclude here that, at the level of curricular statements of outcomes, the intention is that disciplinary knowledge is gifted a high degree of importance, both in terms of content knowledge and procedural knowledge. It is obvious from the examples of cited learning outcomes that the idea of key competencies is imprinted in all analysed curricula. In the CfE and FEP, key competencies are stated as the main principles underpinning the education in Scotland and the Czech Republic. On the other hand, English NC emphasis disciplinary key knowledge and skills as an integrated part of its learning outcomes. It does not separate key competencies from the learning content.

Focusing on statements of curricular intent at least, there is a discrepancy between primary and lower secondary education in the Czech curriculum. The statements of outcomes for lower secondary education are highly descriptive focusing on basic cognitive skills, whereas the primary education outcomes emphasize procedural knowledge leading to expected disciplinary outcomes.

Conclusions

The analyses suggest that, in some respects, there are global trends shaping curriculum reforms in the compared countries. The quality of implementation differs significantly in dependence on the capacity of the entire education system to do so. Scotland is a typical lending country of policy origin while the Czech Republic as a country of policy borrowing. English National Curriculum represents an educational policy emphasizing traditional academic disciplines embedded in disciplinary knowledge. Further research may bring an understanding of how this curriculum model can impact global educational policy.

The comparative analyses showed that at least judging from three curriculum documents included in the analysis, pupils develop both disciplinary knowledge and procedural knowledge during their science/biology study. Disciplinary knowledge continues to be a key purpose within the analysed curricula and statements of intended outcomes as disciplinary objectives are arguably one of the most important purposes. All compared curricula differ significantly in the disciplinary content organisation, statement of intended outcomes of learning and the coherence of particular topics.

In compared countries, biology learning content in educational policy intentions is organised into thematic areas at different levels of organisation. Scottish Curriculum for Excellence classifies the science content on significant concepts of learning with a special emphasis on curriculum coherence. For this purpose, the thematic areas remain the same across all educational levels. In Curriculum for Excellence, the disciplinary knowledge uses basic cognitive aims at first and later employs more advanced types of knowledge. There is an explicit intention that disciplinary content should not be heavily prescribed, but should be flexible to decisions made by the teachers.

In spite of similarities between Czech and Scottish curricula from the point of view of the curriculum reform and competence-oriented curriculum, there are distinctive differences in learning statements organisation and their content between Curriculum for Excellence and Czech Framework Educational Programme. In the Framework Educational Programme, the biology learning content is structured into traditional systematic domains related to biological taxonomy in lower secondary education. The statements of intended learning outcomes are strongly prescriptive in content-based mainly on the own educational objectives rather than the process of learning and knowledge as an instrument to achieve the objectives. Contrary, the learning objectives in Framework Educational Programme primary education prioritise the process of learning and disciplinary knowledge as an instrument to achieve competence-based outcomes. I argue for the distinctive inconsistency in the biology learning objectives between primary and lower secondary curriculum. While the primary education outcomes for Science (Diversity of Nature) are dominantly focused on making science, the lower secondary outcomes for Biology (Natural Science) are based predominantly on delivering descriptive knowledge. Judging from the learning objectives, pupils are learned to recall and understand biology facts and phenomena rather than to use their knowledge in purpose to solve scientific and biology problems.

Focusing on the English National Curriculum, the biology disciplinary content relates both to the traditional systematic approach (noticeably during Key Stage 1 and Key Stage 2) and later predominantly on key biology concepts. The disciplinary objectives ensure that children are taught the essential knowledge in particular subject disciplines. National Curriculum represents a traditional subject-oriented curriculum centred on academic achievements. Compared to the Czech Framework Educational Programme, the outcomes are more specific, both in content knowledge and procedural knowledge and skills.

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Jakub Holec, holec.jakub@gmail.com
National Institute for Education
Weilova 1271/6, 102 00 Prague 10, Czech Republic

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Vývoj matematického vzdělávání na druhém stupni základních škol v České republice po roce 1989

Jarmila Robová, Vlasta Moravcová

Abstrakt

Příspěvek se na základě kvalitativní analýzy především kurikulárních dokumentů, učebnic a studia odborné literatury zabývá příčinami a následky změn ve výuce matematiky na druhém stupni základní školy v uplynulých letech. Nejprve jsou představeny základní dokumenty ovlivňující vzdělávání u nás před rokem 1989. Jádro článku je tvořeno třemi kapitolami, ve kterých jsou rozebírány proměny kurikula matematiky, učebnic a další podstatné aspekty související s vyučováním matematice v posledních třech desetiletích. Na přelomu 80. a 90. let minulého století u nás došlo k odklonu od množinového pojetí matematiky a s tím souvisejícímu vydávání nových učebnic. Pro 90. léta byl charakteristický pokles hodinové dotace výuky matematiky, změny v pojetí učiva (odklon od exaktních definic, snížení důrazu na používání symbolických zápisů aj.). Ve vyučovacích metodách lze ve sledovaném období pozorovat rostoucí příklon ke konstruktivismu a masivní nástup digitálních technologií. Po roce 2000 výuku matematiky na základních školách významně ovlivnilo zavedení rámcových, resp. školních vzdělávacích programů a jednotných přijímacích zkoušek na střední školy. Závěrečné zamyšlení nad současným stavem upozorňuje na rostoucí nároky na práci učitele matematiky.

Klíčová slova: matematické vzdělávání, přijímací zkouška na střední školy, kurikulum, učebnice, ICT, ISCED 2.

Development of Education in Mathematics at Lower Secondary Schools in the Czech Republic after 1989

Abstract

Based upon a qualitative analysis of curricular documents, textbooks and studies of the specialist literature, this article examines the causes and effects of the changes in teaching mathematics at lower secondary school over the past few decades. First, the paper introduces the basic documents influencing education before the year 1989. The core of the article is composed of three chapters in which the transformation of the mathematics curriculum, textbooks and other essential aspects related to mathematics teaching in the last three decades are analysed. At the end of the 1980s and the beginning of the 1990s, mathematics teaching moved away from a set-based concept, prompting the publication of new textbooks. The 1990s were characterised by a decline in the number of maths lessons and also by changes in the concept of the taught content (a move away from exact definitions, reduced emphasis on the use of symbolic notation, etc.). During this period the teaching methods show a growing tendency towards constructivism and the introduction of digital technology on a mass scale. After the year 2000, mathematics at lower secondary schools was profoundly affected by school reforms, especially the introduction of new frameworks, particularly school educational programmes, and the introduction of standardized state entrance exams at upper secondary schools. The final reflection on the current situation draws attention to the growing demands on the work of maths teachers.

Key words: mathematics education, state entrance exam, curriculum, textbooks, ICT, ISCED 2.

Od druhé poloviny dvacátého století dochází k častým změnám ve způsobu života společnosti u nás i v zahraničí, což se přirozeně odráží také v nových požadavcích na školu a systém školního vzdělávání. Školství je vystavováno kritice, že dostatečně pružně nereaguje na změny ve společnosti, jsou na něj kladeny protichůdné ekonomické a sociální požadavky (Kotásek, 1993; Keller & Tvrdý, 2008). Tato kritika postupně přerůstá v požadavek přeměny školy v instituci, v níž jsou žáci připravováni na život v permanentní změně a jsou vedeni k tomu, aby se s těmito změnami dokázali vyrovnat (CEDEFOP, 2009). Teoretickým východiskem koncepce vzdělání se stává idea celoživotního vzdělávání, dochází ke změně paradigmatu učení, ve kterém jde především o menší zaměřenost na obsah a větší důraz na operacionalizaci procedur a výstupy učení (Skalková, 2004; Walterová et al., 2004; CEDEFOP, 2009). Přístup společnosti ke vzdělávání ovlivňují v tomto období různé didaktické modely, které lze rozčlenit do několika základních skupin, a to na didaktické koncepce založené na teoriích vzdělávání, na kurikulárních teoriích, dále na teoriích vyučování a učení, na teoriích komunikace a interakce či přístupy vycházející z konstruktivismu; jejich přehled podávají Janík a Stuchlíková (2010).

Změny ve společnosti mají ve svých důsledcích také vliv na formulaci požadavků, které jsou kladeny na vzdělávací proces. Stručně lze říci, že z pohledu odborníků se v oblasti vzdělávání projevují následující změny a tendence:

- transformace paradigmatu učení,
- požadavek na celoživotní vzdělávání,
- proměny kurikula,
- využívání moderních technologií,
- požadavek rovného přístupu ke vzdělání,
- decentralizace školství.

Uvedené změny se postupně projevují ve vzdělávání žáků na českých školách, a tedy i ve výuce matematiky na jednotlivých stupních školského systému. Úpravy matematického vzdělávání na prvním stupni základních škol ovlivňují výuku na druhém stupni, obdobně změny na druhém stupni nalézají svůj odraz na středních školách. Vzhledem k rozsáhlosti transformace českého školství v uplynulých třiceti letech se však v tomto článku zaměříme především na výuku matematiky na druhém stupni základních škol a v odpovídajících ročnících víceletých gymnázií.

Pro hlubší pochopení změn realizovaných ve výuce matematiky na druhém stupni základních škol se v následujícím textu opíráme zejména o kvalitativní analýzu kurikulárních dokumentů, učebnic matematiky, rozbor zpráv MŠMT i didaktických testů z matematiky. Rovněž vycházíme ze studia odborné literatury, z dlouholetých zkušeností s přípravou budoucích učitelů matematiky a vlastního pozorování změn ve školách z pozice učitele matematiky.

1 Dokumenty ovlivňující matematické vzdělávání u nás

Matematické vzdělávání na našich školách je ovlivňováno nejen uznávanými teoriemi vzdělávání, vyučování a učení, ale také státními i pedagogickými dokumenty a materiály. Jedná se jak o školské zákony, vzdělávací programy, resp. učební plány a osnovy, tak i o učebnice, které učitelé využívají při přípravě na hodinu či během vyučování. Uvedeným typům dokumentů se budeme podrobněji věnovat dále v rámci jednotlivých období.

Na vyučování matematiky u nás má rovněž vliv mezinárodní vzdělávací politika, která je v posledních třiceti letech koncipována v rámci Evropské unie či OECD (*Organisation for Economic Co-Operation and Development*). Evropská komise, která jako výkonný orgán vydává legislativní opatření a řídí politiku Evropské unie, se rovněž zabývá otázkami vzdělávání a zaměřuje se na celoživotní učení a mobilitu, kvalitu a efektivitu vzdělávání, rovnost příležitostí a inovace (EC, 1995).

Z analýzy školských zákonů a závazných dokumentů lze identifikovat následující časová období, ve kterých docházelo k podstatným změnám v koncepci, obsahu či metodách školské matematiky (nejen) na druhém stupni vzdělávání: devadesátá léta 20. století, první dekáda 21. století, druhá dekáda 21. století. Pro pochopení příčin těchto jevů ve vzdělávání matematice v posledních třiceti letech uvádíme také přehled hlavních změn před rokem 1989, zejména pak v osmdesátých letech 20. století.

2 Charakteristické rysy vzdělávání matematice před rokem 1989

V první polovině 20. století převládal u nás i ve světě ve výuce matematiky tzv. *historický přístup*, ve kterém obsah školské matematiky vycházel z historického vývoje matematiky a reflektoval vývoj této vědy především do 17. století. Výrazný rozmach matematiky ve 20. století však přinesl rozvoj teorie množin, algebry, topologie a dalších oborů, nejnovější poznatky publikovali ve svých dílech zejména *bourbakisté*[1]. Postupně se mezi matematiky, včetně bourbakistů, i mezi učiteli matematiky a psychology objevovaly názory, že je třeba pozměnit tradiční výuku matematiky ve školách, a to směrem k zavedení matematických struktur a teorie množin do učiva.

U nás se potřeba *modernizace školské matematiky* projevovala od šedesátých let, v čele snah o zlepšení výuky v duchu modernizace stála Jednota českých matema-

[1]Bourbakisté – skupina (především) francouzských matematiků, kteří od roku 1935 publikují pod pseudonymem Nicola Bourbaki. Jejich publikace ve sledovaném období vycházely ze strukturální koncepce matematiky, důraz byl kladen zejména na logiku a teorii množin.

tiků a fyziků (JČMF)[2]. Po roce 1970 byly nejprve zaváděny změny ve výuce na gymnáziích, později na základních školách a po roce 1980 od 1. ročníku základní školy až k maturitním ročníkům (Mikulčák, 2010). Důraz byl kladen na množinové pojetí matematiky a na její axiomatizaci, s pojmem množina se žáci seznamovali již na úrovni prvního stupně základní školy. Pro konec osmdesátých let je u nás charakteristický odklon od modernizačních tendencí, a tedy i od množinového pojetí školské matematiky.

Nadále převládalo důsledně centralizované řízení školství, které bylo nastoleno od poloviny 20. století, kdy se naše země dostala do oblasti sovětského vlivu; oficiální ideologií ovlivňující i oblast školství byl marxismus-leninismus (EC, 2008/09). Vzdělávání na základních školách v osmdesátých letech ovlivnil především reformní projekt *Další rozvoj československé výchovně vzdělávací soustavy* přijatý v roce 1976. Na jeho základě byla v roce 1978 školským zákonem 63/1978 Sb. prodloužena povinná školní docházka z dosavadních 9 na 10 let, přičemž základní škola měla nově jen osm ročníků[3] a žáci další dva roky museli studovat na některém typu střední školy. Podle tohoto projektu byla školská soustava důsledně budována jako jednotný celek od předškolní výchovy až po zařízení pro výchovu a vzdělávání dospělých, k důležitým cílům projektu patřilo postupné zavádění středního vzdělávání a úplného středního vzdělávání.

Na projekt *Dalšího rozvoje československé výchovně vzdělávací soustavy* reagoval v roce 1984 školský zákon 29/1984 Sb. o soustavě základních a středních škol. Tento zákon zrušil devítiletou základní školu, ve vzdělávací soustavě zůstaly jen osmileté základní školy. Poslední předrevoluční osnovy matematiky pro druhý stupeň základních škol byly schváleny v roce 1986 (MŠ, 1987), celková časová dotace matematiky od 5. do 8. ročníku byla 20 hodin a bylo zde zdůrazněno klíčové postavení předmětu mezi ostatními. Uvedené osnovy ve svých výchovně-vzdělávacích cílech odrážely tehdejší společensko-politické zřízení, měly faktografický charakter, učivo i požadované dovednosti byly rozčleněny podle ročníků a témat. Projevil se zde doznívající vliv modernizačního hnutí.[4] V doporučených metodách práce byly uvedeny vyučovací postupy, které přispívají k aktivnímu osvojení poznatků, užívání problémového učení a skupinové práce.

