Comparison of the National Curriculum from the STEM Perspective with Focus on Technologies and Engineering in the Czech Republic, Poland and Slovakia

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Abstract **- *The* curriculum naturally changes as the world changes. The shape of education responds to social need changes, rapid technological developments, and changes in nature, especially in the context of global warming. On the other hand, cultural frameworks and practices, which make national curricula specific, have a stabilizing function. In the Czech Republic, work is currently underway to innovate a key national curriculum document that specifies what, to what extent, and under what conditions pupils learn in primary schools. To reflect on the new competencies, the new curriculum, and its organization based on different views and experiences from abroad, this comparative study was carried out to compare the curricula in the Czech Republic, Slovakia, and Poland. We did not focus on STEM education as a whole, but only on the field of technology and engineering. Thus, we obtained an answer to the question of whether engineering education is implemented in primary schools in these countries. The aim was not only to compare content but to bring a deeper understanding of the subject matter. To this end, we established 6 criteria based on which we made the comparison. Finally, based on the results of the analysis, we discussed the barriers to the implementation of STEM concepts in education in the Czech Republic and drew negative consequences that could be manifested in the case of ill-considered interventions in the national curriculum.**

DOI: 10.18421/TEM121-67
https://doi.org/10.18421/TEM121-67

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Received: 27 November 2022.
Revised: 27 December 2023.
Accepted: 14 February 2023.
Published: 27 February 2023.

Keywords **- *t*echnology, crafts, STEAM, teaching subject, elementary school, curriculum, comparative study.**

1. Introduction

National educational research is very important, but there are phenomena that it is desirable, and sometimes even necessary, to study more broadly, as geographical boundaries prove to be a limiting factor. There may be very similar conditions for the implementation of education in different countries, but some factors may cause differences that are worth analyzing both in terms of causes and consequences. With the above in mind, in the context of curriculum reform [1], we have encountered the need to answer the question of whether technical education in primary schools is also implemented in culturally close countries such as Slovakia and Poland. If so, to what extent is it similar or different, and what content are pupils in these countries educated with? The answers obtained will help to design a more appropriate form of the framework curriculum.

We encounter curricula in different forms, to which certain levels correspond. This is because the curriculum exists not as a static phenomenon but as a phenomenon that is fluid in nature. J. Průcha [2] distinguishes the following forms of curriculum: conceptual (idea), project, implementation, result, and effect. In the framework of our analyses, we will move to the project level, which is the concrete project, programs, and scenarios of the content and goals of school education. If we draw on the work of Certis C. McKnight. [3], who proposed the so-called three-level analytical model of curriculum:

-the intended curriculum represented by educational policy measures, plans, and objectives,
-implemented curriculum represented by goals and strategies implemented in pedagogical practice (literally "in the classroom"),

-the curriculum achieved, represented by the knowledge, skills, and attitudes acquired by pupils in the course of their education,

Then, in this study, we focus on the level of the intended curriculum. From a methodological point of view, this study falls into the realm of comparative research. Analytical and descriptive approaches will be applied in order to study similarities and differences and to draw conclusions beneficial for the ongoing curriculum reform in the Czech Republic. In this article, we use the term *Technique* in the sense of the name of the subject. In view of cultural differences and correct conceptual understanding, we will make a brief definition of it. It is a traditional teaching subject that dates back to the 1950s [4]. Initially, it was more focused on skill development through working with technical materials such as wood, metal, plastic, and others. Students made various products using tools and implements. Along with technological developments, activities promoting technical thinking and the development of technical knowledge were gradually incorporated into the curriculum. Information technology in the form of a curriculum was introduced into teaching through this subject, but later a new subject, *Computer Science,* was created [5]. *Technology also focuses on the* development of skills, technical thinking, and technical creativity. Sometimes it is also written about *technical education in primary schools*, which we consider to be identical. If we refer to primary school, then we mean initial education for children aged 6 to 14 years.

2. STEAM - the educational concept of the future

Authentic tasks, i.e. problems in the contemporary real world, tend to be inherently more difficult to solve. Increasingly, the simultaneous use of knowledge or skills from different disciplines is required. It is not the case that we switch from one discipline to another in our minds, as we think in context and in the context of the experience gained when solving real-world tasks [6]. The question then arises as to why we acquire knowledge in school education in artificial fragments represented by the subjects taught? At the level of theory, however, transdisciplinary teaching [7], [8] is coming to the fore, the main purpose of which is to understand the world around us. Reflecting on the multidimensionality of the phenomenon or problem under study, and identifying its internal and external relationships, contexts, interactions, and developmental influences is important for learning. Global interdisciplinary and transdisciplinary learning is becoming increasingly popular in schools. Discussions of comprehensive science, technology, engineering, arts, and mathematics (STEAM) education are emerging, further shifting the traditional STEM educational paradigm [9], [10], which has been criticized for its lack of space for the development of creativity. Our society requires much more than an understanding of individual STEAM fields; it requires application, creation, and ingenuity.

