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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.

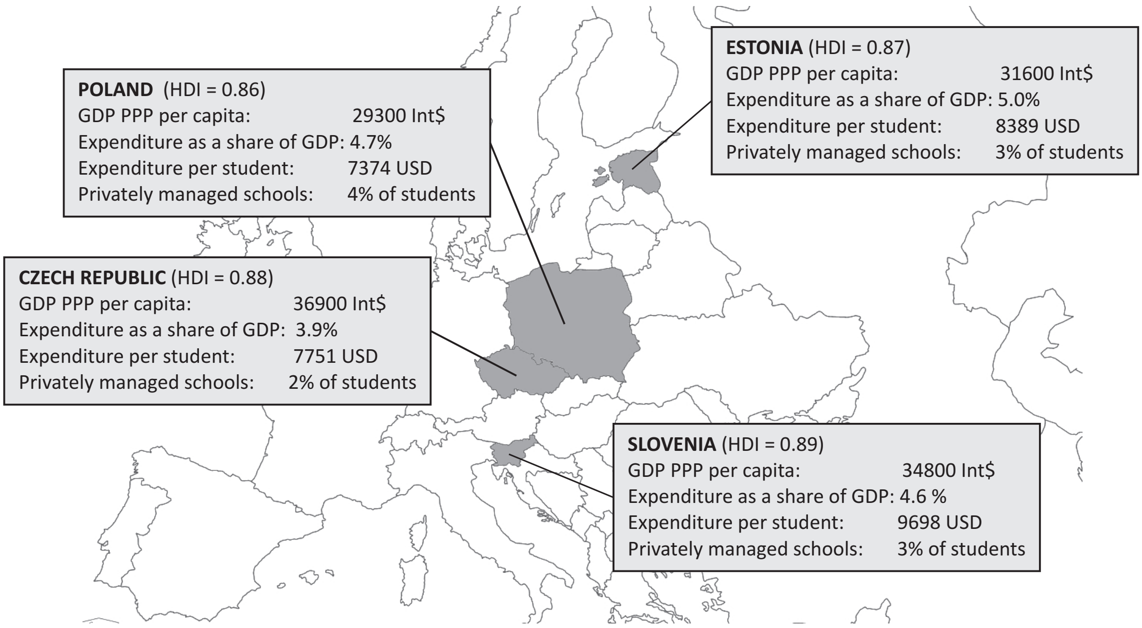

Fig. 1: For each country, the values of Human Development Index (HDI), gross domestic product purchasing power parity (GDP PPP) per capita, expenditure on education as a share of GDP, annual expenditure per student and the ratio of students attending privately manage schools are indicated

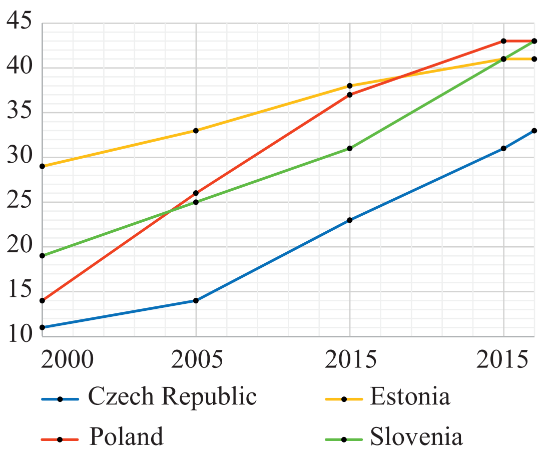

Fig. 2: The ratio of people aged 25–34 with finished tertiary education

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.