Osnovy matematiky platné v osmdesátých letech již zahrnovaly užívání kalkulaček, neboť od školního rou 1982/1983 byly povoleny ve výuce matematiky od 7. ročníku základní školy; od školního roku 1988/1989 dokonce již od 5. ročníku. Podle osnov měli žáci využívat kalkulátory při výpočtech s desetinnými čísly, s procenty či při určování druhých mocnin a odmocnin. Jednalo se tedy o využívání této pomůcky jako prostředku pro ulehčení numerických výpočtů. Celostátní učebnice matematiky pro tyto ročníky vydané Státním pedagogickým nakladatelstvím od roku 1988 obsahovaly kapitoly, ve kterých se žáci seznamovali se základy práce s jednoduchým typem kalkulátorů (Robová, 2012).

[2]Společnost Jednota českých matematiků a fyziků byla založena v roce 1862. K jejím hlavním cílům patří zlepšovat výuku matematiky a fyziky na školách, připravovat učebnice matematiky a fyziky, motivovat žáky a studenty ke studiu přírodovědných a technických oborů. JČMF sdružuje vědce, inženýry, učitele i studenty a žáky. Je také odborným garantem *Matematické* (1951) a *Fyzikální olympiády* (1959) od začátku existence těchto soutěží, rovněž dlouhodobě vydává časopisy zaměřené na matematiku, fyziku a jejich výuku (JČMF, 2012).

[3]Vedle osmileté základní školy byla ve školské soustavě ponechána základní devítiletá škola.

[4]Ve vzdělávacích cílech předmětu *Matematika* na druhém stupni ZŠ bylo uvedeno, že žáci „. . . seznámí se s prvky logiky, s pojmy matematická věta, definice a s prováděním jednoduchých důkazů; seznámí se se základními množinovými pojmy. . . “ (MŠ, 1987: s. 10).

3 Devadesátá léta 20. století

Rok 1989 přinesl zásadní politické i společenské změny, které u nás významně ovlivnily vzdělávání v dalších letech. Zatímco v předchozích desetiletích byl systém řízení a správy oblasti školství výrazně centralizovaný a na všech úrovních školského systému byl uplatňován jednotný přístup z hlediska výchovně-vzdělávacích cílů, učebních plánů a osnov i učebnic, po roce 1990 došlo k jeho výraznému uvolnění. Této situaci napomohla decentralizace školské správy, ke které došlo na základě zákona č. 564/1990 Sb. Tento zákon podřídil školy přímo MŠMT, které zřídilo školské úřady na okresní úrovni. Další reforma veřejné správy v roce 2000 postupně převedla školskou správu zpět na územní orgány; MŠMT si ponechalo koncepční kompetence (EC, 2008/09).

Změna školských zákonů souvisejících se vzděláváním ve školách však trvala 15 let (MŠMT, 2009). Školský zákon č. 29/1984 Sb. uvedený v předchozím textu byl doplněn novelami a platil až do roku 2004.

Důsledkem uváděných změn byla postupná humanizace vzdělávání, které směřovalo od popisného a faktografického pojetí k aktivnímu a tvořivému učení žáků. Podle Trávníčka (1998) podstata humanizace matematického vzdělávání spočívá v tom, že cíle, obsah i průběh vzdělávání se mají stát žákům bližší a potřebnější.

Proces humanizace byl částečně spojen s požadavkem na snížení počtu hodin matematiky na základních a středních školách. Jedním z uváděných důvodů pro pokles hodin matematiky bylo, že v předlistopadovém období „matematicko-přírodovědná a polytechnická složka všeobecného vzdělání expandovala na úkor složky společenskovědní, jazykové a esteticko-výchovné. Toto posilování bylo – ať již právem či neprávem – považováno za součást dehumanizující a indoktrinační vzdělávací politiky. Po politickém převratu při oprávněné snaze o vyrovnání disproporcí se váha přírodovědné složky oslabila, zejména v důsledku zvýšeného důrazu na předměty humanitního zaměření a zaostávající výuku cizích jazyků.“ (Brockmeyerová-Fenclová & Kotásek, 1999: s. 59) Matematika a přírodovědné předměty doplácely na přeceňování významu techniky, neboť byly zdůrazňovány nikoli jejich stránky humanitní, ale jejich aplikace, počtářské techniky a spojení se životem, tj. se životem socialistické společnosti (Calda, 1992).

K 31. prosinci 1992 zanikla Česká a Slovenská Federativní republika, nástupnickými státy se staly Česká republika a Slovenská republika; tato událost více ovlivnila řízení školství než charakter vzdělávání matematice. V roce 1995 vstoupila Česká republika do OECD a následně se mimo jiné zapojila do aktivit této organizace v oblasti mezinárodního testování TIMSS[5] (*Trends in International Mathematics and Science Study*).

[5] V rámci TIMSS je zjišťována úroveň znalostí a dovedností žáků 4. a 8. ročníku základních škol v matematice a v přírodovědných předmětech. Testování se koná pravidelně od roku 1995 ve čtyřletých cyklech. Podrobnější informace o účasti a výsledcích českých žáků v testování TIMSS s ohledem na rozsah příspěvku neuvádíme. Jsou k dispozici v dokumentech zpracovaných Mezinárodní asociací pro hodnocení výsledků vzdělávání (*The International Association for the Evaluation of Educational Achievement*), která organizuje šetření TIMSS na mezinárodní úrovni (https://timssandpirls.bc.edu/), a v dokumentech České školní inspekce (https://www.csicr.cz/Prave-menu/Mezinarodni-setreni/TIMSS).

3.1 Školské zákony a dokumenty, učební osnovy a učebnice

Novela školského zákona v roce 1990 (č. 171/1990 Sb.) zavedla soukromé a církevní školy, zkrátila povinnou školní docházku na devět let a zřídila nepovinný 9. ročník. Zároveň vznikla víceletá gymnázia, která měla mít nejméně čtyři a nejvíce osm ročníků. Tato novela dále umožnila postupnou liberalizaci obsahu a organizace vzdělávání, byly uvolněny učební plány, neboť školy měly možnost upravit učební plán v rozsahu 10 % z hodinové dotace a učební osnovy jednotlivých předmětů v rozsahu 30 % hodinové dotace, rovněž byla dána jistá volnost v používání učebnic a dalších pomůcek (MŠMT, 2009).

V roce 1995 byla přijata další novela (č. 138/1995 Sb.), která, kromě jiného, zavedla od školního roku 1996/1997 povinný 9. ročník na základní škole; novela rovněž zrušila pětiletá a sedmiletá gymnázia.

Od školního roku 1991/1992 začaly platit upravené učební osnovy matematiky pro druhý stupeň základních škol (MŠMT, 1991), které kromě odstranění ideologických formulací a požadavků na vzdělávání snížily závaznost učebního plánu a osnov. Počet hodin matematiky včetně dalších předmětů byl stanoven v rozsahu od minimální po maximální možný počet hodin týdně (tab. 1); v každém ročníku měla být alespoň jedna hodina týdně půlena.

Tab. 1: Počet hodin matematiky na 2. stupni základní školy od roku 1991 (MŠMT, 1991)

	Ročník				
	5.	6.	7.	8.	Celkem
Matematika	4–5	4–5	4–5	4–5	16–20

Učební osnovy obsahovaly pro každý ročník přehled tematických celků s orientačním počtem hodin[6] pro každý celek; po přehledu následovaly jednotlivé tematické celky s výčtem pojmů bez uvedení požadovaných dovedností žáků. Učivo rýsování zahrnuté předchozími osnovami (MŠ, 1987) do hodin matematiky bylo přesunuto[7] do volitelného předmětu *Rýsování a základy technického kreslení*, který byl vyučován v 7. nebo 8. ročníku. V závěru osnovy obsahovaly metodická doporučení, ve kterých byly zařazeny i cíle vzdělávání matematice. K nim patřila nejen příprava žáků ke studiu na středních školách a využívání poznatků matematiky v běžném životě, ale také rozvíjení jejich logického myšlení a racionálního přístupu k řešení problémů (MŠMT, 1991).

Po opětovném zavedení povinné devítileté školní docházky v roce 1990 bylo potřeba vypracovat osnovy matematiky pro tehdy ještě nepovinný 9. ročník ZŠ. Ty byly vydány v roce 1993 (MŠMT, 1993) pro přechodné období, neboť povinným se tento ročník stal až od roku 1995. Do 9. ročníku byly vedle opakování učiva z předchozího období zařazeny operace s lomenými algebraickými výrazy, funkce[8], rovnice, nerovnice, trigonometrie pravoúhlého trojúhelníku, povrchy a objemy těles a základy statistiky a finanční matematiky. Žáci si mohli v tomto ročníku vybrat navíc volitelný předmět *Technické kreslení*. Metodická doporučení uváděla obecné

[6]Časové dotace u jednotlivých tematických celků nebyly na rozdíl od předchozích osnov (MŠ, 1987) závazné, závazné nebylo ani řazení tematických celků v rámci ročníku; vyučující sám určoval postup výkladu témat včetně metodického přístupu (MŠMT, 1991).

[7]Pouze v 5. ročníku byl ponechán celek *Základní pravidla rýsování* a v metodických doporučeních bylo uvedeno, že „vyučující pak ve výuce geometrie dbá na úroveň rýsování ve všech ročnících." (MŠMT, 1991: s. 13).

[8]Kromě lineární funkce se žáci seznamovali s kvadratickou funkcí včetně grafu a jeho užití při řešení kvadratických rovnic a nerovnic.

cíle učiva v 9. ročníku, ke kterým patřily matematické vědomosti a dovednosti, ačkoliv požadované žákovské dovednosti nebyly v těchto osnovách explicitně uvedeny. Oproti předchozím učebním osnovám zde byla také zmíněna doporučení týkající se diferenciace žáků. Kvůli nedostatku učebnic matematiky vhodných pro nově zavedený poslední ročník byl součástí osnov i seznam doporučené literatury pro žáky i pro učitele.

Vzhledem k rozvolnění vzdělávacích požadavků po roce 1989 a k připravovaným novým vzdělávacím programům vznikla potřeba sestavit standardy vzdělávání. *Standard základního vzdělávání* schválený v roce 1995 (MŠMT, 1999c) představil společensky žádoucí podobu povinného základního vzdělávání a obsahoval vzdělávací cíle i kmenové učivo[9]. Vzdělávací cíle zahrnovaly poznávací cíle, dovednosti a kompetence[10], hodnoty a postoje; kmenové učivo bylo závaznou součástí vzdělávacích programů. Oproti předchozím učebním osnovám se tento dokument vyznačoval nově rámcovým vymezením učiva po vzdělávacích oblastech a oborech. V oblasti *Matematika* byly vymezeny čtyři okruhy: *Aritmetika*, *Geometrie*, *Algebra* a *Užití matematiky a základy statistiky*, které obsahovaly velmi stručný výčet základních témat. Ačkoliv se jednalo o standard vzdělávání pro daný stupeň školské soustavy, lze pozorovat koncepční shodu s následně vytvořenými vzdělávacími programy, neboť ty ze standardu vycházely.

V průběhu devadesátých let byly schváleny tři různé vzdělávací programy pro základní vzdělávání, a to *Základní škola* s platností od 1. 9. 1996 (MŠMT, 1996), *Obecná škola*[11] (MŠMT, 1997a) a *Národní škola* (MŠMT, 1997b), oba s platností od 1. 9. 1997. Program *Základní škola* navazoval na dosavadní koncepci vzdělávání, druhé dva programy přinášely určité změny;[12] počet hodin matematiky na druhém stupni byl však v programu *Základní škola* (tab. 2) a *Obecná škola* stejný. Program *Národní škola* požadoval minimálně 15 hodin matematiky na druhém stupni, školy si však v rámci nadstavbové části mohly zvolit i další hodiny. Vzhledem k tomu, že se většina základních škol[13] u nás řídila programem *Základní škola*, zaměříme se v dalším textu na učební plány a učivo tohoto programu.

Oproti předchozím osnovám (MŠMT, 1991) se program *Základní škola* odlišoval důrazem na činnostní pojetí vyučování a na rozvíjení osobnosti žáka. Vymezení učiva mělo spíše rámcový charakter a nebyly zde uvedeny doporučené hodinové dotace pro jednotlivé tematické celky. Matematika společně s výukou českého jazyka tvořila hlavní osu základoškolského vzdělávání. Učební plán uváděl pro výuku matematiky na druhém stupni časovou dotaci 4 hodiny týdně (tab. 2). Učební osnovy ma-

[9]Kmenové učivo bylo v dokumentu charakterizováno jako „obsahové jádro základního vzdělávání, jeho podstatné prvky, které jsou předmětem vzdělávání všech žáků absolvujících povinnou školní docházku.“ (MŠMT, 1999c: s. 6).

[10]Jedná se o první výskyt pojmu *kompetence* v porevolučním období v námi analyzovaných dokumentech. Z textu *Standardu pro základní vzdělávání* vyplývá, že slova *kompetence* a *schopnost* jsou zde chápána jako synonyma, např. „V základním vzdělávání jde o takové elementární kompetence, jako je schopnost jasného, srozumitelného a správného vyjadřování, schopnost pracovat s matematickými pojmy, . . . “ (MŠMT, 1999c: s. 8).

[11]Původně se tento vzdělávací program nazýval pro 1. stupeň základní školy *Obecná škola* a pro 2. stupeň *Občanská škola*; oba byly jako modelové programy schváleny s účinností od 1. 9. 1996.

[12]Program *Občanská škola* si kladl na druhém stupni za cíl výchovu občana a byla zde vyvážená skladba předmětů včetně společenskovědních, mezi povinnými předměty byla i *Rodinná výchova* (Piťha & Helus, 1996). Program *Národní škola* kladl důraz na autonomii škol z hlediska diferenciace učebních plánů a místních podmínek, výchova a vzdělávání měly mimo jiné více směřovat k praktickému životu (MŠMT, 1997b).

[13]Program *Základní škola* na školách výrazně převažoval, programy *Obecná škola* a *Národní škola* se v širším měřítku neujaly (UN, 2003).

Tab. 2: Počet hodin matematiky na 2. stupni základní školy od roku 1996 dle vzdělávacího programu *Základní škola* (MŠMT, 1996)

	Ročník				
	6.	7.	8.	9.	Celkem
Matematika	4	4	4	4	16

tematiky byly koncipovány po ročnících. V každém tématu obsahovaly výčet učiva následovaný činnostně formulovaným přehledem toho, co by měl žák umět. Nakonec byly zmíněny příklady rozšiřujícího učiva. V posledním ročníku bylo zařazeno také téma *Základy finanční matematiky* a alternativní téma *Základy rýsování*[14].