The integration of disciplines across science, technology, engineering, arts, and mathematics, as well as the creation and development of transferable skills, is seen as key. Students should be able to transfer knowledge across disciplines and creatively solve problems in different contexts. Transferability also means the use of knowledge in further education and in everyday personal and working life [11], [12], [13].

The STEAM concept belongs to the phenomenon of the so-called new curriculum, which is characterized by learning in context, practical applicability of knowledge, and greater emphasis on the development of the student's personality, including well-being. "The 'new curriculum' has challenged traditional subjects and their boundaries and, in particular, has introduced a competency-based approach that focuses on 'information seeking' or 'skill formation' and neglects factual knowledge. This is a consequence of the problems brought about by globalization - in addition to the threat to identity, and the increase in economic and social disparities between citizens of many countries [14].

The counterpart of the STEM or STEAM concept is the HASS (Humanities and Social Sciences) concept, which is widely encountered in the United States, Canada, Australia, and other countries [15].

3. Concept and conceptual organization of primary education in the Czech Republic, Poland, and Slovakia

Primary education in the Czech Republic is the only stage of education that is compulsory for the entire pupil population. It comprises two content, organizational and didactic successive stages - grades 1 to 5 and grades 6 to 9, see Table 1. Education at stage 1 is based on the recognition, respect, and development of the individual needs, abilities, and interests of each pupil. It has an activity and practical character which, while applying appropriate methods, motivates pupils to continue learning, leads them to learning activity and to the knowledge that it is possible to search, discover, create and find an appropriate way of solving problems [16]. At Key Stage 2 of primary education, pupils acquire the knowledge, skills, and habits that enable them to learn independently and to form values and attitudes that lead to deliberate and cultured behavior, responsible decision-making, and respect for the rights and responsibilities of citizenship.

There are no specific curriculum subjects for either of the two levels at the national curriculum level. Competences and curriculum frameworks are laid down, both of which are divided into individual learning areas.

It is up to the schools themselves to divide the curriculum into individual subjects, as well as to determine the breadth of content (it is possible to integrate curriculum from different educational areas) and the names of the subjects. At the first level, one teacher provides the teaching. In practice, however, there are cases where computer science, vocational education (or technology), and physical education are provided by other teachers with the appropriate qualifications. At the second level of primary school, more than one teacher with the appropriate professional qualifications is involved in teaching.

Table 1 Comparison of education systems at ISCED 1 and 2 level.

	Czech Republic	Poland	Slovakia
ISCED 1	6 - 11 years (5 years)	7 - 10 years (3 years)	6 - 10 years (4 years)
ISCED 2	12 - 15 years (4 years)	11 - 15 years (5 years)	11 - 15 years (5 years)

In Poland, the first level includes grades 1 to 3 and the second level includes grades 4 to 8. At the first level, one teacher teaches. The aim of the school is to introduce the child to the world of knowledge, to prepare him/her to fulfill his/her duties as a pupil and to support his/her self-development. The school provides a safe environment and a friendly atmosphere for learning, taking into account the individual capabilities and learning needs of the pupil. The most important goal of education in primary school is to nurture the integral biological, cognitive, emotional, social and moral development of the pupil. At the first level of primary school, since 2017, education has been implemented in the form of integrated teaching [17]. Content-wise, it focuses mainly on teaching Polish language, mathematics, social education, science, art education, information education, music education, and foreign language education. The division of lessons into individual compulsory educational activities is carried out by the teacher who conducts the lessons. Although the rule is that the teaching is carried out by one teacher, it is possible for information education and some other educational content to be taught by teachers with the appropriate professional qualifications. In this case, the information education is then delivered with a time allocation of 1 hour per week. At the second level of primary school, the following subjects are taught [18]: Polish language, foreign language, music education, art, history, social sciences, nature, geography, biology, chemistry, physics, mathematics, informatics, technology, physical education, safety education, family education, and ethics.

Teaching is provided by teachers with appropriate credentials. Primary education is also divided into two levels in Slovakia. The first level includes grades 1 to 4 and the second level includes grades 5 to 9. In Key Stage 1, balanced attention is paid not only to the cognitive and intellectual aspects of education but also to the social and emotional development of pupils. Moving on to Key Stage 2, pupils have acquired the foundations of language, mathematics, science, cultural and media literacy, which will be further developed over time. Teaching in Key Stage 1 is provided by one teacher, while in Key Stage 2 individual subjects are taught by teachers with the appropriate qualifications. At both levels, a cross-curricular approach is favored in teaching through the learning areas and cross-curricular themes. Cognitive activities such as active self-discovery, searching, exploration, investigation, finding out something new, for example, the results of an experiment or trial, interpretation, or the creation of a variety of verbal, pictorial, and graphic texts that make up the social and cultural world are encouraged in teaching.

4. Analysis of conceptual curriculum documents from the perspective of the technology and crafts curriculum

Competences and technology curricula are conceptualized quite differently from country to country. It is clear that different countries are based on different societal priorities, and this is reflected in the different integration of the curriculum across subjects, the different placement in each year group, and the diversity in the choice of specific topics emphasised. The technosphere is a vast area of the world, alongside the biosphere and the sociosphere, and therefore only the most relevant, lasting and didactically valuable knowledge is selected. In order to carry out the planned comparison of the curriculum documents, it was first necessary to carry out a content analysis and identification of the expected learning outcomes and learning material. The results of the analysis are presented in the following text.