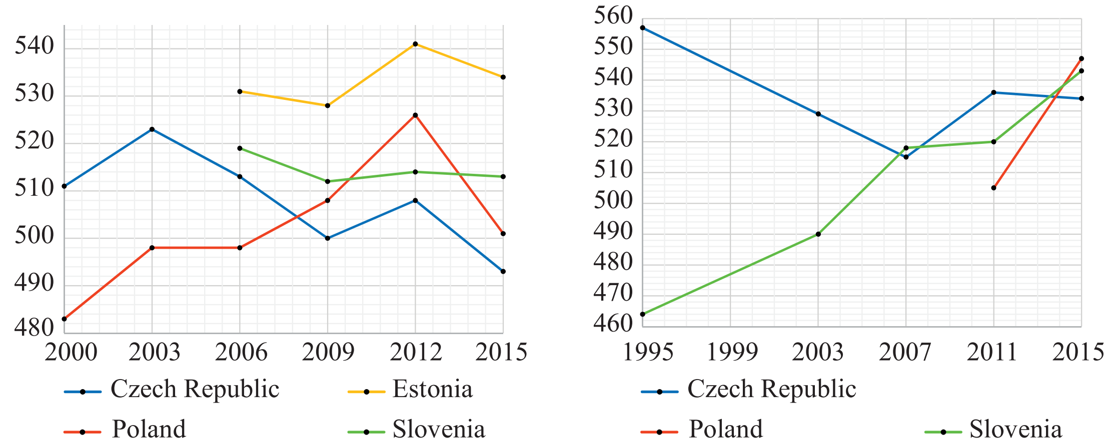

Fig. 3: On the left the PISA national scores in scientific literacy; Estonia and Slovenia have participated since 2006. On the right the TIMSS national scores for 4th grade pupils

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).

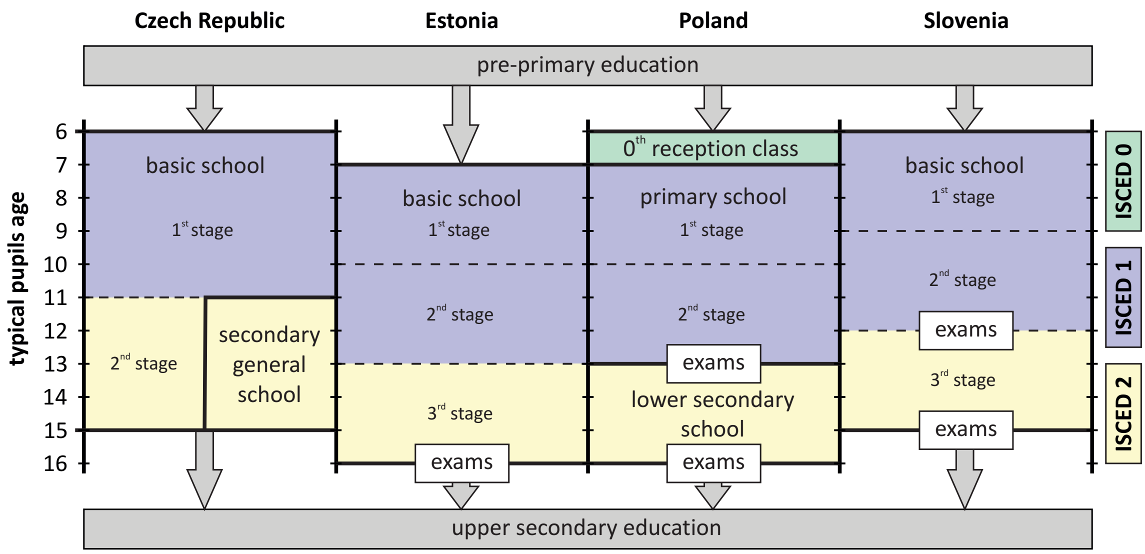

Fig. 4: Full-time compulsory educational system in Czech Republic, Estonia, Poland and Slovenia

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 2^{nd} and 3^{rd} 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 6^{th} grade, and further in math, the native language and a third subject chosen by the ministry in 9^{th} 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: √ = taught in *Physics*, √S = taught in *Science*, × = not taught at lower secondary school level

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

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