V devadesátých letech byl zrušen státní monopol na vydávání učebnic. Vznikaly nové učebnice pro základní školy, ale byly opakovaně vydávány i starší z období před rokem 1989. Vzhledem k rozsáhlosti trhu s učebnicemi vyvstala potřeba posuzovat jejich kvalitu. Ačkoliv i učebnice vydávané před rokem 1989 obsahovaly schvalovací doložku Ministerstva školství, v porevolučním období se tato doložka stala zárukou jejich určité kvality. Tím si stát ponechal určitý vliv na proces tvorby, publikování a přijímání učebnic, a to zejména prostřednictvím závazných kurikulárních dokumentů a schvalovacích mechanismů (Sikorová, 2007).

V nových učebnicích byl dobře pozorovatelný odklon od exaktních definic matematických pojmů včetně snížení důrazu na symbolické zápisy matematických vztahů. Jednalo se například o sady učebnic vydávané Státním pedagogickým nakladatelstvím, nakladatelstvím Prometheus či Prodos. Ilustrujme uvedené změny na pojmu *nepřímá úměrnost* ze dvou učebnic matematiky pro 7. ročník vydaných s odstupem 17 let. Učebnice z osmdesátých let zavádí pojem takto:

> Nepřímá úměrnost je množina všech takových uspořádaných dvojic $[x; y]$, že $y = \frac{k}{x}$, $x \neq 0$, kde k je pro všechna x stále stejné kladné číslo, které nazýváme koeficient nepřímé úměrnosti. (Műllerová et al., 1982: s. 160)

Učebnice z konce devadesátých let obsahuje následující text:

> Nepřímá úměrnost je závislost, kde se jedna veličina zvětšuje a druhá úměrně zmenšuje (nebo naopak). Tato závislost se vyjádří vztahem $y = \frac{k}{x}$. (Molnár et al., 1999: s. 94)

Ve vzdělávání na gymnáziích devadesátá léta znamenala také řadu změn. Počet ročníků víceletých gymnázií se ustálil na šest či osm (MŠMT, 1995). V roce 1994 byl vydán generalizovaný učební plán gymnázia s osmiletým cyklem, časová dotace matematiky je uvedena v tab. 3 (Hrubý, 2007; MŠMT, 1995).

Tab. 3: Počet hodin matematiky v nižších ročnících osmiletého gymnázia od roku 1994 (MŠMT, 1995)

	Ročník				
	1.	2.	3.	4.	Celkem
Matematika	5	5	4	3	17

Změny v gymnaziálním vzdělávání přirozeně vyústily v potřebu nových učebnic. Od roku 1994 byly vydávány nové učebnice matematiky pro nižší ročníky osmiletých gymnázií. Tyto učebnice vznikaly v nakladatelství Prometheus na základě spolupráce s Jednotou českých matematiků a fyziků. Jedná se o sadu učebnic, která obsahuje 4 až 5 tematicky zaměřených dílů pro každý ročník. Oproti učebnicím pro základní školu jdou v učivu více do hloubky a obsahují více témat. Tato sada je dodnes jedinou řadou výhradně určenou pro nižší gymnaziální vzdělávání; učitelé však mohou využívat také učebnice pro druhý stupeň základní školy.

[14] *Základy rýsování* mohl vyučující zařadit podle svého uvážení a skladby žáků namísto některého algebraicky zaměřeného celku, např. tématu *Lomený výraz* (MŠMT, 1999c).

3.2 Další aspekty výuky matematiky

V průběhu devadesátých let lze u nás pozorovat postupné směřování ke konstruktivistickému pojetí vzdělávání matematice. Pro takové pojetí je charakteristický důraz na aktivní podíl žáka při získávání matematických vědomostí i dovedností včetně uvědomění si zásadní role jeho motivace. Tyto tendence lze z pohledu nižšího sekundárního vzdělávání vysledovat také v koncepci a obsahu kurikulárních dokumentů koncem devadesátých let. Ve vzdělávacím programu *Základní škola* (MŠMT, 1996) je uvedeno, že „Vyučování matematice směřuje k tomu, aby se žáci naučili: provádět početní výkony…, řešit úlohy z praxe…, provádět odhady…, dokazovat jednoduchá tvrzení a vyvozovat logické závěry z daných předpokladů“ (MŠMT, 1996: s. 67). Jednotlivé tematické celky jsou rovněž formulovány s důrazem na činnosti žáka; např. v tématu o čtyřúhelnících je uvedeno, že žák by měl umět „rozlišovat jednotlivé druhy rovnoběžníků a znát jejich vlastnosti; rozlišovat jednotlivé druhy lichoběžníků a znát jejich vlastnosti, …“ (MŠMT, 1996: s. 89). Objevily se také první odborné české příspěvky k tématu konstruktivismus, např. (Cachová, 1998; Hejný & Kuřina, 1998; Daňhelková & Jirotková, 1999).

3.3 Technologie ve výuce matematiky

Kalkulačky nadále nacházely uplatnění ve výuce matematiky ve školách, a to především v tematických celcích s náročnějšími numerickými výpočty, jako jsou výpočty s desetinnými čísly, s mocninami i odmocninami apod. Využívání kalkulaček záviselo na úvaze vyučujících; osnovy pro druhý stupeň základní školy požadovaly, aby se žák s kalkulačkou seznámil, ale míra jejího využívání záležela na situaci v dané třídě (MŠMT, 1991). Později vydané osnovy pro víceletá gymnázia uvádějí zařazení kalkulaček v konkrétních okruzích např. desetinná čísla, mocnina a odmocnina (MŠMT, 1999b).

Ačkoliv první osobní počítače začaly být využívány ve výuce již v devadesátých letech, jejich rozsáhlejšímu rozšíření bránil jak jejich nedostatek, tak i chybějící vhodný výukový software včetně nízké připravenosti samotných učitelů. Důležitým krokem ke zlepšení situace bylo proto schválení dokumentu *Státní informační politika – cesta k informační společnosti* v roce 1999 a jeho rozpracování v rámci *Koncepce státní informační politiky ve vzdělávání* (SIPVZ) v roce 2000.

Vzhledem k výše uvedeným příčinám se ve školách v zahraničí více než počítače používaly levnější kalkulátory s grafickým displejem, tzv. grafické kalkulačky. Větší displej umožňoval zapisovat nejen matematické výrazy, ale také například zobrazovat grafy funkcí či statistické diagramy (Robová, 1999a, 1999b, 2004). Hlavním přínosem této pomůcky byla možnost vizualizace matematických objektů. U nás však tyto kalkulátory nedosáhly většího rozšíření, výjimečně byly využívány na některých středních průmyslových školách. Jedním z důvodů bylo chybějící vyjádření postoje MŠMT k používání grafických kalkulaček ve výuce matematiky.

4 První dekáda 21. století

Zásadní změnou ovlivňující také vzdělávání u nás byl vstup České republiky do Evropské unie v roce 2004. Některé principy a strategie v souladu s evropskými doporučeními pronikaly do českého vzdělávání již ve druhé polovině devadesátých let 20. století. Z analýz tehdejšího stavu českého školství[15] v porovnání s vývojovými tendencemi vzdělávání v rámci Evropské unie vyplynula mimo jiné potřeba přípravy a realizace kurikulární reformy a zavedení národního evaluačního systému například v podobě maturitní zkoušky, jejíž požadavky budou z části definované státem (Čerych et al., 1999).

Za první dokument kurikulární reformy je považován *Národní program rozvoje vzdělávání v České republice* (MŠMT, 2001), známý jako *Bílá kniha*. Jeho východiskem byl dokument *Koncepce vzdělávání a rozvoje vzdělávací soustavy v České republice* (MŠMT, 1999a) zveřejněný v květnu 1999 a určený k veřejné diskuzi. Jádrem reformy bylo vytvoření dvouúrovňového participativního modelu kurikula po vzoru zemí Evropské unie. Na první úrovni je postaveno tzv. národní kurikulum, které představují závazné *rámcové vzdělávací programy* (RVP). Ty definují obecné cíle vzdělávání, klíčové kompetence a povinné výstupy obsahových oblastí za jednotlivá období. Na základě RVP pak školy samostatně vytváří své *školní vzdělávací programy* (ŠVP), které představují druhou úroveň kurikula. Školy v ŠVP upřesňují hodinové dotace vzdělávacích oblastí, výstupy a obsah učiva v jednotlivých ročnících. Smyslem reformy bylo zvýšit autonomii škol a převést více pravomocí na ředitele. Jednou ze zásadních změn byl zřetel k individuálním vlastnostem žáka (Maňák, Janík & Švec, 2008). Tuto zcela novou koncepci vzdělávání upravil školský zákon č. 561/2004 Sb.

4.1 Kurikulární dokumenty a učebnice

Na počátku dekády se na základních školách vyučovalo podle osnov z roku 1996 (MŠMT, 1996). První verze[16] (MŠMT, 2005) *Rámcového vzdělávacího programu pro základní vzdělávání* (RVP ZV) vstoupila v platnost v roce 2005. Základní školy začaly vyučovat dle svých ŠVP v 1. a 6. ročnících nejpozději od 1. 9. 2007. Některé dosavadní předměty byly sloučeny do společných vzdělávacích oblastí (například v RVP ZV vzdělávací oblast *Člověk a příroda* slučuje fyziku, chemii, přírodopis a zeměpis). Matematice zůstala ponechána samostatná oblast *Matematika a její aplikace*.

Porovnáme-li poslední platné osnovy s RVP ZV, vidíme, že celková časová dotace 16 hodin matematiky na druhém stupni se zpočátku nezměnila. RVP ZV již ale nestanovuje počty hodin v jednotlivých ročnících, pouze specifikuje, že výuka matematiky má probíhat v každém ročníku (MŠMT, 2005: s. 106). *Opatřením ministryně školství, mládeže a tělovýchovy* ze dne 26. 6. 2007 byl celkový počet hodin výuky matematiky snížen na 15 (MŠMT, 2007).

Vzdělávací obsah oblasti *Matematika a její aplikace* je v RVP ZV pro druhý stupeň rozčleněn na čtyři tematické okruhy: *Číslo a proměnná*; *Závislosti, vztahy a práce s daty*; *Geometrie v rovině a v prostoru* a *Nestandardní aplikační úlohy a problémy* (MŠMT, 2005: s. 32–33). V rámci každého okruhu jsou uvedeny závazné očekávané výstupy popisující, co by měl žák umět, a učivo, které je v RVP ZV chápáno pouze jako doporučený prostředek k dosažení předepsaných výstupů a stává

[15] MŠMT. (1996). *Školství v pohybu. Výroční zpráva o stavu a rozvoji výchovně vzdělávací soustavy v letech 1995–1996.* Praha: ÚIV; MŠMT. (1998). *Školství na křižovatce. Výroční zpráva MŠMT o stavu a rozvoji výchovně vzdělávací soustavy v letech 1997–1998.* Praha: ÚIV; MŠMT. (2000). *Na prahu změn. Výroční zpráva MŠMT o stavu a rozvoji výchovně vzdělávací soustavy za rok 1999.* Praha: ÚIV.

[16] RVP ZV je průběžně aktualizován (viz http://www.nuv.cz/t/prehled-uprav-rvp-zv-1, cit. 23. 4. 2019). Základní koncepce poslední verze (MŠMT, 2017) se od původního dokumentu neliší. Na podstatně změny týkající se výuky matematiky dále upozorňujeme.

se závazným až na úrovni ŠVP. Podstatným rozdílem oproti posledním osnovám je absence rozdělení učiva do jednotlivých ročníků, absence doporučeného rozšiřujícího učiva a méně konkrétní popis obsahu i výstupů vzdělávání matematice. Podíváme-li se například na téma *trojúhelník*, z osnov (MŠMT, 1996: s. 22) se dozvíme, že se jedná o učivo 6. ročníku. Žák má být seznámen se speciálními typy trojúhelníků, dále s jeho vnějšími a vnitřními úhly, výškami, těžnicemi, trojúhelníkovou nerovností, konstrukcí podle věty *sss* atd. V činnostně formulovaných výstupech je potom shrnuto, že žák by měl umět třídit a popsat trojúhelníky, sestrojit výšky a těžnice trojúhelníku, sestrojit kružnici opsanou a vepsanou trojúhelníku a dopočítat velikost vnitřního úhlu trojúhelníku, jsou-li dány velikosti jeho dalších dvou vnitřních úhlů. Rozšiřující učivo obsahuje vlastnosti těžiště, střední příčku a mnohoúhelníky. Obsah trojúhelníku, věty o shodnostech a podobnostech trojúhelníku a další konstrukční úlohy jsou specifikovány v dalších ročnících. Oproti tomu v RVP ZV (MŠMT, 2005) se slovo trojúhelník objevuje pouze šestkrát, z toho v povinných výstupech dvakrát, a sice na konci 5. ročníku žák „narýsuje a znázorní základní rovinné útvary (čtverec, obdélník, trojúhelník a kružnici); užívá jednoduché konstrukce“ (MŠMT, 2005: s. 31) a ve výstupech v 9. ročníku v souvislosti s větami o shodnosti a podobnosti trojúhelníků. Jedinou konkrétnější informací v (nezávazném) učivu je „trojúhelníková nerovnost“ (MŠMT, 2005: s. 33). RVP ZV tedy nedává učiteli odpověď na to, zda má absolvent základní školy vědět něco o těžnicích, výškách, opsané a vepsané kružnici a dalších, s trojúhelníkem souvisejících pojmech.

Poslední předreformní osnovy pro víceletá gymnázia (MŠMT, 1999b) vstoupily v platnost 1. 9. 1999. Novinkou bylo, že tematické celky nebyly doplněny doporučenou hodinovou dotací ani nebyly rozřazeny do jednotlivých ročníků. Obsah učiva byl v osnovách rozdělen na povinné a doporučené rozšiřující učivo. Dále byla pro každý předmět stanovena minimální povinná hodinová dotace v každém ročníku, přičemž ředitel školy mohl tuto hodinovou dotaci navýšit z disponibilních hodin. Hodinová dotace zůstala stejná jako v letech 1994–1999 (tab. 3). Nezávazný návrh vhodné posloupnosti matematických témat včetně orientačních časových limitů s ohledem na využití disponibilních hodin podali Houska a Hrubý (1999).