4.1. Czech Republic

In the Framework Educational Programme [16], technology curricula are represented to the greatest extent in the educational areas of *Man and the World of Work* and *Informatics*.

The Human and the World of Work educational area is divided into four thematic areas at Level 1, of which the following two are directly related to technology: *Working with small materials* and *Construction activities*.

These two areas are compulsory and all pupils must pass them.

At Level 2, the curriculum is divided into eight thematic areas and the techniques are related to the following: *Working with Technical Materials*, *Design and Construction*, *Household Operation and Maintenance*, *Working with Laboratory Equipment,* and *Using Digital Technology*. The educational content is implemented at both levels 1 and 2 and is intended for all pupils (i.e. boys and girls without distinction). Pupils learn to work with different materials and acquire basic work skills and habits. They learn to plan, organize and evaluate work activities independently and in teams. In all subject areas, pupils are consistently encouraged to observe the principles of safety and hygiene at work.

At 1. The expected learning outcomes of the thematic unit *Working with small materials* are set out as follows: the pupil creates various objects from traditional and non-traditional materials using simple procedures; the pupil works according to verbal instructions and patterns; the pupil creates various products from the given material using appropriate working operations and procedures based on his/her imagination; the pupil uses elements of folk traditions in creative activities with various materials; the pupil chooses appropriate working tools, tools and implements in relation to the material used; the pupil maintains order in the workplace and observes the principles of hygiene and safety at work; provides first aid in case of an accident. The thematic unit *Construction activities* then contain the following expected learning outcomes: the pupil masters elementary skills and activities when working with construction kits; the pupil performs simple assembly and disassembly when working with construction kits; the pupil works according to verbal instructions, a model, a simple sketch.

At 2. The *Human and the World of Work* thematic unit *Working with Technical Materials* contains the following expected learning outcomes: the pupil performs simple work with technical materials and observes technological discipline; the pupil solves simple technical tasks with an appropriate selection of materials, tools and implements; the pupil organises and plans his/her work activity; the pupil uses technical documentation, prepares his/her own simple sketch of the product; the pupil observes general principles of safety and hygiene at work and the principles of safety and protection when working with tools and implements; provides first aid in case of an accident.

The thematic unit *Design and construction* contain the following expected outcomes: the pupil assembles a model according to instructions, sketches, plans, and simple programs; the pupil designs and assembles simple structural elements and verifies and compares their functionality, load-bearing capacity, stability, etc.; the pupil assembles, disassembles and maintains simple objects and equipment; the pupil observes the principles of occupational safety and hygiene and safety regulations and provides first aid in case of accidents. The thematic unit *Operation and maintenance of the household* include the following expected outcomes: the pupil performs simple payment and household accounting operations; the pupil masters simple working procedures for basic household activities and is familiar with the operating instructions for common household appliances; the pupil correctly handles tools, instruments, tools and equipment, including maintenance performs minor household maintenance. The thematic unit *Working with laboratory equipment* contains the following expected learning outcomes: the pupil selects and makes practical use of appropriate working procedures, apparatus, equipment, and tools for carrying out specific observations, measurements, and experiments; the pupil draws up a report on the aim, progress and results of his/her experimental work and formulates the conclusions reached; the pupil searches available information sources for all the materials that will best help him/her to carry out the experimental work; the pupil observes the rules of safe work and environmental protection during experimental work; the pupil provides first aid in case of an accident in the laboratory. The thematic unit *Use of digital technologies focuses on* the achievement of the following expected learning outcomes: the pupil masters the basic functions of digital technology; diagnoses and troubleshoots basic problems in the operation of digital technology, the pupil interconnects individual digital devices; the pupil works in a user-friendly way with mobile technologies - travel, business, education, entertainment; the pupil takes care of digital technology and protects it from damage.

At the first stage of primary school, the framework educational programme allocates 5 hours to the educational area of Man and the World of Work, and 3 hours in the second stage, with 1 hour being obligatorily devoted to the non-technical thematic unit The World of Work. It is noteworthy that while in Poland and Slovakia all pupils are taught the content uniformly at the state level, in the Czech Republic schools choose at least one additional subject area, taking into account local conditions, implementation possibilities, and pupils' educational needs.

4.2. Poland

As stated in the subject curriculum document [19], the main objective of the educational area in *Technology* is for pupils to learn the practical procedures of technical activities by carrying out simple projects based on the processing of different materials using appropriate tools and equipment.

In practical activities, pupils acquire the correct behavioral habits that are necessary for adult working life. They should develop the ability to work with real tools, taking into account the necessary health and safety requirements. Through the use of the practical activities method, the subject of *Technology* becomes a space for the verification and practical use of knowledge already known from subjects such as mathematics, biology, computer science, and physics. In Technique classes, pupils discover their predispositions, technical and professional interests, and talents. It is also mentioned in the above document that the subject of technology is an indispensable link between general education and vocational education. It is during this course that future technicians and engineers should discover their predispositions.

