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Frequent Limits and Advantages of Conditions for Geology Education: Example of Czech and Slovak State Curricula

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∞ Geology is a subject of low interest for many pupils and teachers. The present study aims at examining the organizational conditions for geology education using the model of the Czech Republic and Slovakia, drawing from the national curricula. The study discusses the possible reasons for the unpopularity of the field worldwide and proposes general recommendations that would contribute to increasing interest in geoscience. The main drawbacks of geology education seem to be the large volume of required knowledge, its thematic structure, and a lack of links to real life. The Czech curriculum is vaguely and theoretically defined, placing demand on pupils, especially in the area of memorizing given information and practically pays no attention to recommended teaching methods. In contrast, the Slovak curriculum better reflects current trends. In general, it is necessary to implement continuous educational support for geology teachers and restructure the geology syllabus so that individual sub-fields are interlinked. Moreover, the learning outcome definition should include action-based education, fieldwork, experimenting, and similar elements.

Keywords: content analysis, ISCED 2, geology education, geology syllabus, national curriculum

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Pogoste omejitve in prednosti pogojev za izobraževanje o geologiji: primer češkega in slovaškega nacionalnega učnega načrta

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∞ Geologija je področje, za katero ima veliko učencev in učiteljev nizko raven zanimanja. Namen te študije je preučiti organizacijske pogoje za izobraževanje o geologiji na primeru Češke in Slovaške, pri čemer se sklicujemo na nacionalne učne načrte obeh držav. Študija obravnava mogoče razloge za nepriljubljenost tega področja v svetu in predlaga splošna priporočila, ki bi prispevala k povečanju zanimanja za geoznanost. Zdi se, da so glavne pomanjkljivosti izobraževanja o geologiji velika količina zahtevanega znanja, njegova tematska struktura in pomanjkanje povezav z resničnim življenjem. Češki učni načrt je ohlapno in teoretično opredeljen; pred učence postavlja veliko zahtev, zlasti na področju pomnjenja podanih informacij, in dejansko ne posveča pozornosti priporočenim učnim metodam. Nasprotno pa slovaški učni načrt bolje odraža trenutne smernice. Na splošno bi bilo treba izvajati stalno izobraževalno podporo učiteljem geologije in prestrukturirati učni načrt za geologijo, tako da bi bila posamezna podpodročja med seboj povezana. Poleg tega bi morala opredelitev učnih izidov vključevati izobraževanje skozi gibanje, terensko delo, eksperimentiranje in podobne oblike izobraževanja.

Ključne besede: vsebinska analiza, ISCED-2, izobraževanje o geologiji, učni načrt za geologijo, nacionalni učni načrt

Introduction

As an elementary natural science, geology represents a genuine link between other natural sciences, such as biology, geography, chemistry, and physics. It has the largest base of elementary and applied scientific disciplines (Pyle, 2008). The importance of geology education does not lie merely in acquiring knowledge of minerals, the Earth's history, the evolution of life, and practical disciplines. Currently, its rising value is concentrated in an interdisciplinary and integrated study of global exo- and endogenous processes that help to better understand the large natural catastrophes (e.g., earthquakes, tsunamis, volcano eruptions, landslides) as well as relatively slow transformation (e.g., in the climate, the related sea-level changes, or desertification). Researchers and teaching experts realise the importance of comprehending phenomena and interactions between human beings and inanimate nature; therefore, the terms 'Earth Science' or 'Geoscience Literacy' were introduced (Wyssession et al., 2009). These terms capture the relationship of human beings to inanimate nature influenced by understanding the basic concepts of Earth's complex systems, the ability to find and assess information, and to communicate meaningfully about inanimate nature (Wyssession et al., 2009). The National Geographic Company introduced a similar term: 'Geo-Literacy'. It focuses on a complex understanding of geology knowledge, as well as geography and local history. These aspects enable society to protect national and cultural resources and the quality of life efficiently (Edelson, 2014).

Geology education is similar across Europe. The field is rarely taught as a separate subject at the secondary level. The geological contents are most commonly included in the subjects of geography, natural sciences and biology (Brajković et al., 2018; Káčovský et al., 2021). Geology tends to be disliked as a field (e.g., Fermeli et al., 2011; Lewis, 2008). Stereotypically, it is viewed as less rigorous than biology, chemistry, or physics. This enhances misconceptions about the width, depth, and necessity of geology education (Lewis & Baker, 2010). Undoubtedly, other natural science disciplines also face low interest from pupils. However, no other field requires such demanding training of teachers, laborious class preparation, and well-conceived teaching as geology (e.g., Zamalloa & Sanz, 2020). One rarely hears arguments for removing biology or chemistry from the secondary-school curriculum (Ridky, 2002). However, between 1983 and 2009, the Czech and Slovak educational systems at grammar schools contained no obligatory geology classes, for example (Turanová, 2000). Global underestimation of the importance of the whole geoscience field, along with insufficient pupil preparation, leads to an inevitable drop in the number

of students enrolled in study programmes focused on geoscience (Meléndez et al. 2006, 2007).

Despite the above-mentioned facts, the topic of geology education has paradoxically not gained much popularity in educational periodicals. Few research papers published in regular science education periodicals deal with geology compared to other scientific fields (e.g., Zmalloa et al., 2020). Dealing with the role of geology in the curricular documents that shape the form of education is necessary. Moreover, according to the main findings of the research of Pešková et al. (2019), who focused on teachers' acceptance of curriculum reform in the Czech Republic, education also faces another difficult situation. Teachers who focus on the development of learners' abilities or subject knowledge tend to be more reluctant to accept reforms. Subject matter-centred teachers may be afraid of a decline in learners' knowledge, whereas learner-centred teachers may be concerned about formalism and decreasing autonomy.