Na nižším stupni osmiletého gymnázia osnovy sice zohledňovaly *Standard základního vzdělávání* (MŠMT, 1999c) schválený roku 1995, ale také byl brán zřetel na to, že učitelé pracovali s vybranými žáky a mohli tedy postupovat ve výuce rychleji a jít více do hloubky. Tomu přispívala i hodinová dotace matematiky (srovnej tab. 2 a 3). V osnovách pro víceletá gymnázia nalezneme na rozdíl od osnov pro základní školy (MŠMT, 1996) mezi povinným učivem například deltoid a jeho obsah, délku oblouku kružnice, obsah kruhové úseče a výseče nebo graf funkce $y = |x|$ (MŠMT, 1999b: s. 106–107).

Od 1. 9. 2007 se výuka v prvních ročnících osmiletých gymnázií, stejně jako v 6. ročnících základních škol, řídí RVP ZV (šestiletá gymnázia se řídí RVP ZV od 1. 9. 2009). Zároveň však gymnázia zůstávají výběrovými školami a je obvyklé, stejně jako před zavedením kurikulární reformy, že výuka matematiky je zde náročnější než na základních školách. Díky tomu vznikají na víceletých gymnáziích zřetelné rozdíly mezi minimálními požadovanými výstupy v národním kurikulu a reálným obsahem výuky.

Dalším úskalím kurikulární reformy pro šestiletá gymnázia jsou chybějící minimální výstupy na konci 7. ročníku základního vzdělávání. Žáci přicházejí z různých základních škol s odlišnou úrovní znalostí, zatímco někteří z nich jisté učivo v 6. nebo 7. ročníku probírali, jiní jej ještě neznají. Problémem je již samotné nastavení požadavků k přijímacím zkouškám.

Ve vydávání učebnic matematiky pokračoval trend započatý v devadesátých letech minulého století. Vycházely nové řady (například v nakladatelstvích Fraus, Didaktis či Nová škola), ale i aktualizace dříve vydaných učebnic. Kromě toho po roce 2000 rostl počet pracovních sešitů. Na přechodnou dobu byla povinnou součástí učebnic informace o klíčových kompetencích (v souladu s RVP ZV), které kniha rozvíjí. Přestože od zavedení kurikulární reformy není určeno rozřazení učiva do jednotlivých ročníků, v názvech učebnic ročníky zůstaly. S rostoucím počtem učebnic roste bohužel také počet těch, které ne vždy jdou příkladem svým grafickým (Moravcová, 2017) i odborným zpracováním.[17]

4.2 Další aspekty výuky matematiky

V roce 2000 bylo v rámci OECD zahájeno další mezinárodní testování, a sice šetření PISA (*Programme for International Student Assessment*). V rámci PISA je zkoumána úroveň čtenářské, matematické a přírodovědné gramotností patnáctiletých žáků. Testování probíhá každé tři roky, přičemž se pravidelně střídá jeho hlavní náplň. Matematická gramotnost byla zkoumána v letech 2003 a 2012;[18] zhoršující se výsledky našich žáků vyvolaly diskusi odborné veřejnosti (Mandíková & Palečková, 2014).

Do výuky matematiky nadále pronikají konstruktivistické přístupy. Více je zdůrazňována důležitost podnítit žákovu aktivitu, rozvíjet jeho schopnost samostatně a kriticky myslet, vést ho k budování vlastní poznatkové struktury. Hejný a Kuřina (2001) hovoří o *didaktickém konstruktivismu* a uvádějí deset zásad vystihujících jejich pedagogické přesvědčení o kvalitní výuce matematiky. Kuřina (2002) také rozvinul *realistický konstruktivismus* připouštějící transmisi potřebných partií učiva. Didaktikou matematiky s ohledem na konstruktivistický přístup se zabývá také kniha editovaná Hejným, Novotnou a Stehlíkovou (2004). Příkladem metody založené ryze na konstruktivistickém pojetí učení je metoda profesora Milana Hejného, která je podle informací společnosti H-mat v současnosti používaná téměř na pětině[19] českých základních škol.

4.3 Technologie ve výuce matematiky

Od první dekády 21. století jsou klasické kalkulačky v hodinách matematiky běžně používanou pomůckou. Učitelé se v hodinách matematiky potýkají s tím, že vzhledem k různorodosti typů kalkulaček žáci často nevědí, jak jednotlivé funkce kalkulaček využívat.

RVP ZV (MŠMT, 2005) obsahuje doporučení, aby žáci analyzovali i modelovali závislosti pomocí vhodného počítačového software nebo grafických kalkulátorů. Grafické kalkulačky však ani v tomto období do českých škol v širší míře nepronikly.

[17] V některých učebnicích posledních let registrujeme zejména didaktické nedostatky, nejednotnost nebo neúplnost definic apod. Například v učebnici Binterové, Fuchse a Tlustého (2007) je podle definice na str. 9 čtverec speciálním případem obdélníku, podle definice na str. 59 však nikoliv. Oba přístupy jsou sice možné, domníváme se však, že by matematické pojmy měly být žákům vykládány jednotně.

[18] Podrobnější informace o účasti a výsledcích českých žáků v testování PISA s ohledem na rozsah příspěvku neuvádíme. Jsou k dispozici v dokumentech OECD (http://www.oecd.org/pisa/) a v dokumentech ČŠI (https://www.csicr.cz/Prave-menu/Mezinarodni-setreni/PISA).

[19] Údaj čerpán z https://www.h-mat.cz/hejneho-metoda (cit. 23. 4. 2019). Uvedený podíl škol zahrnuje i školy, kde je Hejného metoda využívána pouze na prvním stupni.

V souvislosti s rozšířením počítačů do škol se rychleji rozvíjely výukové programy; vedle symbolických matematických programů typu *Derive* a tabulkových editorů to byly i programy umožňující manipulaci s již nakreslenými objekty, tzv. *programy dynamické geometrie*. U nás byl ve výuce matematiky nejdříve využíván placený[20] software *Cabri*, resp. jeho vylepšená verze *Cabri II Plus*, a později také *Cabri 3D*. V letech 2001–2006 rozšíření uvedených programů do škol výrazně napomohl projekt SIPVZ, v němž si učitelé mohli volit vzdělávací kurzy zaměřené na využití programu *Derive* či *Cabri II Plus*[21].

Ve školách se během této dekády rozšířily také interaktivní tabule díky jejich financování z evropských strukturálních fondů, rozsáhlejší využívání však nalezly spíše na prvním stupni základních škol. Stále více škol využívá ve výuce matematiky materiály dostupné online.

5 Druhá dekáda 21. století

Pro období po roce 2010 je charakteristické především zavádění jednotných zkoušek garantovaných státem. Po několika odkladech a úpravách (Hrubá, 1999; MŠMT, 2000a; MŠMT, 2000b; MŠMT, 2009) je od roku 2011 realizována nová podoba státní maturitní zkoušky. Dalším krokem MŠMT v této oblasti bylo zavedení jednotné přijímací zkoušky z českého jazyka a matematiky na střední školy. Výrazný je stále rostoucí vliv digitálních technologií a jejich užití ve vzdělávacím procesu. Dále je kladen důraz na aktivní učení a podporu inkluzivního vzdělávání. Důsledkem uvedených trendů je mimo jiné zvyšování nároků na učitele.

5.1 Kurikulární dokumenty a učebnice

RVP ZV byl od svého zavedení několikrát aktualizován. Matematiky se týká úprava z roku 2013, kdy byla na první stupeň základního vzdělávání navrácena propedeutika zlomků.[22] V témže roce byl také RVP ZV doplněn o přílohu *Standardy pro základní vzdělávání* včetně standardů vzdělávací oblasti *Matematika a její aplikace*. Ty obsahují ke každému očekávanému výstupu seznam indikátorů, tj. konkrétních dovedností žáka prokazujících dosažení daného výstupu, a ilustrativní úlohu.

Již v roce 2011 vydalo MŠMT *Doporučené učební osnovy předmětů ČJL, AJ a M pro základní školu* (MŠMT, 2011), patrně s cílem upřesnit RVP ZV a poskytnout tak školám podrobnější podklady pro tvorbu a realizaci ŠVP; v podstatě se jedná o ukázkové kapitoly ŠVP pro český a anglický jazyk a pro matematiku. Za povšimnutí stojí, že v učebním plánu je doporučená hodinová dotace matematiky na druhém stupni základní školy 18 hodin, tedy je o 3 hodiny navýšena z disponibilních hodin. Důvodem tohoto navýšení je „rozvoj matematické gramotnosti a úspěšné osvojování poznatků v dalších vyučovacích předmětech“ (MŠMT, 2011: s. 1–3). Tyto doporučené osnovy jsou velmi podrobně rozpracované a srovnatelné s posledními platnými osnovami (MŠMT, 1996) před zavedením kurikulární reformy.

[20] Vedle komerčních programů mohli učitelé používat programy *Geonext*, *C.a.R*, později i *GeoGebru*; tyto programy měly českou lokalizaci, resp. *C.a.R* slovenskou.

[21] Program *Cabri II Plus* doporučilo pro výuku MŠMT; používání programu záleželo ale na rozhodnutí učitele.

[22] Podle RVP ZV z roku 2005 se žáci na prvním stupni základní školy seznamovali pouze s přirozenými čísly, což bylo kritizováno ve spojitosti se zhoršujícími se výsledky žáků 4. ročníků v mezinárodním testování TIMSS (VÚP, 2011: s. 39).

Nabídku učebnic pro základní školy rozšířilo nakladatelství Fraus o řadu učebnic matematiky pro první stupeň dle *Hejného metody*, která začala postupně vycházet od roku 2007. Na tyto učebnice navázala řada učebnic pro druhý stupeň z nakladatelství H-mat. Novinkou poslední dekády je vydávání digitálních učebnic – interaktivní učebnice matematiky pro základní školy nabízí rovněž nakladatelství Fraus. V posledních letech bylo také kromě aktualizovaných vydání již zavedených učebnic vydáno několik nových řad učebnic a sbírek úloh, zpravidla doplněných pracovními listy či dokonce různými didaktickými pomůckami (například řada z nakladatelství Tvořivá škola).

5.2 Další aspekty výuky matematiky

Po pilotním ověřování v letech 2015 a 2016 zavedlo MŠMT na jaře 2017 jednotnou přijímací zkoušku na střední školy zakončené maturitou. Žáci skládají zkoušku z českého jazyka a matematiky formou didaktických testů, které mají obdobný charakter jako testy používané ve společné části maturitní zkoušky. Ředitelé středních škol sice mohou nastavit další kritéria pro přijetí žáků, avšak dle § 60d aktuální úpravy školského zákona 561/2004 Sb. musí zohlednit výsledky jednotné přijímací zkoušky z alespoň 60 %. V jejich kompetenci je také nastavení hranice úspěšnosti zkoušky. Jednotné přijímací zkoušky jsou vedle státní maturity a testování prováděného Českou školní inspekcí[23] dalším nástrojem k evaluaci kvality vzdělávání matematice v České republice, byť zde narážíme na fakt, že je nekonají všichni absolventi základních škol.

Didaktické testy z matematiky zadávané v rámci jednotných přijímacích zkoušek obsahují široce otevřené úlohy[24], otevřené úlohy[25] a uzavřené úlohy[26]. Žák zaznamenává odpovědi do tzv. *záznamového archu*. Na vypracování 16 úloh (přijímací řízení na šestiletá gymnázia a čtyřleté studijní obory s maturitou), respektive 14 úloh (přijímací řízení na osmiletá gymnázia), je 70 minut a povolenými pomůckami jsou pouze psací a rýsovací potřeby. Testové úlohy vycházejí z RVP ZV, v případě testů pro přijetí na šestileté gymnázium z doporučených osnov (MŠMT, 2011). Požadavky jsou podrobně specifikovány na webových stránkách Centra pro zjišťování výsledků ve vzdělávání.[27] Před zavedením jednotné přijímací zkoušky některé střední školy používaly přijímací testy vytvořené společností Scio, které sestávaly pouze z uzavřených úloh. Přestože volba charakteru úloh jednotných přijímacích testů je opakovaně v médiích terčem kritiky, zařazení otevřených úloh považujeme za krok správným směrem. Současná jednotná přijímací zkouška díky chybějící centrálně nastavené dolní hranici úspěšnosti nemůže stoprocentně zajistit minimální vstupní úroveň žáků nastupujících do maturitních oborů středních škol. Dává však najevo určitou úroveň

[23] Česká školní inspekce (ČŠI) je správním úřadem s celostátní působností. Byla zřízena zákonem č. 561/2004 Sb. dne 1. 1. 2005. Jejím prostřednictvím je zajišťováno hodnocení vzdělávací soustavy v České republice v oblasti vzdělávání a školských služeb (https://www.csicr.cz/cz/ZAKLADNI-INFORMACE/O-nas, cit. 25. 4. 2019). Od školního roku 2015/2016 ČŠI provádí pravidelné testování žáků 9. ročníků základních škol a 2. ročníků středních škol, pomocí nějž sleduje rozvoj gramotností žáků včetně matematické. Je též realizátorem mezinárodních výzkumů včetně výše zmíněných TIMSS a PISA.

[24] Úlohy, v nichž žák uvádí nejen výsledek, ale i postup řešení, jehož správnost je součástí hodnocení.

[25] Žák uvádí pouze výsledek úlohy.

[26] Žák vybírá odpověď z nabízených možností.

[27] Dostupné z https://www.cermat.cz/specifikace-pozadavku-k-jednotnym-prijimacim-zkouskam-1404035551.html (cit. 23. 4. 2019).

znalostí, které by měl žák v ideálním případě při přechodu ze základní na střední školu mít.

S výukou matematiky úzce souvisí rozvíjení finanční gramotnosti žáků, jejíž potřeba se začala zvyšovat v devadesátých letech 20. století v souvislosti s porevolučními změnami v tržní ekonomice a bankovnictví. Na základě vládního rozhodnutí z roku 2005 byl zformulován *Systém budování finanční gramotnosti na základních a středních školách* (MF, MŠMT & MPO, 2006), v němž je definována finanční gramotnost a její standardy. Dokument dále podrobněji představuje záměr začlenit tuto aktuální oblast do vzdělávání. V roce 2013 byla finanční gramotnost implementována do RVP ZV jako součást vzdělávací oblasti *Člověk a svět práce*.

5.3 Technologie ve výuce matematiky

Pro druhou dekádu 21. století je na českých základních i středních školách patrný nárůst využívání programu dynamické geometrie *GeoGebra*, která nahradila placený software. Technologický vývoj umožnil využívání různých systémů hlasovacích zařízení zobrazujících odpovědi žáků na testové úkoly či otázky učitele v reálném čase. Školy také více využívají výukové webové stránky.