The subject *Technology* plays an important educational role, teaches respect for the material goods produced, and creates the attitude of conscious use of technical means, respecting the principles of occupational health and safety, applicable regulations, respect for property, and cooperation in the group. Technology prepares young people to use modern technical equipment efficiently, responsibly, and safely for everyday use and to cope with an ever-changing technical reality.

The Polish curriculum is not defined at the national level through expected learning outcomes, but through broader objectives, which are divided into 6 areas.

The first area, *Recognition and principles in functioning of technical objects*, contains the following objectives [19]: perception of the elements of a technical device as a material property created by man; identification of various technical elements in immediate contact; classification of technical elements into a specific group (structural, mechanical, electrical, communication, etc.).); differentiating the structural elements of selected tools, devices and technical equipment; explaining the operation of selected tools, devices and technical equipment; finding and interpreting technical information about equipment; determining the advantages and disadvantages of material and design solutions used to produce technical products; identifying, assessing and eliminating irregularities during the operation of technical equipment; finding information about modern areas of technology, curiosities and technical inventions; designing and constructing models of technical equipment using different materials.

The second area, *Planning and implementing practical technical activities (from idea to product),* includes the following objectives: Recognition of the need to produce a technical product and motivation to take action; analysis of the possibility of using the product produced; planning and carrying out activities of varying degrees of difficulty; use of technical drawings, reading verbal and drawing instructions to plan and carry out productive work; drawing up a work plan (listing technological activities, justifying the sequence of technological activities, estimating the time needed to carry out each activity); organisation of the workplace (selection of tools, apparatus and equipment for processing the material); respecting the rules and norms governing the process of producing a technical product (technological regulations, health and safety rules, group cooperation); communicating in a professional language; seeking information on the possibilities of improving the activities or products being carried out; anticipating the consequences of one's own technical actions, taking well-thought-out measures and in accordance with the work plan; appreciating one's own possibilities in terms of planning and implementing and upgrading the products created; developing the characteristics: accuracy, precision and prudence; economical and rational management of material, time and own potential; sense of responsibility for the results of group work; self-assessment of the planned implementation of the technical product.

The third area, *Efficient and safe use of tools and technical equipment,* has the following target focus: interpretation of information on safe operation on technical equipment and its reliability; analysis of operating instructions; effective use of basic hand and mechanical tools, measuring instruments and household appliances; the anticipation of risks associated with improper use of technical equipment; analysis of health and life-threatening situations when working with tools and technical equipment; procedures for dealing with work-related accidents, the ability to provide first aid in typical situations; maintaining order in the workplace; observing safety rules and occupational hygiene; learning responsibility and caution when handling tools and operating technical equipment; respect for tools, instruments, technical equipment and one's own and another person's work.

The fourth area, *Appreciation of values and technological threats in terms of integral human development and respect for human dignity,* includes the following objectives: recognition of the technical achievements that have contributed to the

development of technological progress and thus of man (easier work, comfort of life); characterization of the threats in modern civilization caused by technological progress (wars, terrorism, environmental pollution, threats to mental and somatic health, etc.); prediction of threats from various products of technology and technical equipment.

The fifth area, *Developing technical creativity,* includes the objectives of: learning about oneself and one's predispositions to perform technical tasks; developing technical interests; learning to be creative and rational.

The last, sixth area of objectives, entitled *Building a pro-environmental attitude*, includes the following: adopting a responsible attitude for the present and future state of the environment; forming the ability to sort and directly reuse waste; ecotechnologies that help to protect the environment; environmentally sound management of technical products, especially worn-out ones.

It also defines the curriculum, which is divided into 6 areas: work culture, transport education, material engineering, technical documentation, mechatronics, and production technology. The individual content areas are further specified in more detail and the reader is therefore referred to publication [19].

4.3. Slovakia

Technical education in Slovakia is implemented to the greatest extent within the educational area of *Man and the World of Work*. At the first level, the educational area contains suggestions for work activities and work procedures that guide pupils to acquire basic skills in various areas of human work. Within this educational area, there is one subject of Work Education, which focuses on the formation of practical work habits of pupils, thus complementing their basic education [20]. Thus, pupils are exposed to an important component necessary for the application of a person in real life and the labour market. They learn about and use technical materials, construct, folk traditions and crafts, and occupations and gain their first experience of the World of Work. Non-technical subjects such as the basics of catering and food preparation are also included in the work-based learning course.

At the second level of primary school, the *Human and the World of Work* educational area includes a wide range of work activities and technologies that guide pupils to acquire psychomotor skills and knowledge in various areas of real life and the world of work [21]. The area includes a single subject called Technology, which focuses on more complex work activities and technologies, and on pupils' independence and teamwork.

Pupils are encouraged to acquire basic user skills in different areas. They learn about the labour market in terms of their future career orientation [22]. They come into direct contact with technology in its various forms and in its wider context. The course provides pupils with the space and opportunity to develop their creative technical thinking appropriately.