6 Závěr a diskuse

Shrneme-li hlavní změny ve vzdělávání matematice na 2. stupni základní školy v posledních třiceti letech, jedná se o snižování počtu hodin matematiky, zobecnění obsahu kurikula a rozvolnění cest k jeho naplnění, posun výuky od zaměřenosti na učivo směrem k žákovi a k procesu jeho učení, výrazný nárůst využívání technologií ve školské matematice a o zavedení jednotné přijímací zkoušky na střední školy.

Snižování hranice minimálního počtu hodin matematiky na druhém stupni základní školy z 20 na 15 od předrevolučního období po současnost dokládá tab. 4. Uvedený pokles souvisel se zaváděním nových předmětů na druhém stupni v porevolučních letech, konkrétně se zavedením druhého cizího jazyka. Snížení hodinové dotace matematiky může mít, dle našeho názoru, negativní dopad na společenské vnímání role matematiky jako základního vyučovacího předmětu na druhém stupni základní školy.

Tab. 4: Přehled vývoje počtu hodin matematiky na druhém stupni základní školy

Kurikulární dokument	*Osnovy* (MŠ, 1987)	*Osnovy* (MŠMT, 1991)	*Základní škola* (MŠMT, 1996)	*RVP ZV* (MŠMT, 2005)	*Opatření* (MŠMT, 2007)
Počet hodin matematiky na druhém stupni ZŠ	20	16–20	16	16	15

Mírně odlišný byl vývoj počtu hodin matematiky v nižších ročnících osmiletých gymnázií. V roce 1994 byl tento počet ustanoven na 17, nezměnil se ani nastolením posledních předreformních osnov pro víceletá gymnázia v roce 1999. Od zavedení kurikulární reformy po roce 2000 se nižší ročníky víceletých gymnázií řídí RVP ZV pro druhý stupeň základní školy, minimální hodinová dotace matematiky tedy klesla nejprve na 16, posléze na 15 hodin. Je však obvyklé, že ji ředitelé víceletých gymnázií navyšují z disponibilních hodin na 16 až 18.[28] Zajímavostí je, že 18hodinovou dotaci

[28] Údaj byl zjištěn na základě analýzy desítek učebních plánů osmiletých gymnázií v celé České republice. Je třeba podotknout, že i na mnohých základních školách je celková hodinová dotace matematiky na druhém stupni větší než 15 hodin.

výuky matematiky uvádějí i doporučené učební osnovy (MŠMT, 2011) vypracované Ministerstvem školství, mládeže a tělovýchovy. To si lze vysvětlit tak, že i MŠMT si uvědomuje, že 15 hodin je pro optimální dosažení požadovaných výstupů málo.

Přirozeně se nabízí otázka, zda snížení počtu hodin matematiky na druhém stupni nemá negativní vliv na kvalitu výuky. Výzkum v této oblasti však nedává jednoznačnou odpověď. Některé výsledky ukazují, že existuje přímá vazba mezi délkou doby studia a znalostmi a dovednostmi, které během této doby jedinec získá, jiné, že tomu tak není (Průcha, 2012). Je však evidentní, že snížení hodinové dotace musí vést ke snížení objemu probraného učiva nebo času na jeho procvičení. Systematickou přípravu a procvičení však považujeme za důležitou součást učení se matematice. Obojí často probíhá také formou domácích úkolů. V posledních letech se na téma *domácí úkoly* rozpoutala živá diskuse – odpůrci z řad rodičů žáků vystupují v médiích proti zadávání domácích úkolů a argumentují přetěžováním žáků. Vhodně zadané domácí úkoly však mohou vést k prohlubování žákových znalostí a dovedností, neboť jsou nedílnou součástí procesu učení. Je však třeba, aby žáci byli k psaní úkolů motivováni (Maňák, 1992). S domácí přípravou souvisí také další fenomén posledních let – doučování. Zatímco námitky proti zadávání domácích úkolů rostou, roste paradoxně i poptávka po soukromém doučování matematiky včetně intenzivní přípravy na přijímací zkoušky.

Národní kurikulum matematiky prošlo v uplynulých třiceti letech značným vývojem. Od jednotných učebních plánů a osnov matematiky, které vymezovaly hodinové dotace a řazení tematických celků včetně jejich podrobného obsahu, se posunulo k rámcovým vzdělávacím programům vymezujícím očekávané výstupy vzdělávání pouze v tzv. uzlových bodech vzdělávání. V posledních letech jsou rámcové vzdělávací programy podrobovány kritice, že neposkytují dostatečné podklady k naplňování cílů vzdělávání (Janík et al., 2010). Důležitým aspektem kurikulárních reforem je postoj učitelů ke změnám, které s reformou souvisejí (Maňák, Janík & Švec, 2008; Pešková, Spurná & Knecht, 2017). Názor učitelů na reformu kurikula v souvislosti s RVP ZV však není konzistentní (Straková, 2007).

V současné době se pracuje na revizi kurikula (nejen) matematiky s cílem reagovat na dosavadní výsledky reformy i na vývoj společnosti. Úkolem je „jednoznačně a závazně vymezit rozsah a obsah vzdělávání společný pro všechny, který by měl být základem pro individuální rozvoj každého žáka[29]“. Lze tak pozorovat pokračující trend odklonu orientace kurikula od učiva k žákovi. Charakteristickým rysem revize je vypracování očekávaných výsledků učení žáka v jednotlivých tématech vzdělávacích oblastí vztažených k uzlovým bodům vzdělávání (pro druhý stupeň jde o 9. a nově také o 7. ročník). Revize probíhají po linii jednotlivých vzdělávacích oblastí napříč všemi stupni vzdělávání od preprimárního po střední. Skupina pro revizi vzdělávací oblasti *Matematika a její aplikace* zahájila práci jako jedna z prvních v létě 2017 a v září 2018 dokončila podklady k úpravám kurikula. Zvažuje se také zařazení konkrétních dovedností z finanční gramotnosti do revidovaného kurikula matematiky, což považujeme za přínosné.

Kurikulární změny úzce souvisejí s tvorbou učebnic matematiky. Můžeme v nich pozorovat odklon od exaktních definic, zdůvodňování, přesného vyjadřování i používání matematické symboliky. V důsledku uvolnění trhu po roce 1989 začala mnohá nakladatelství vydávat zcela nové řady učebnic, zároveň se však udělování schvalovacích doložek MŠMT stalo benevolentnější. V důsledku toho se na trhu objevily

[29]NÚV. *Revize RVP: Záměr, důvody a cíle.* Dostupné z http://www.nuv.cz/t/rrvp (cit. 26. 4. 2019).

i učebnice sporné kvality, zvýšil se však důraz na barevnost textu, zařazení obrázků a obecně zatraktivnění vzhledu učebnice. Zodpovědnost za volbu vhodné učebnice a případnou korekci matematických chyb, které se v ní vyskytují, byla přenesena na školu, potažmo učitele (Maňák & Knecht, 2007). V posledních letech se staly atraktivními pracovní sešity, které jsou součástí téměř každé řady základoškolských učebnic matematiky. Žáci nemusí formulovat celé věty, narýsovat si zadání úlohy atd., pouze vyplňují čísla do připravených kolonek nebo dokreslují čáry do předkresleného obrázku. Pracovní sešity bezesporu usnadňují učitelům i žákům práci a umožňují procvičit v daném čase více učiva. Zároveň se však domníváme, že jejich nadužívání může u žáků negativně podporovat schopnost správně formulovat matematické myšlenky a v důsledku toho omezovat rozvoj jejich logického myšlení.

Potřeba státu zajistit kvalitu vzdělávání v současných rozvolněných podmínkách vedla k zavedení jednotných přijímacích zkoušek na střední školy a jednotné maturitní zkoušky. Přijímacími zkouškami však neprocházejí všichni žáci končící základní školu. Česká republika tak v Evropě zůstává jednou z posledních zemí, která nemá vypracovaný systém národního testování (Dvořák, 2015). Z hlediska výsledků vzdělávání mají jednotné přijímací zkoušky z matematiky na střední školy potenciál poskytovat zpětnou vazbu nejen rodičům a školám, ale i samotným zřizovatelům základních škol, a mohou tak podpořit objektivizaci klasifikace na základních školách. Jako pozitivní hodnotíme i to, že přijímací zkoušky zahrnují znalosti a dovednosti z geometrie, což by mohlo přispět k podpoře výuky geometrie na školách.

Posun od transmisivního přístupu ve výuce matematiky směrem ke konstruktivistickému lze pozorovat nejen v současných kurikulárních dokumentech, ale také v nových učebnicích a používaných výukových metodách na školách. Na změnu metod učení matematice má značný vliv také rozmach digitálních technologií. Ty sice mohou přispívat k aktivnímu osvojování pojmů a dovedností žáků, jejich smysluplné zapojení však klade další nároky na práci učitele.

Důsledkem rychlého vývoje společnosti v posledních letech je, že školský systém nestačí reagovat na její požadavky a potřeby z hlediska vzdělávání, a to nejen v matematice. Stále více se tak ukazuje naléhavost „otázky, v čem má spočívat základní a v čem střední všeobecné matematické vzdělávání člověka naší doby a člověka blízké budoucnosti“ (Trávníček, 1998: s. 259).

Poděkování

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Jarmila Robová, jarmila.robova@mff.cuni.cz
Vlasta Moravcová, vlasta.moravcova@mff.cuni.cz
Univerzita Karlova, Matematicko-fyzikální fakulta
Katedra didaktiky matematiky
Sokolovská 83, 186 75 Praha 8, Česká republika

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Vývoj přírodovědného vzdělávání v České republice od roku 1989

Svatava Janoušková, Pavel Teplý, Hana Čtrnáctová, Jan Maršák

Abstrakt

V posledních 30 letech prochází český vzdělávací systém řadou změn. Tyto změny lze také pozorovat v proměně paradigmatu přírodovědného vzdělávání, která je do značné míry dána otevřeností vzdělávacího systému k novým, globálním trendům ve vzdělávání. Cílem autorů práce je zmapovat tento vývoj v prostředí ČR. Na základě kvalitativní analýzy strategických a koncepčních dokumentů MŠMT a dokumentů tvořených organizacemi jakými jsou např. Česká školní inspekce je demonstrován širší kontext přírodovědného vzdělávání v ČR. V druhé části článku se na základě analýzy cílového zaměření kurikul v oblasti přírodovědného vzdělávání od roku 1989 autoři zaměřují na proměnu cílů v oblasti přírodovědného vzdělávání. Autoři docházejí k závěru, že proměna přírodovědného vzdělávání v kurikulu nižšího sekundárního vzdělávání respektuje mezinárodní trendy. Kurikulum také z většiny zohledňuje cíle aktuálních národních i mezinárodních strategických dokumentů. I přesto autoři pro budoucí revize kurikula navrhují některé změny, kterými jsou například vymezení konceptu přírodovědné gramotnosti/kompetence a větší prosazení důležitosti přírodovědného vzdělávání do všeobecných vzdělávacích cílů.

Klíčová slova: přírodovědné vzdělávání, přírodovědná gramotnost, kurikulum, RVP.

Science Education Development in the Czech Republic since 1989

Abstract

The Czech education system has been undergoing a number of changes in the past 30 years. Changes took place also in science education; a paradigm shift – mostly due to the new educational system open for new educational trends – can be recognized.

This article maps these changes in the Czech Republic. Strategic and conceptual documents originating from the Ministry of Education and documents drafted by organizations as e.g. Czech School Inspectorate are examined by a thematic qualitative analysis. Based on the findings, authors present a broader context of science education. In the second part of the article the authors focus on changes in the objectives for science education by analyzing the target orientation of curricula since 1989. The authors conclude that the shift of science curriculum for lower secondary schools reflects current trends in education. The curriculum is also reflective of the goals and objectives of key national and international educational strategies. Still, authors suggest some changes for the future curricular revisions, for example: Explicit definition of scientific literacy/competence in the curricula, and a greater emphasis on science education in the general curricular goals.

Key words: science education, scientific literacy, curriculum, Framework Educational Programme.

Již od přelomu 80. a 90. let minulého století prochází celosvětově přírodovědné vzdělávání řadou změn a nese se ve znamení hledání nového postavení i pojetí přírodovědných oborů (Škoda & Doulík, 2009). Někteří autoři, např. Osborne a Wittrock (1983) hovoří o krizi přírodovědného vzdělání, která zasáhla nejen anglosaský svět, ale také země bývalého východního bloku. Obě do té doby uplatňovaná paradigmata pojetí přírodních věd – humanistické i scientistické, se zdála být příliš rigidní v kontextu postupně se globalizujícího světa. Bylo je proto třeba nahradit paradigmaty jinými, která by více odrážela dynamické změny probíhající ve vědě, technologii i celospolečenském uspořádání (Maršák & Janoušková, 2006). Opuštění původních pojetí bez existence pojetí jiného je však vždy složité. Zpravidla víme, co je na původních pojetích špatné, ale nacházení pojetí nového provází řada problémů a nejistot. Tyto problémy a nejistoty jsou zapříčiněny zejména roztříštěností názorů komunity vědců a dalších expertů v oblasti vzdělávání na směr, kterým by se vzdělávání mělo ubírat. Tato názorová roztříštěnost má zpravidla dva důvody. Prvním důvodem je ovlivnění vzdělávání názorovými proudy ve společnosti, na něž často působí nějaké nadnárodní uskupení – EU, OECD, UNESCO apod. Druhým důvodem je pak skutečnost, že je možné se opřít pouze o poměrně limitované množství systematicky provázaných dat, pocházejících z aktuálních výzkumů v oblasti přírodovědného vzdělávání, jež by napomohla pochopit aspekty přírodovědného vzdělávání, které pomáhají posouvat žáky i celou společnost žádoucím směrem.[1] Přitom celospolečenský tlak na optimalizaci školního vzdělávání ve všech oborech, včetně přírodovědných, je již dvě desetiletí enormní.

Počátek 21. století s sebou však nese ještě další výzvy v oblasti národního vzdělávání. Touto výzvou je globalizace. Globalizace je zpravidla chápána jako celosvětové zintenzivnění sociálních vztahů, které vede k tomu, že se lokální události utvářejí podle dění vzdáleného tisíce kilometrů a naopak (Held, 1991). Z tohoto důvodu globalizace maže do určité míry národní hranice, posiluje a vyžaduje určitou soudržnost a zásadně ovlivňuje uspořádání národní identity (Torres, 2002). To se nutně muselo odrazit a odráží ve vzdělávací politice, a to zvláště proto, že globalizace se měla odehrávat jako nástup a rozvoj společnosti a ekonomiky založené na vědění. Vědění tedy stojí a stálo v centru zájmu politiků i expertů (blíže viz Kopecký, 2013). To může mít pozitivní, stejně jako negativní důsledky. Pozitivním efektem globalizace může být tzv. learning policy, kdy se do národních systémů přejímají na základě hlubokých analýz ty prvky, které ho mohou zlepšit. Nekritickým, nesystémovým či sociokulturně nevhodným přijímáním celkového směřování vzdělávacích politik (nesystémová politika, borrowing policy) však ve vzdělávacích systémech mohou nastat také takové posuny, které jeho stabilitu naruší.