The content is aimed at building pupils' relationships with technology, its safe use, and safe working with technology. Pupils learn about the real conditions of the labour market, modern machinery and equipment, and the function of basic household installations. They are encouraged to design and manufacture appropriate products and to learn about basic technical materials and technologies. Depending on its conditions (material and technical and personnel), the school may teach a thematic unit on home economics in the subject of technology, which includes the following topics: planning and management of the household, the world of work, domestic work and household maintenance, manual work, family preparation, cultivation, and husbandry. The educational area of *Man and the World of Work,* thus appropriately complements the system of educational areas by adding an important component necessary for people's employment in real life and society. The subject content is intended for all pupils, regardless of gender.

The content of education is defined in the form of educational standards objectives (performance and content). At the first level, the following objectives are defined; students differentiate between different natural and technical materials and their importance for human beings; understand technology as a tool for solving real-life problems; know the basic properties of materials and the possibilities of their use in practice; gain knowledge of work activities in selected occupations and professions; learn about folk traditions, crafts and make traditional products; reinforce their positive moral and volitional qualities in solving technical problems; work and manage work activities in a team; handle simple tools for working materials safely and observe occupational hygiene; design their ideas in constructing simple static and moving models. The following objectives are defined for the second grade; students differentiate and use natural and technical materials, tools, and equipment safely; learn to follow established rules and adapt to changed or new tasks and working conditions; experiment with ideas, materials, technologies, and techniques; develop appropriate habits for family life; feel responsible for their own health, human relationships and finances, as well as for the comfort and safety of their immediate environment; feel responsible for the quality of their own and others' work outcomes;

acquire basic work skills and habits in different work areas, organise and plan work and use appropriate tools, instruments and equipment at work and in everyday life; perform basic tasks persistently and consistently, apply creativity and own ideas in work activities and in making efforts to achieve a quality result; develop new attitudes and values in relation to human work and the environment; understand work and work activities as opportunities for self-realisation, self-actualisation and the development of entrepreneurial thinking; orient themselves in various fields of human activity, forms of physical and mental work, acquire the necessary knowledge and skills relevant to employment opportunities, to the choice of their own professional orientation and to further professional and life orientation.

The performance standard at the first level includes the thematic units *Man and Work, Creative Use of Technical Materials, Fundamentals of Construction, Catering and Food Preparation, Folk Traditions, and Crafts and Technical Materials*. In the second level, the topics are *Man and technology; Man and production in practice, Technical materials and working methods for their processing, Electrical energy, and electrical circuits, Graphic communication in technology, Machines, and equipment in the home, The world of work, Electrical appliances in the home, Technical electronics, Technical creation, Home installations, Machining of materials, Creative activities and Simple machines and mechanisms*.

5. Comparative analysis of identified content in conceptual curriculum documents

Based on the findings presented in the previous chapter, it is possible to get a fairly good idea of the content in technical education at the level of the national curriculum in each state. However, let us now focus on conducting a deeper analysis by noting various similarities and differences. To this end, we have set out six criteria that we consider important for drawing not only practically applicable conclusions but will also be useful in terms of developing the theory of subject didactics.

5.1. The existence of a technically oriented subject

The Framework Education Programmes have introduced more freedom into the organization of school teaching. Schools have gained autonomy, in particular through a two-tier curriculum. In all the countries studied, schools design their school curricula, taking into account their conditions, capacities, and educational objectives.

The Czech Republic has the highest degree of autonomy, which is also reflected in the fact that schools can design subjects of any size in terms of the volume of the curriculum. Cross-curricular integration and learning in context are desirable. Similarly, schools can choose arbitrary titles, which is why one can find titles such as *Technology, Technical Education, Practical Activities, Work-based Learning,* and others in Czech schools.

Some schools are integrating technical curricula with science or art curricula. In these cases, however, there is a disadvantage in terms of the teacher's expertise. Faculties of education train teachers of technology as a separate qualification [23], therefore, the teaching of technology curriculum that is implemented by an art, biology, or physics teacher may not be of high quality.

Schools in Slovakia implement, in accordance with the state educational programme, subjects clearly called *Work Education* (1st grade of primary school) and *Technology* (2nd grade of primary school), see [22]. This contributes to uniformity in schools, which is particularly advantageous when pupils transfer between schools (e.g. when changing residence). There is also the advantage that the existence of a clearly profiled subject makes it easier to market textbooks. It is clear what the content should be, and a more predictable demand for textbooks can be expected.

In Poland, there is also a uniquely named subject, namely *Technique*, which is implemented at the 2nd level of primary school.

5.2. Inclusion of technology in the curriculum

In the Czech Republic, the framework curriculum defines the total minimum time allocation for each educational area. Specifically, for the educational area of *Man and the World of Work*, this is 5 hours/week at the first level and 3 hours/week at the second level. Schools are free to determine which grade they include the curriculum in. When drawing up the school curriculum, the school creates subjects to which it assigns a time allocation according to the educational areas (fields of study) from which the subject originated.

In the event that the school wishes to increase the time allocation of a subject, e.g. because it has included a cross-cutting topic, created more subjects from one subject area, expanded the educational content in other ways, etc., it draws the time allocation from the available time allocation. This is relatively rich compared to other countries - specifically 16 hours for primary 1 and 18 hours for primary 2.

In Poland, the minimum numbers for each subject are determined by the Framework Curriculum.It stipulates that the subject of *Technology* should be given the prescribed 3 hours, one in the fourth year, one in the fifth year, and one in the sixth year. Principals have a total of 3 teaching hours at their disposal, which they can use freely, e.g. to reinforce the time allocation for the subject of *Technology*. However, given the total number of available teaching hours, it can be assumed that principals will reinforce a subject other than *Technology*.

It is also worth noting that, while in the Czech Republic the head teacher can include the teaching of Technology in any year, in Poland the years are fixed.

The Slovak Framework Curriculum provides for the subject of *Labour Teaching*, which is implemented in the 1st year of school. Primary school; 2 hours - one in the third and one in the fourth year. In the second level, the subject of *Technology* is subsidised with five lessons, one in each year.

5.3. Commitment to the implementation of the technology curriculum

The degree of autonomy schools have in deciding what the content of education will be varies. In the Czech Republic, it reaches such a level that schools at the second level of primary school can essentially omit the teaching of technology, technical materials, and working with technical tools altogether. Career guidance is compulsory for schools, which choose at least one additional subject. For example, a school may implement a compulsory *World of Work* topic and choose a *Food Preparation* topic. Thus, pupils in primary school are only obliged to study technology in the first cycle, and can avoid it altogether in the second cycle, which is what happens in many schools. This results in pupils leaving primary school without technical literacy, struggling with technical thinking, and not being skilled, which manifests itself in everyday life situations. There is also the problem that pupils do not have enough opportunities to learn about technical professions during their primary education, which can be reflected in their future career orientation. There have long been calls for curriculum change.

In Slovakia, pupils in the subjects of *Work Education* and *Technology* are required to complete all of the curriculum. These are therefore full-fledged and clearly profiled subjects.

Similarly, in Poland, the subject of *Technology* is taught to all pupils and schools have no possibility to intervene.

5.4. Provision of teaching by approved teachers

Accurate data on the extent to which teaching of Technology is provided by approved teachers is virtually non-existent.

However, research findings [24], [25] confirm that when teaching is delivered by an approved teacher, it can be considered to be of higher quality. There is a significant difference in the quality of teaching delivered by approved and qualified teachers as opposed to unqualified and unapproved teachers. However, we can assess the conditions that facilitate or hinder the provision of teaching by approved teachers. On the one hand, the demand for technology teachers in schools, and on the other hand, the preparation of future technology teachers.

A major problem for the implementation of quality technology teaching in primary schools is the low time allocation. Consider the following case: A full-time teacher in the Czech Republic has to teach 22 hours per week and if schools can only deliver one hour per week of technical education at primary 2, then 21 hours per week are needed to teach other subjects. It is a fact that future teachers are trained to teach two subjects as part of their studies, but even this does not solve the problem. It is unlikely that a teacher would teach another subject for 21 hours a week, even in the case of mathematics or mother tongue, which tend to be the subjects with the largest time allocation. Logically, therefore, school principals do not ask for technology teachers, as they will have no use for them. Part-time jobs are not common in education. In Slovakia and Poland, although there is a state-mandated compulsory scope of teaching technology in primary schools, the scope is still relatively low compared to mathematics, mother tongue, or foreign language.

In all the countries studied, future teachers are prepared for the teaching profession at universities. In the Czech Republic, the following universities provide systematic undergraduate training for approved teachers of "Technique and practical activities":

Faculty of Education of Palacký University in Olomouc, Faculty of Education of West Bohemia University in Pilsen, Faculty of Education of Masaryk University in Brno, Faculty of Education of Hradec Králové University, Faculty of Education of Ostrava University, Faculty of Education of South Bohemia University in České Budějovice. Teacher training corresponds to modern trends and includes both traditional crafts (working with wood, metal, plastics, etc.) and modern technologies (robotics, electronics, CNC machining, 3D printing, etc.). The studies in the Czech Republic and Slovakia are conducted in a structured form. First, students complete a bachelor's degree programme (duration of study 3 years) and then a follow-up master's degree (duration of study 2 years). As bachelor students, graduates can work as teaching assistants, and after completing the master's programme as qualified teachers.

In the Czech Republic, there is no fixed name for the study programme (field of study), but in the case of the Bachelor's degree, we encounter the names *Technology and Practical Activities with a Focus on Education* (Palacký University in Olomouc), *Technical Education with a Focus on Education* (University of Ostrava), *Technical and Information Education with a Focus on Education (*Masaryk University in Brno), *Technical Education and Practical Activities with a Focus on Education 2.* (the University of South Bohemia in České Budějovice).