Článek se snaží zmapovat, jak na shora popsané trendy reagovala a reaguje Česká republika. Zaměřuje se proto na proměny přírodovědného vzdělávání v České republice v posledních 30 letech na úrovni nižšího sekundárního vzdělávání. První část článku přináší analýzu dokumentů nadnárodní a národní povahy, které se bezprostředně dotýkají vzdělávací politiky v oblasti přírodovědného vzdělávání v České republice. Druhá část článku se zaměřuje na bližší analýzu proměny kurikul zejména v oblasti cílů přírodovědného vzdělávání a jejich vazbu na dokumenty analyzované v první části. Poznatky v článku vycházejí z obsahové analýzy dokumentů (vzdělávacích standardů) zpracované softwarem Atlas.ti pomocí systémů kódování.

[1] V rámci přírodních věd jsou systematizovány informace zejména ve výzkumech TIMSS a PISA, které však ani zdaleka neposkytují odpovědi na všechny potřebné otázky.

1 Proměny přírodovědného vzdělávání v České republice

1.1 Devadesátá léta – období hledání identity přírodních věd a první globální výzkumy

Jak bylo uvedeno v úvodu článku, 90. léta byla celosvětovým hledáním nového pojetí přírodovědného vzdělávání. Česká republika, která procházela reformou školského systému, nebyla výjimkou. Pokud bychom přesto měli určit směr, jímž se přírodovědné vzdělávání začalo ubírat, pak to bylo zaměření na interdisciplinární pojetí přírodovědného vzdělávání, které se začalo více orientovat na komplexní témata se silnou tzv. sociální relevancí. Vzdělávání v přírodních vědách se dle odborníků mělo zaměřovat na taková témata, která měla potenciál být využívána žákem v jeho praktickém životě – pro jeho profesi i zodpovědné chování, při rozhodovacích procesech i jeho životě v postupně se globalizujícím světě (blíže viz Maršák & Janoušková, 2006). Je však nutno podotknout, že přes skutečnost, kdy se celosvětově začalo přistupovat k přírodovědnému vzdělávání jako prostředku pro pochopení světa a orientace v něm, docházelo v tomto období k významnému odklonu zájmu žáků o studium přírodovědných a technologických oborů, které žáci považovali za velmi náročné (Osborne & Wittrock, 1983). Tato krize přetrvala do počátku 21. století a její existence byla vnímána decizní sférou, například Evropskou komisí (EC), jako velmi závažná, neboť přírodní vědy a na ně navazující výzkum nových technologií byly a jsou jedním ze silných předpokladů úspěchu a konkurenceschopnosti zemí (blíže viz např. Gago et al., 2004; Krammer, 2017). Hledání cesty z této krize pak bylo předmětem zájmu odborných skupin od počátku 21. století (viz dále).

Devadesátá léta však nejsou jen obdobím hledání nových přístupů k výuce přírodních věd. Jsou také obdobím vzniku a realizace prvních globalizovaných výzkumů v oblasti měření dosažených výsledků žáků v přírodních vědách. Dopad těchto komparativních šetření na vzdělávací systémy účastnících se zemí byl, možná pro některé překvapivě, mimořádný. Prvním výzkumem, který je pravidelně realizován ve čtyřletém cyklu na globální úrovni (zahrnuje zpravidla více než 50 zemí světa) od roku 1995, je výzkum TIMSS (Trends in International Mathematics and Science Study) koordinovaný společností The International Association for the Evaluation of Educational Achievement (IEA). Druhý výzkum realizovaný Organizací pro hospodářskou spolupráci a rozvoj (OECD) je výzkum PISA (Programme for International Students Assessment), který je uskutečňován v tříletých cyklech od roku 2000 (připravoval se však od konce 90. let). Uvedených výzkumů se pravidelně účastní i Česká republika.

Oba výzkumy představují nové směřování v úvahách o vzdělávacích systémech jednotlivých zemí založených na tzv. evidence based policy (politice založené na důkazech). Konec devadesátých let a zejména počátek 21. století se tak proto nese v duchu tvorby indikátorových systémů a získávání velkého množství dat o různých aspektech fungování společnosti, vzdělávací soustavy nevyjímaje. Politika založená na důkazech se měla nést v duchu transparentnosti, odpovědnosti a demonstrace oprávněnosti prováděných změn. Je však potřeba si uvědomit, že indikátorové systémy zaváděné pro vysoce komplexní systémy se potýkají s řadou problémů – jejich největší slabinou pak paradoxně je, že se snaží takové systémy, ať se týkají jakékoli sociální reality, popsat několika málo čísly, což principálně není možné (blíže viz Morse, 2004; Janoušková & Maršák, 2008a, b).

Společnost dnešní doby je doslova posedlá „čísly“ (Morse, 2004) a možnostmi jejich interpretace. Bohužel taková interpretace není vždy jednoduchá, dokonce není vždy v konkrétním čase nebo na základě získaných informací možná. Přesto je požadována. Původně dobrý záměr začlenění vědeckých poznatků do politických rozhodnutí tak někdy může selhávat. Hluboké vědecké poznání sociální reality je totiž velmi obtížné a její pochopení může trvat dlouho, což se neslučuje s nutností dělat rychlá (politická) rozhodnutí a zavádět příslušná opatření v reálném čase. Podobným úskalím mohou vzdělávací politiky jednotlivých zemí čelit v případě, že za základ svých rozhodnutí berou jen údaje ze shora uvedených mezinárodních výzkumů, nebo pokud si dokonce vytknou jako hlavní cíl přírodovědného vzdělávání dosáhnout úspěchu v těchto šetřeních.

I když výsledky obou výzkumů vždy přitáhnou pozornost decizní, odborné i laické veřejnosti, je to zejména výzkum PISA, který stojí v centru zájmu vzdělávacích politik řady zemí světa. Šetření PISA totiž sleduje mj. vzdělávací výsledky patnáctiletých žáků v matematice, přírodních vědách a čtenářských dovednostech, a právě populace patnáctiletých žáků představuje v řadě zemí uzlový bod ve vzdělávání (přechod mezi nižším a vyšším sekundárním vzděláváním)[2]. Pro vzdělávací politiky řady zemí se proto PISA stala „zlatým standardem“ kvality vzdělávání a v řadě případů byla a je spouštěčem vzdělávacích reforem (Sjøberg, 2015). Pro mnoho zemí, kde neprobíhá testování úrovně znalostí a dovedností žáků na národní úrovni, totiž představuje toto šetření jediný obrázek o dosažených vzdělávacích výsledcích žáků, přičemž tyto výsledky lze srovnat ještě s dalšími zeměmi.

Výzkum PISA je na jedné straně často velmi oceňován – jedná se o unikátní globální standardizované měření založené na definicích gramotností stanovených konsenzuálně mezinárodním týmem; je pravidelně opakováno, lze v něm tedy sledovat určité trendy; je doprovázeno řadou důležitých informací o žácích a jejich rodinném zázemí, lze tedy na základě nich provádět detailnější analýzy závislosti socioekonomických proměnných na vzdělávacích výsledcích žáků atp.

Na druhé straně je však třeba si uvědomit limity tohoto šetření. V odborné literatuře (blíže viz např. Prais, 2003; Sjøberg, 2014; Fernandez-Cano, 2016) se obecně diskutuje problém samotného vymezení jednotlivých gramotností, které nezohledňuje kurikula a sociokulturní aspekty jednotlivých zemí, ale vychází z názoru odborníků na to, co je v globálním světě potřeba z rámce testovaného obsahu zvládnout. Diskutuje se však i metodologie výzkumu (kvalita úloh a jejich překladu, testování nikoli přírodovědného obsahu, ale schopnosti číst delší texty uvozující úlohy, i statistické zpracování). Kritici varují před přikládáním přílišné váhy tomuto šetření bez dalších národních analýz, které by výsledky umožnily v národním kontextu lépe interpretovat.

V České republice v devadesátých letech ani na počátku 21. století nebyla mezinárodní šetření hnacím motorem změn přírodovědného vzdělávání. Důvody pro tuto skutečnost byly dva. Prvním důvodem byla nutnost zaměřit se na zásadní proměnu celého vzdělávacího systému, aby odpovídal potřebám nově se rodící demokratické společnosti. To byl úkol i z hlediska proměny struktury kurikul jednotlivých oborů dosti náročný – přistupovalo se postupně ke zvyšování autonomie škol. Druhým, neméně závažným důvodem, byla skutečnost, že výsledky ČR v mezinárodním šetření TIMSS, které se uskutečnilo v roce 1995, byly nadprůměrné – žáci 8. ročníku

[2] Výzkum TIMSS provádí šetření dosažených vzdělávacích výsledků žáků 4. a 8. ročníků. Řada zemí, ČR nevyjímaje, však po zavedení šetření PISA ustoupila od šetření vzdělávacích výsledků žáků na úrovni 8. ročníků a mají tak k dispozici data pouze o žácích 4. ročníku základních škol.

dosáhli v přírodních vědách 574 bodů a umístili se tak na čele žebříčku účastnících se zemí. Zdálo se tedy, že stávající přístup k výuce přírodních věd nese dobré výsledky (blíže viz ÚIV, 2002; Tomášek et al., 2008). V roce 2000 pak v rámci šetření PISA žáci ČR dosáhli v úrovni přírodovědné gramotnosti výsledku nad průměrem zemí OECD. I když nebyl výsledek tak vynikající jako u šetření TIMSS, stále byl v porovnání s dalšími gramotnostmi – matematickou a čtenářskou - velmi uspokojivý (blíže viz ÚIV, 2002; Blažek & Příhodová, 2016). TIMSS a PISA se proto staly z hlediska utváření cílů přírodovědného vzdělávání vítanou inspirací (viz např. MŠMT, 2007), ale nikoli hnacím motorem jeho změn. Na rozdíl od zkvalitnění počítačové gramotnosti se pak přírodovědná gramotnost neprosadila ani do cílů strategických směrů Dlouhodobého záměru vzdělávání a rozvoje vzdělávací soustavy ČR (2007).

1.2 Počátek 21. století – badatelsky orientovaná výuka

Další reforma, která měla přispět k vytvoření úplné autonomie škol v České republice, začala probíhat od roku 2001 (blíže viz MŠMT, 2001). V té době se Česká republika chystala na vstup do Evropské unie, což reformu do značné míry ovlivnilo, a to v celkovém pojetí přístupů ke vzdělávání. Akcent byl kromě předmětových vědomostí a dovedností kladen také na rozvoj univerzálnějších žákovských vědomostí a dovedností, tzv. klíčových kompetencí (blíže viz Hučínová, 2005). Oblast vzdělávání v přírodních vědách pak zasáhl ještě další nový celosvětový fenomén, a tím se stala badatelsky orientovaná výuka (IBSE). I když badatelsky orientovaná výuka nebyla rozhodně novým konceptem a v řadě zemí se s ní pracovalo od 60. let 20. století, lze se domnívat, že jejímu většímu prosazení v evropském kontextu napomohly jednak některé realizované projekty (např. projekty ESTABLISH, MASCIL, POLLEN, S-TEAM, TEMI), jednak zpráva Evropské komise zpracovaná týmem kolem Michela Rockarda s názvem *Science Education NOW: A Renewed Pedagogy for the Future of Europe*. Tato zpráva konstatovala, že v evropských zemích dochází k odklonu zájmu mladých o studium přírodních věd, a to navzdory tomu, že přírodní vědy jsou vnímány pro společnost jako zásadní. Konstatovala také, že jedním z důvodů nezájmu mladých lidí o přírodní vědy je způsob jejich výuky a že podpora inovací v přírodovědném vzdělávání, resp. vyučování, je roztříštěna. Ve zprávě je opakovaně zdůrazněna nutnost podpory takových metod výuky v přírodovědném vzdělávání na školách, které povedou od převážně deduktivních k badatelsky orientovaným metodám výuky, což se odráží i v doporučeních a závěrech ve zprávě (blíže viz EC, 2007). Zprávu Evropské komise (EC) v tomto smyslu podpořila i britská studie s názvem Science Education in Europe: Critical reflections vedená renomovanými vědci Osbornem a Dillonem (2008). Obě studie považují badatelsky orientovanou výuku zejména za motivační prvek pro zvýšení zájmu mladých lidí o přírodní vědy, což odpovídá studiím dalších autorů, jakými jsou Crawford (2000), Holbrook a Kolodner (2000) či Marx et al. (2004). To však nevypovídá nic o její efektivitě ve smyslu utváření znalostí žáků; v tomto smyslu je metoda stále intenzivně diskutována jak zastánci, tak odpůrci daného přístupu (viz např. Kirschner et al., 2006; Bunge, 2012). V souvislosti s potřebou inovovat přístupy k výuce přírodovědných oborů se samozřejmě v obou zprávách diskutují také příslušné úpravy kurikula, které by nové, časově náročné metody umožnily, a dále potřeba podpory učitelů v jejich osvojování. V britské zprávě je zdůrazňována také skutečnost, že kurikulum má být nastaveno tak, aby umožnilo orientaci žáků v běžném i profesním životě a umožnilo jim také pochopit komplexnější jevy, které je obklopují. Tento trend, jak jsme uvedli shora, se doposud zachovává již od 90. let v celé Evropě, ČR nevyjímaje.

Vzhledem k tomu, že v období, kdy se badatelsky orientovaná výuka začala celosvětově více prosazovat do vzdělávání, byla reforma školství v České republice téměř u konce, koncept badatelsky orientované výuky se do nově připravených kurikul nepromítl. Důvodem nebylo zásadnější odmítání této myšlenky ze strany odborné a decizní sféry, jako spíše skutečnost, že kurikulum nemělo explicitně předepisovat metody a postupy ve výuce na školách; to bylo ponecháno na samotných školách. Navíc charakteristika vzdělávacích oblastí Dítě a svět (Rámcový vzdělávací program pro předškolní vzdělávání – RVP PV), Člověk a jeho svět (Rámcový vzdělávací program pro základní vzdělávání – RVP ZV) a Člověk a příroda (RVP ZV) zavedení tohoto přístupu nijak nebránila. Pojem badatelsky orientovaná výuka také nefiguruje v žádném z dlouhodobých záměrů mezi lety 2007–2015. Lze tedy konstatovat, že na rozdíl od jiných zemí nebyla a není aplikace badatelsky orientované výuky prosazována systémově a její využití se odvíjí pouze od zájmu učitelů o její aplikaci ve výuce.