*Technical Education and Practical Activities Teaching (*Palacký University in Olomouc), *Technical Education* (University of Ostrava), Technical *and Information Education Teaching for Primary Schools* (Masaryk University in Brno), Teaching *for Secondary Schools (*Masaryk University in Brno), *Teaching for Secondary Schools (*Masaryk University in Brno). It is also possible to complete an engineering technical study and then complete a course in pedagogy.

Considering the situation abroad, it can be stated that there are more higher education institutions per capita in the Czech Republic than usual. In Slovakia, where there is a compulsory subject of *Technology*, only 3 higher education institutions train qualified teachers: The faculty of Pedagogy of the Charles University in Nitra, the Faculty of Natural Sciences of the University of Medical Sciences in Banská Bystrica and the Faculty of Natural Sciences of the University of Prešov. Compared to the Czech Republic, the name of the study programme is unified, namely *Učiteľstvo techniky*, for both Bachelor's and Master's degrees. In Poland, there is an elaborate career system for the teaching profession. Teacher training is markedly different from the Czech Republic. The local faculties of education (institutes) do not, as a rule, prepare teachers for particular endowments. When someone wants to become a teacher, he or she usually goes to study the subject and then (or at the same time as studying) takes a course in pedagogy. In the case for teachers of technology, a candidate would study any technical field and then take a course in pedagogy, or he or she can also take a course in technical and informational education offered by some universities, such as the Poznań University of Technology, the Świętokrzyska University of Technology or the Pedagogical University of Kraków.

5.5. Content focus on information technology

In all the countries studied, there are separate courses, or even entire educational areas focused on computer science and digital technologies. In the case of the Czech curriculum, there is an educational area *Informatics* [5], in Poland there is a compulsory subject *Informatics* and in Slovakia there is an educational area *Mathematics and Information Work*. In conjunction with technical subjects, this ensures optimal preparation for life in an era when Industry 4.0, robotics, and artificial intelligence play a significant role in production. It should be noted that computer science does not replace technology in schools, as the nature of the two subjects is different. While computer science focuses on the development of computational thinking, programming, and algorithmisation, technology develops the field of technical thinking, involves working with tools, creates ideas about the functioning of machines, and develops dexterity (manual skill). By its very nature, a technology curriculum cannot be replaced by a computer science curriculum. The two are different, but in some moments complementary and form higher units of knowledge.

5.6. The curriculum, its relevance, and perspective

When comparing and assessing the curriculum documents, we will focus on their relevance, timeliness, and perspective. We will look at the first stage of primary education. As we have already mentioned, in the Czech Republic, pupils at this level encounter technology on a compulsory basis, as it is a fixed curriculum. Even though the curriculum has been in force for over 17 years, it is still relevant. This is due to the sophisticated selection of the curriculum, which is based on the needs of children observed over a long period of time. This has resulted in the selection of a well-reasoned, sufficiently enduring, promising and pupil-developing curriculum. As a result, pupils are exposed to simple tools, and appropriate technical materials, learn to understand traditional manufacturing processes, create products and work with technical kits. The area of digital technology, such as robotics, is represented in computer science.

In Poland, the subject of technology is included only in the second grade of primary school, however, the first two years of the second grade correspond to the first grade in the Czech Republic (4th and 5th grade). Thus, also in Poland, pupils aged about 9 and 10 are exposed to technology. In 2018, a curriculum reform took place and the curriculum was redefined. It is rather specific, which is basically a positive thing, because if the curriculum is defined very generally, some teachers complain that they do not know what specifically they are supposed to teach about. It is possible to show pedagogical creativity, but then there may be differences between schools.

This is not a bad thing in principle, but it is a fact that this phenomenon hinders the commercial production of textbooks. The curriculum defined in Poland is modern and forward-looking. On the positive side, the curriculum is not one-sided, but covers various areas such as planning and implementing practical technical activities (from idea to product), the principles of technical objects, the efficient and safe use of tools and technical equipment, developing technical creativity or developing a pro-environmental attitude.
In particular, the environmental friendliness of technical objects resonates in the contemporary world (e.g. electromobility and energy-efficient buildings). In fact, this curriculum could become a model for other countries in terms of content.

In the Slovak curriculum, it should be emphasised that already in the third year pupils create products from technical materials using various tools. This develops fine motor skills, the ability to work with basic tools and to learn about the properties of materials. In the context of basic construction, they learn, for example, to identify the individual parts of a bicycle and to carry out simple maintenance. There is a clear connection with everyday life. Pupils also work with various technical building blocks. Even though the Slovak curriculum is not as sophisticated as the Polish one, we have to say that it provides an excellent basis for carrying out quality teaching.

In the case of the second level in primary school of the Czech Republic, we have already mentioned the problem of school autonomy. They can decide not to implement technical education and pupils will not encounter the curriculum at all or only fragmentarily. Thematic units such as working with technical materials or design and construction are still relevant and promising, but innovation in the educational field as a whole is desirable. The following subjects are covered in the Framework Curriculum: PDAs, CD and DVD players, mobile phones; convergence of technologies, multiplexing; computer programmes for processing voice and graphic information; operating systems, intercommunication of devices (synchronisation of PDAs with PCs); mobile services - operators, tariffs. Problematic areas of the curriculum are also found in other educational areas and this is a situation that requires more extensive adjustment, which is why the so-called "Great Revision" of the Framework Curriculum of the Primary Education Programme was launched.

As we have already mentioned, the Polish curriculum is exemplary in terms of technical education. However, the problem is that pupils only encounter the curriculum in Years 4, 5 and 6. This also creates difficulties in terms of career orientation, with low motivation to choose technical careers.

In Slovakia, by contrast, the subject of technology is taught in every year of primary school in Key Stage 2. It is well set up in terms of content. The absence of robotics could be criticised, but this area is fully represented in computer science. The technology curriculum is well set and no adjustments are needed.

6. Discussion of results and conclusion

The comparative research investigation carried out in this study helped to demonstrate that there is an explicitly defined technology curriculum in all the countries studied. This is directed towards the development of knowledge but also focuses on skill, attitude, and value levels. A remarkable finding is that the technology curriculum is relatively limited, as is the case for other subjects such as mathematics, physical education, mother tongue, history, etc.

It can therefore be considered as a full-fledged component of education. However, what needs to be taken into account is the fact that education will increasingly become differentiated in terms of different curricular architectures. The framework curricula, especially in the Czech Republic, provide considerable freedom in how the curriculum is organised into individual subjects. Rather, in some schools, we can expect to see integrative tendencies in curriculum design.

The looseness of the state curriculum, typical especially for the Czech Republic, leads in some cases to a one-sided focus, thematic imbalance, and emphasis on selected areas that can be "conveniently" and inexpensively implemented. This results in the fact that teaching that requires material equipment (more expensive teaching aids in the form of pupils' experimental kits, tools for working with technical material or consumables themselves) or places increased demands on teachers in the form of the use of non-traditional teaching methods and forms (instruction, research-oriented teaching, excursions) is not included in the curricula at all or only to a minimal extent.

Due to the lack of specificity of the Framework Education Programmes, there are also situations where schools do not have technology teachers or do not even implement technology as a subject. Expected learning outcomes that are directly related to technology are not met through systematic teaching, but through field trips or project-based learning.

Some schools are achieving the expected technology-focused learning outcomes in physics in terms of partial implementation of STEM. However, this results in pupils not developing skills at all, not being exposed to different production processes, and, as a consequence, not developing technical creativity. This tends to be due to several factors, most notably that the physics lab is not a materials workshop.

Another problem is that the physics teacher is not a teacher of technology and therefore does not have the necessary professional and didactic competencies.

As a consequence, the non-implementation of technical education in primary schools in the form of a separate clearly profiled subject has resulted in low demand for teachers in this field, which naturally affects the operation of departments preparing qualified teachers. It could jeopardise them to the point of closure. At the same time, it is precisely those departments that carry out pedagogically oriented research and develop didactics as a scientific and applied discipline.

In the previous text, we pointed out the practical consequences that could arise from ill-considered changes to key curriculum documents at the state level.

The consequences can be devastating and the damage is very difficult to repair. We, therefore, draw the following conclusions:

1) One of the future paths that can be applied in innovation efforts is that the technology curriculum will be covered by a subject framework, i.e. the national curriculum documents will direct schools to create a separate subject of *Technology*, similar to the Slovakian [21] .
2) It is desirable to take care of the diversity of the content of the curriculum providing sufficient opportunities for the implementation of gender-balanced teaching, including topics reflecting current issues - e.g. building a pro-environmental attitude, threats in modern civilization caused by technological progress (wars, terrorism, environmental pollution, threats to mental and somatic health, etc.). The Polish curriculum appears to be exemplary in this respect [19].
3) The application of STEM in the form of a simple combination of physics, biology, chemistry, technology, engineering, and mathematics, or just part of these subjects, is also not an optimal solution. The application of STEM to the conditions of education in the Czech Republic requires a more conceptual approach, which must be reflected, among other things, in well-prepared and proven textbooks, specially equipped classrooms and competent teachers. The curriculum of other subjects cannot be taught by a teacher of one of the original subjects without further training. This could result in a preference for a selected curriculum and, conversely, the suppression of certain topics or poor quality teaching, as a whole.

In general, the Framework Curricula support integrated learning and the application of cross-curricular relationships, but they present the STEM disciplines as separate teaching subjects with no apparent support for linking learning activities. It is possible that the implementation of such integration is automatically expected of schools and teachers, but there is no indication that this is actually the case. In the Czech Republic, at the level of the national curriculum, we observe a competition of individual disciplines that tend to assert themselves at the expense of others. Historically, technology (engineering) has been the discipline under threat, which is also evident from the imbalance in the time allocation for individual subjects. This has been pointed out in the past by Hašková and Bánesz [26] and Lukáčová [27].

Acknowledgements

The paper was supported by the following project: TL03000535 - Development of a system to support the implementation of an innovative concept of technical education in primary schools in the Czech Republic.

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