Společně s badatelsky orientovanou výukou se také celosvětově začaly více prosazovat vzdělávací programy založené na principu STEM[3], tedy principu, který apeluje na větší provázanost inovativní výuky matematiky, přírodních věd a technologií. I když se koncept objevoval již od 90. let 20. století, větší pozornosti se mu začalo dostávat ve druhé polovině první dekády 21. století. Koncept lze však v zásadě chápat jako spojení dvou již shora popsaných přístupů. STEM prosazuje nutnost zasadit výuku do kontextu běžného života, kde používáme kombinaci poznatků přírodních věd s dalšími vědními obory (např. matematikou) a technologiemi, a iniciuje proměnu přístupu k výuce přírodních věd, která zvýší možnost jejich pochopení i zájem o ně (blíže viz např. Zeidler, 2016; Bybee, 2010). Často je prostředkem pro tuto změnu míněna badatelsky orientovaná výuka. Princip STEM se podobně jako badatelsky orientovaná výuka v kurikulu České republiky nevyskytuje. Koncepce RVP ji však umožňuje.

Ke konci první dekády 21. století se v České republice dostalo (krátkodobě) více pozornosti také konceptu gramotností vymezených v šetření PISA. V tomto období vznikly dvě příručky zabývající se problematikou vymezení jednotlivých gramotností (blíže viz Faltýn et al., 2010; VÚP, 2011) a dále v projektu České školní inspekce s názvem Národní systém inspekčního hodnocení vzdělávací soustavy v České republice (NIQES) realizovaného od roku 2011. Přírodovědná gramotnost také figurovala v oblasti stanovených reformních kroků, které byly definovány v Dlouhodobém záměru vzdělávání a rozvoje vzdělávací soustavy v ČR (2011–2015), konkrétně v bodu A2.2 „Podpořit oblast oborových didaktik a zlepšit úroveň vzdělávání ve spolupráci s fakultami vzdělávajícími učitele a prostřednictvím systému DVPP“. Do kurikul všeobecného vzdělávání se však koncept nijak neprosadil, a to navzdory skutečnosti, že v daném období probíhaly jeho dílčí revize (blíže viz Janoušková et al., 2019).

1.3 Druhá dekáda 21. století – věda a poznání pro občany

Počátek 21. století se minimálně v rámci Evropy nese v duchu motta: Docílit v Evropě chytrého, udržitelného a inkluzivního růstu (blíže viz EC, 2010). To je dle odborníků Evropské komise možné za předpokladu, že si všichni občané osvojí důležité znalosti, které jim napomohou aktivně participovat ve společnosti a zodpovědně

[3]Definice STEM není konsenzuálně vymezena (Breiner et al., 2012). V obecnějším pojetí ji lze chápat také jako jakékoli hnutí směřující k reformám ve výuce příslušných předmětů, které by vedly ke zvýšení zájmu studentů o výuku přírodovědných oborů.

se podílet na jejím rozvoji. Pro dosažení tohoto cíle byla zpracována odborná zpráva s názvem *Přírodovědné vzdělávání pro zodpovědné občanství* (Science Education for Responsible Citizenship, Hazelkorn et al., 2015), která vytyčuje šest cílů a opatření, které by měly být naplněny pro žádoucí rozvoj Evropy. Těmito cíli jsou (i) kontinuální přírodovědné vzdělávání začínající v úrovni preprimárního vzdělávání; (ii) rozvoj žádoucích kompetencí a přechod od STEM ke STEAM – provázání přírodovědného, technického a matematického vzdělávání s dalšími vědními disciplínami; (iii) zlepšení přípravy učitelů a dalšího vzdělávání učitelů pro zajištění dobrých výsledků vzdělávání; (iv) spolupráce mezi aktéry ve formálním, neformálním a informálním vzdělávání a spolupráce s podniky a dalšími aktéry vzdělávání ve společnosti pro zvýšení zájmu o studium a budoucí zaměstnání v oblasti přírodních věd; (v) posílení vědy a výzkumu v oblasti přírodních věd a komunikace jejich výsledků se společností; (vi) propojení nových poznatků v oblasti přírodovědného vzdělávání na lokální, národní a mezinárodní úrovni při zohlednění sociálních potřeb a globálního vývoje. Za inovaci ve smýšlení o přírodovědném vzdělávání však můžeme považovat pouze přechod od STEM k STEAM zahrnující ještě Arts, všechny ostatní cíle jsou v zásadě totožné s cíli, které byly zmiňovány v předchozích obdobích. Badatelsky orientovaná výuka zůstává stále akcentována v rámci obou zmíněných konceptů.

Česká republika pro druhou dekádu 21. století disponuje dvěma zásadními dokumenty vztahujícími se ke vzdělávání. Prvním je Strategie vzdělávací politiky do roku 2020 (MŠMT, 2015a) a druhým je Dlouhodobý záměr vzdělávání a rozvoje vzdělávací soustavy České republiky na období 2015–2020 (MŠMT, 2015b). Strategie vzdělávací politiky je mj. klíčovým dokumentem a zároveň podmínkou pro čerpání prostředků z Evropské unie. Její prioritní osy jsou proto nastaveny poměrně obecně a přírodovědné vzdělávání se tak v dokumentu explicitně v prioritách vzdělávání nevyskytuje. Dlouhodobý záměr, který na danou strategii navazuje, pak přírodovědné vzdělávání zmiňuje ve třech případech. Prvním je formulace opatření, která mají směřovat k zlepšení podmínek základního vzdělávání. Zde lze nalézt mj. opatření směřující ke zvýšení kompetencí pedagogů, jež má vést ke zlepšení vzdělávacích výsledků žáků; akcent je v tomto opatření kladen na čtenářskou, přírodovědnou a matematickou gramotnost (blíže viz MŠMT, 2015b; opatření B4.3). Druhým případem je formulace opatření směřujícího k modernizaci systému odborného středního vzdělávání, přičemž tato modernizace má vést k intenzivnějšímu a efektivnějšímu rozvoji přenositelných znalostí. Opatření explicitně zmiňuje nutnost revizí kurikul přírodovědných a technologických oborů (blíže viz MŠMT, 2015b; opatření C4.1). Rozvoji přírodovědného a technologického vzdělávání ve středním odborném vzdělávání je v Dlouhodobém záměru věnována pozornost i ve smyslu možnosti navyšování kapacit v oborech s tímto zaměřením. Třetím případem je formulace opatření směřující k podpoře efektivní formy vzájemného sdílení zkušeností mezi pedagogy. V opatření se explicitně uvádí nutnost podpory DVPP s cílem zlepšení metodiky vzdělávání v matematice a přírodovědných předmětech (blíže viz MŠMT, 2015b; opatření H10.2).

Druhá polovina druhé dekády 21. století je však pro Českou republiku z hlediska přírodovědného vzdělávání velmi zásadní. Po více než 10 letech začíná v České republice zásadní revize kurikul od úrovně předškolního vzdělání do úrovně vyššího odborného i všeobecného vzdělávání. Základy reformy prozatím představují nový přístup k tvorbě jednotného kurikula, které by vytvářel jediný rozsáhlý tým a zajistil tak dobré vazby mezi jednotlivými stupni vzdělávání v jednotlivých vzdělávacích oblastech, resp. oborech. Vzhledem k tomu, že revize jsou teprve na počátku, nelze činit prozatím mnoho závěrů. Zásadní a alarmující pro přírodovědné vzdělávání je však skutečnost, že v prozatímním návrhu kompetencí, resp. gramotností, figurují následující kompetence/gramotnosti: matematická, digitální, komunikace v mateřském jazyce a cizích jazycích, kulturní povědomí a vyjádření, v oblasti vědy, technologií a inženýrství, personální a sociální, k učení, občanská, k podnikavosti. Přírodovědná kompetence/gramotnost ve výčtu zatím nefiguruje a je pouze implicitní součástí kompetence v oblasti vědy[4], technologií a inženýrství. Je však nutno podotknout, že vědy mohou být chápány jako vědy různého druhu, nejen přírodní.

2 Vývoj cílů přírodovědného vzdělávání pro úroveň nižšího sekundárního vzdělávání – metodologie

V další části článku se chceme věnovat vývoji cílů přírodovědného vzdělávání na úrovni nižšího sekundárního vzdělávání, které byly specifikovány v zamýšlených kurikulech (vzdělávacích standardech) v posledních třiceti letech. Pro analýzu byly zvoleny dva kurikulární dokumenty – Standard základního vzdělávání (MŠMT, 1995)[5] a Rámcový vzdělávací program pro základní vzdělávání (VÚP, 2005; MŠMT, 2017), které pokrývají shora uvedené období a zahrnují všechny revize přírodovědného kurikula v dané době. Dokumenty byly analyzovány (obsahová analýza) jako celek, tj. cíle přírodovědného vzdělávání byly identifikovány nejen ve specifických cílech oborů, resp. charakteristice vzdělávací oblasti přírodovědných oborů (tyto dva analyzované segmenty si odpovídají), ale také v úvodních obecných částech kurikul.

Pro systém kódování byl využit software Atlas.ti. Software umožnil přehledně označovat úseky v rozsáhlých textech souvisejících s přírodovědným vzděláváním (kurikulech) a údaje v něm uvedené kategorizovat a konceptualizovat. Kategorie byly odvozeny deduktivně (viz např. Mayring, 2000) od definice přírodovědné gramotnosti dle studie Gramotnosti ve vzdělávání (VÚP, 2011) s mírnou úpravou ve čtvrté kategorii, kam byla navíc zařazena subkategorie *zdraví a zdravý životní styl*. Terminologie použitá v jejím vymezení napomohla lépe interpretovat získané údaje. Reliabilita dat byla zajištěna dvojím nezávislým kódováním dokumentů a konzultací s tvůrcem obou kurikul, který napomohl nejasnosti interpretovat. Kódovací klíč je uveden v tab. 1.

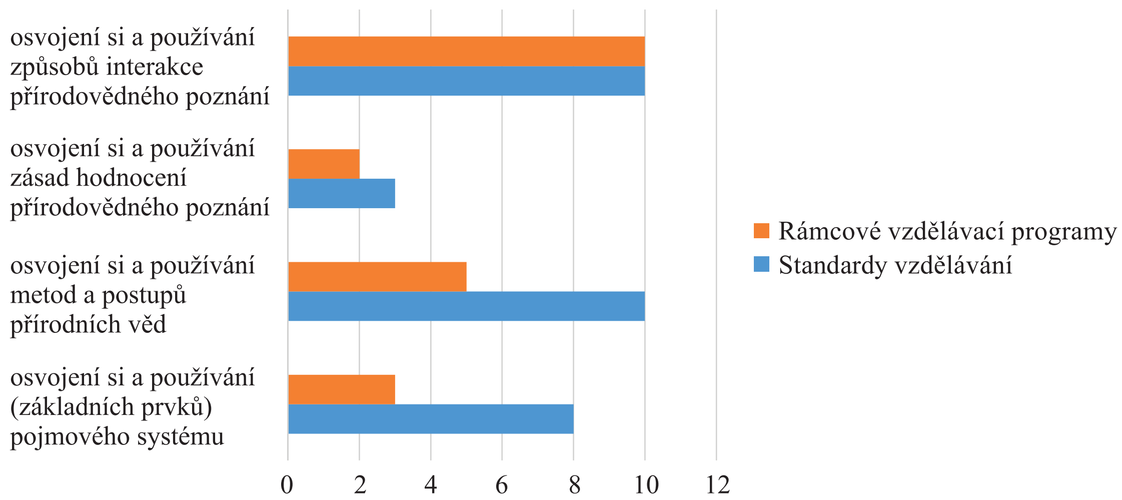
Jako orientační proxy proměnná významnosti konkrétních kategorií/témat přírodovědné gramotnosti byla zvolena četnost jednotlivých kategorií i subkategorií. Podle některých autorů (např. Saldaña, 2013) sice frekvence výskytu nemusí odpovídat vždy významnosti dané kategorie/tématu, na druhou stranu autoři jako Weber (1990) uvádějí, že v případě obsahové analýzy dokumentů lze hypotetizovat, že vyšší relativní počty zastoupení dané kategorie/tématu odráží vyšší zájem o kategorii/téma jako takovou. Výzkum v oblasti kurikula s využitím četností témat, resp. kategorií, byl realizován např. ve studii Malekipour et al. (2017).

[4]Doporučení Evropského parlamentu a rady z 18. prosince 2006 o klíčových schopnostech pro celoživotní učení 2006/962/ES však definuje Mathematical competence and basic competences in science and technology; science je při bližší analýze dokumentu definována jako kompetence v oblasti přírodních věd.

[5]Předmětem analýzy nebyl specificky Standard pro základní vzdělávání – Chemie (Janoušková et al., 2013). Tento Standard sice přináší minimální cílové požadavky na vzdělávání, ale jsou v něm rozpracovány pouze očekávané výstupy RVP ZV v daném oboru s cílem ukázat možné způsoby hodnocení dosažení těchto výstupů. Jedná se tedy výhradně o obsahový standard (viz Janoušková et al., 2012) rozpracovávající to, co je již v RVP zahrnuto. Daný Standard nepřináší více poznání v dané problematice než RVP ZV (2017), jehož je součástí.

Tab. 1: Kódovací klíč (upraveno podle VÚP, 2011)

Kategorie/téma	Subkategorie
osvojení si a používání základních prvků pojmového systému přírodních věd	• osvojení si základních pojmů • osvojení si základních zákonů, principů, hypotéz, teorií a modelů
osvojení si a používání metod a postupů přírodních věd	• empirické metody a postupy • racionální metody a postupy
osvojení si a používání způsobů hodnocení přírodovědného poznání	• způsoby testování (potvrzování či vyvracení) objektivity, spolehlivosti a pravdivosti přírodovědných tvrzení (dat, hypotéz apod.) • způsoby zjišťování chyb či zkreslování dat v přírodovědném zkoumání • kritické zhodnocení informací (včetně médií)
osvojení si a používání způsobů interakce přírodovědného poznání s ostatními segmenty lidského poznání	• matematické prostředky v přírodovědném poznávání • používání prostředků moderních technologií • personální rozhodování a řešení problémů • důsledky aplikací přírodovědného poznávání pro člověka a jeho prostředí • zdraví a zdravý životní styl



Graf 1: Četnost výskytu kategorií/témat ve Standardu a Rámcovém vzdělávacím programu pro základní vzdělávání

V našem článku četnost kategorií napomáhá především lépe strukturovat uvažování o výsledcích kvalitativního výzkumu (frekvenci jednotlivých kategorií/témat shrnuje graf 1). Kromě četnosti kategorií/témat byla totiž dále sledována distribuce kategorií/témat v kurikulu, tj. zda jsou kategorie/témata vázány převážně/výhradně na přírodovědné obory v kurikulu, či zda jsou zahrnuty též v obecných částech kurikula a představují obecně významný cíl v rámci vzdělávání. Výsledky také kvalitativně popisují vztahy zjištěné mezi jednotlivými kategoriemi.

3 Výsledky obsahové analýzy kurikul

3.1 Standard základního vzdělávání

Standard základního vzdělávání (dále Standard) zahrnuje všechny kategorie/témata, které jsou uvedeny v pravém sloupci tab. 1. Jednou ze dvou nejčetněji zastoupených kategorií je kategorie *osvojení si a používání způsobů interakce přírodovědného poznávání s ostatními segmenty lidského poznávání*, což je v přímém souladu s přístupem k výuce přírodních věd od 90. let minulého století. Tato kategorie/téma je natolik zásadní, že je opakovaně zmiňována i v obecných vzdělávacích cílech kurikula (4 z 10 výskytů). V rámci dané kategorie je důraz kladen zejména na schopnost žáků řešit problémy a rozhodovat se (poučeně) v běžných životních situacích, na důsledky aplikací přírodovědného poznávání pro člověka a jeho (životní) prostředí a na zdraví a zdravý životní styl. I to je v souladu s obecným trendem přírodovědného vzdělávání, který trvá od 90. let doposud. Ve vzdělávacích cílech je zmiňována rovněž komunikace *prostřednictvím číselných a prostorových znaků a útvarů*, což je pro přírodní vědy typické; můžeme tedy konstatovat, že implicitně je zahrnuta i subkategorie *matematických prostředků v přírodovědném poznávání.* Používání prostředků moderních technologií ve vztahu k přírodovědnému vzdělávání zmiňována v cílech není.

Další z nejčetnějších kategorií zahrnutých ve Standardu základního vzdělávání je kategorie/téma *osvojení si a používání metod a postupů přírodních věd.* Počet výskytů obou subkategorií (racionální a empirické metody) je ve Standardu ekvivalentní. Podstatné je, že kategorie je zahrnuta již v obecných cílech Standardu (i když méně než ve specifických cílech oborů) a je tedy obecně považována za významnou. Je také třeba podotknout, že využívání racionálních (někdy i empirických) metod je podstatou řešení komplexních, často multidisciplinárních problémů a slouží k personálnímu rozhodování. Mezi popisovanou kategorií a subkategorií *personální rozhodování a řešení problémů* je tedy významný synergický vztah. Kladení důrazu na používání empirických i racionálních metod ve výuce přírodních věd je dlouholetou tradicí, která je v posledních letech stále více akcentována. Četnost i rozložení této kategorie ve Standardu proto není překvapující.

Další kategorií/tématem, která je součástí Standardu, je kategorie *osvojení si a používání základních prvků pojmového systému přírodních věd.* Zde je četnost zastoupení kategorie třeba brát s určitou rezervou. Důvodem je skutečnost, že v kurikulech je značná část prostoru věnována vzdělávacímu obsahu jednotlivých oborů a vzdělávací obsah sám obsahuje řadu konkrétních pojmů, principů, zákonů, modelů či teorií. My jsme se ovšem zaměřovali na deklaraci těchto subkategorií v cílech vzdělávání, nikoli ve vzdělávacím obsahu samotném. Důvodem je skutečnost, že zejména média dlouhodobě hovoří o nadměrném zastoupení faktů ve vzdělávání a jejich memorování žáky (viz např. Respekt, 1/2016). To laickou veřejnost často vede k přesvědčení, že osvojování si pojmů, konceptů atp. není podstatné a důraz má být kladen ve výuce na jiné žákovské dovednosti. Bez toho však výuka přírodovědných oborů i výuka jako taková přirozeně postrádá smysl. Bez osvojení si pojmů, zákonů, principů, modelů apod. nemohou být rozvíjeny další kategorie/témata přírodovědné gramotnosti zde uvedené a deklarace jejich osvojení v obecných vzdělávacích cílech i v cílech specifických je tak zásadní.

I u této kategorie můžeme konstatovat, že je zahrnuta jak v obecných cílech kurikula, tak ve specifických cílech přírodovědných oborů (zde je zastoupena více). Obecné cíle kurikula mluví specificky o nutnosti osvojení pojmů a faktů. Fakta jsou objekty, jevy a procesy a různé druhy vztahů mezi nimi, implicitně je tedy zahrnuta i druhá subkategorie. Oblast přírodovědná hovoří o nutnosti pochopení přírodních jevů a procesů, což není bez znalosti pojmů, zákonů a principů možné. Specifické cíle jsou ve Standardu poměrně nekonzistentně pojaty a kombinují cíle obecně formulované (např. ve fyzice) s cíli poměrně oborově specifickými (např. biologii a geologie). Obecně lze však říci, že na tuto kategorii/téma je kladen v oblasti přírodovědné i v jednotlivých přírodovědných oborech Standardu poměrně velký akcent.

Nejméně frekventovanou kategorií/tématem je ve Standardu *osvojení si a používání způsobů hodnocení přírodovědného poznání*. V obecných cílech Standardu je zdůrazněna nutnost kritického posuzování informačních zdrojů, což přibližně odpovídá subkategorii *kritického hodnocení (pseudovědeckých) informací*. Ve specifických cílech můžeme kategorii nalézt jen v oboru fyzika, další obory ani oblasti s touto kategorií nepracují. Tato skutečnost pravděpodobně souvisí s tím, že daná kategorie přírodovědné gramotnosti je z hlediska výuky poměrně náročná a například koncept kritického myšlení, který s kategorií/tématem souvisí, se v České republice začal prosazovat spíše ke konci 20. a na začátku 21. století s rozvojem dostupnosti informačních zdrojů, především internetu.

3.2 Rámcový vzdělávací program pro základní vzdělávání

Pro analýzu Rámcových vzdělávacích programů (dále RVP ZV) byly vybrány dva dokumenty, původní RVP ZV z roku 2007 a nově revidovaný RVP ZV z roku 2017. V analyzovaných cílech RVP ZV (VÚP, 2007) a RVP ZV (MŠMT, 2017) nebyly identifikovány zásadnější rozdíly a dále je tedy pojednáváno o dokumentu jako o dokumentu jediném. Rámcový vzdělávací program pro základní vzdělávání zahrnuje všechny kategorie/témata, které jsou uvedeny v tab. 1. Z hlediska četnosti zastoupení je opět velmi akcentována kategorie *osvojení si a používání způsobů interakce přírodovědného poznání s ostatními segmenty lidského poznání*. V obecné části kurikula (týkající se kompetencí[6]) je zastoupena subkategorie *používání prostředků moderních technologií*, *personálního rozhodování a řešení problémů, zdraví a zdravého životního stylu a vztah člověka k životnímu prostředí*. Podobnost mezi RVP ZV a Standardem je velká. Větší rozdíl je jen ve zdůraznění významu moderních technologií jako komunikačního nástroje s ostatním světem. To je vzhledem k rozmachu a nutnosti využívání technologií v běžném i profesním životě poměrně očekávatelná změna. Ještě významněji je kategorie/téma *osvojení si a používání způsobů interakce přírodovědného poznání s ostatními segmenty lidského poznání* zastoupena ve vzdělávací oblasti Člověk a příroda a částečně také v průřezovém tématu Environmentální výchova. Významný podíl zařazení této kategorie/tématu v kurikulu reflektuje dlouhodobou snahu kurikul napříč zeměmi o propojení přírodovědného vzdělávání s běžným životem.

Druhou nejčetněji zařazovanou kategorií/tématem v kurikulu je *osvojení si a používání metod a postupů přírodních věd*. Stejně jako v případě Standardu existuje významná vazba mezi touto kategorií a subkategorií *personální rozhodování a řešení problémů*. V obecné části kurikula je tato kategorie zahrnuta v kompetenci k řešení problémů. Zahrnuta je rovněž v charakteristice vzdělávací oblasti Člověk a příroda. Přestože jsme v metodologické části konstatovali, že četnost výskytu konkrétních ka-

[6] Vzhledem k tomu, že klíčové kompetence mají být naplňovány ve všech vhodných oborech obsažených v RVP ZV, lze dle našeho názoru považovat i obecně formulované kategorie, resp. subkategorie, za kategorie potencionálně spjaté s přírodovědným vzděláváním.

tegorií v kurikulu je jen orientační a nemusí nutně odrážet významnost dané kategorie ve vzdělávání, zde stojí relativně nižší četnost výskytu kategorie/tématu (oproti Standardu) za zamyšlení. Dle našeho názoru, opřeného o zkušenost z tvorby kurikul, je nižší četnost způsobena tím, že přírodovědné vzdělávací obory jsou sloučeny pod jednu oblast (Člověk a příroda) s totožnou charakteristikou a kategorie/téma *osvojení si metod a postupů* se tudíž neopakuje znovu u každého oboru zvlášť, jak je tomu ve Standardu. Domníváme se také, že nižší četnost výskytu dané kategorie nemá souvislost s tím, že základní školy při tvorbě kurikula vyvíjely na decizní sféru tlak směřující k rušení laboratoří (z ekonomických důvodů). To mohlo vést k určité změně přístupu k výuce na úrovni školních kurikul, ale na úrovni RVP ZV se to nepromítlo. Metody a postupy přírodních věd tak zůstaly důležitou částí kurikula, což odpovídalo a odpovídá celosvětovému trendu.

Obdobně jako v případě Standardu je také v RVP ZV kategorie/téma *osvojení si a používání základních prvků pojmového systému přírodních věd* zařazena jak do obecné části kurikula (kompetence k učení), tak do charakteristiky oblasti Člověk a příroda. Kompetence k učení explicitně hovoří o nutnosti propojování poznatků z různých vzdělávacích oblastí, resp. vzdělávacích oborů, a zmiňuje nutnost osvojení si „termínů“, což lze chápat jako pojmy. Charakteristika oblasti Člověk a příroda hovoří o nutnosti pochopení zákonitostí přírodovědných procesů a užitečnosti přírodovědných poznatků. Relativně nižší četnost výskytu, stejně jako v případě Standardu, vychází ze skutečnosti, že konkrétní pojmy, zákony, principy, teorie či modely jsou uvedeny přímo ve vzdělávacím obsahu jednotlivých oborů, konkrétně v očekávaných výstupech, případně učivu. Rozdíl četnosti mezi Standardem a RVP ZV je dán skutečností, že řada konkrétních zákonů a principů byla uvedena již ve specifických cílech. Při kódování pouze obecných vyjádření by četnost výskytu kategorie/tématu byla ekvivalentní. Podstatné je deklarování nutnosti se poznatkům přírodních věd učit, což, jak jsme uvedli již v případě Standardu, je nutnou podmínkou pro úspěšné zvládnutí dalších kategorií/témat přírodovědné gramotnosti tak, jak jsou zde uvedeny.

Poslední kategorie/téma zahrnuté v RVP ZV je kategorie *osvojení si a používání způsobů hodnocení přírodovědného poznání*. Na rozdíl od Standardu je četnost uvedení kategorie/tématu významnější. Je to dáno zejména zařazením průřezového tématu Mediální výchova. V obecné části kurikula je možno nalézt danou kategorii/téma v kompetenci k řešení problémů, kde je uvedena v souvislosti s ověřením správnosti řešení konkrétních problémů. V části týkající se specificky přírodovědných oborů (oblast Člověk a příroda) je zahrnuta subkategorie týkající se *způsobů testování (potvrzování či vyvracení) objektivity, spolehlivosti a pravdivosti přírodovědných tvrzení (dat, hypotéz apod.)*. Vyhodnocení věcné správnosti, logické argumentační stavby a hodnotové platnosti a kritický přístup k informacím, tedy subkategorie *kritického hodnocení informací*, je řešena jednak v charakteristice průřezového tématu Mediální výchova, jednak v přínosu tohoto průřezového tématu k rozvoji osobnosti žáka. V této kategorii/tématu tak můžeme zaznamenat nejvýznamnější posun v cílech vzdělávání (včetně přírodovědného) za posledních třicet let.

4 Závěr

Rozsáhlá rešerše přístupů k přírodovědnému vzdělávání za posledních třicet let na mezinárodní i národní úrovni a analýza cílů vzdělávání, resp. přírodovědného vzdělávání, ukázala, že Česká republika respektuje většinu zahraničních trendů, které se ve výuce objevují a revize kurikula posunula, alespoň v rovině zamýšleného kurikula, přírodovědné vzdělávání žádoucím směrem. Současné nastavení kurikula umožňuje rozvíjet všechny vzájemně provázané dimenze přírodovědné gramotnosti, jak byly vymezeny ve VÚP (2011). Tyto dimenze odpovídajícím způsobem korespondují s analyzovanou literaturou týkající se vymezení přírodovědné gramotnosti v současnosti a korespondují rovněž s obecnými cíli vzdělávání, které jsou dány aktuálními strategickými dokumenty národní i mezinárodní povahy.

Z pohledu aktuálních revizí je dle našeho názoru nutné se zasadit o explicitní vymezení přírodovědné kompetence/gramotnosti jako jedné z neopominutelných kompetencí; zachování, případně větší prosazení důležitosti přírodovědného vzdělávání do všeobecných vzdělávacích cílů, pokud budou v novém kurikulu specifikovány; zachování, případné zpřesnění stávajících specifických cílů přírodovědného vzdělávání (oblast Člověk a příroda) tak, aby mohly být rozvíjeny všechny kategorie přírodovědné gramotnosti zde uvedené (viz tab. 1); zachování vybraných průřezových témat (zde diskutovaná Environmentální výchova a Mediální výchova) a při jejich absenci zajistit přesun relevantních cílů k specifickým cílům přírodovědných oborů; diskuzi optimálních metod a postupů ve výuce (BOV a STEAM).

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Svatava Janoušková, svatava.janouskova@natur.cuni.cz
Pavel Teplý, pavel.teply@natur.cuni.cz
Hana Čtrnáctová, hana.ctrnactova@natur.cuni.cz
Univerzita Karlova, Přírodovědecká fakulta
Katedra učitelství a didaktiky chemie
Hlavova 2030/8, Praha 2, Česká republika

Jan Maršák, jmarsak@seznam.cz
nezávislý expert, Česká republika

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Adresa redakce
Pedagogická fakulta, Univerzita Karlova, Magdalény Rettigové 4, 116 39 Praha 1
e-mail: scied@pedf.cuni.cz

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