Therefore, in the context of the unstable position of geology, this study finds it necessary to focus on the content of the curricula, as well as on the conditions for classes arising from the documents, meaning the formal conditions of an organisational character. Furthermore, recommended teaching methods, pupils' acquired knowledge and skill requirements and the overall approach to pupils and their education should be addressed.

The study primarily aims at examining the conditions for geology education arising from the national curriculum for the ISCED 2 level, using the model of the Czech Republic (hereafter: Czechia) and the Slovak Republic (hereafter: Slovakia), pointing out the possible reasons leading to the unpopular position of the field. These two countries differ from the rest of Europe in geology education: the content of geology is placed within biology and is called 'Inanimate nature' in the curriculum. Moreover, the educational systems of both countries have similar historical contexts. Czechia and Slovakia had exactly the same chance to change their curriculum at the same period. For these reasons, the comparison of both states is more transparent. Although the analysis is performed on only two examples of the curriculum, other comparative studies with a similar focus, but different states, are taken into account (e.g., Jedličková et al., 2019; Káčovský et al., 2021). The study discusses the possible causes of the negative perception of geology arising from the conception of the curriculum and brings general proposals to eliminate them and to increase interest in the field among pupils.

Research Questions

Combining our research goals with the theoretical background, we formulated the following research questions:

- What is the current position of geology in curricular documents in Czechia and Slovakia?
- In what ways and to what extent do the Czech and Slovak curricula present the educational content of geology?
- Do curricular documents in Czechia and Slovakia recommend specific teaching methods suitable for geology classes?

Historical context of teaching Geology in Czechia and Slovakia

The historical context of the Czech and Slovak education systems draws from the principles of Marie Theresa's schooling reform in the 18th century. Natural sciences, including geological sciences, entered the curriculum to a larger extent in 1773, according to Kočárek (1978). Mineralogy, mainly crystallography and the mineralogical system dominated the geoscience curriculum until the end of the 18th century. Petrography also marginally affected the content. Geological processes constituted a part of physical geography classes at that time. The beginning of the 19th century saw the rising significance of geology within education, although mineralogy retained its dominant position. Secondary school teachers took a state exam at universities solely for mineralogy until 1921 (Turanová, 2000).

Czechoslovakia was established in 1918, and it accepted the Austrian educational organisation with no major changes. The schooling reform of 1932/1933 rearranged curricula and joined them into comprehensive complexes. National schools taught mineralogy as part of the subject Natural Sciences (equivalent to Biology at ISCED 2 level) in the sixth year. The seventh year continued with significant sedimentary and metamorphic rocks, followed by substantial igneous rocks in the eighth year. Geological knowledge represented a part of the subject of Geography (Turanová, 2000).

The educational system of the restored Czechoslovak Republic after the Second World War fell under the influence of the Soviet educational model. The educational system between 1945 and 1948 used curricula and textbooks from the 1930s. The geological curriculum remained a part of the subject of Natural Sciences. Geological sciences recorded the first attempts to teach actively with clear demonstrations. Turanová (2000) marks this era as the period of a dynamic approach.

After 1948 and the passing of the Act on Unified Schooling, primary schools taught geology within Natural sciences in the complete scope. It included the most frequent minerals and rocks, an overview of historical geology, and an introduction to dynamic geology. However, 1953 brought radical changes in curricula. It led to a significant reduction of geosciences and fragmentation of geological topics to several subjects: Physical Geography, Chemistry, and Biology (Turanová, 2000). The curriculum had a descriptive character. Links among geological phenomena remained unnoticed, and the knowledge of most pupils was minimal. The content of geosciences as a whole re-entered the curriculum of Natural Sciences in 1963/64. The compulsory school attendance was extended to nine years at the time. Classes stressed dynamics, polytechnical education, and lab work. Mineralogical excursions were organised to a much larger extent.

The changes in curricula in 1984 became a critical moment in the current history of geology teaching. Obligatory classes on the subject at the higher secondary school level were cancelled. Since then, geology was taught as an optional subject spanning two years. Its content was rich, containing planetary geology, mineralogy, and petrology, as well as general, historical, and regional geology or environment protection and formation. Nevertheless, it was practically not taught at grammar schools (Turanová, 2000).

The revolution in 1989 brought crucial political changes. However, geology education saw no major modifications. Curricula were slightly adjusted, but teaching methods largely remained. Czechoslovakia was divided in 1993. Both new countries committed to reforming their curricula and creating them on their own. Detailed information on the course of curricular reform is provided, for example, by Pešková et al. (2019, p. 77) or Hřivnová (2021, p. 85).

Actual changes came after more than two decades. The Czech and Slovak primary and lower secondary systems are mostly single-structured and called 'elementary education'. Both countries use a two-level curriculum structure: the state and school levels. The state level introduces a nationwide framework document. It defines the educational concept, goals, and basic content of education with general conditions for its implementation. The school document provides the framework for the implementation of education at specific schools. It is defined by individual schools in line with the nationwide framework document. The Czech national curriculum was introduced in 2006. It largely influenced the first version of the Slovak curriculum that came out in 2008. The Slovak curriculum later underwent major changes, and the so-called Innovated State Curriculum was introduced in 2015. The two mentioned national curricula returned geology among obligatory subjects at both levels of secondary education (MŠMT, 2017, 2021; ŠPÚ, 2009, 2015).

History shows that geology education in Czechia and Slovakia never had a fundamental status. Constant changes in the curriculum and the ambiguous relation of the geosciences to other natural sciences led to underestimating the importance of the geosciences and pupils' insufficient education. The unfavourable state plays a crucial role in the low interest in the field of both students and teachers. The reduction of geology classes at the higher secondary school level caused the interruption of the practice of qualified geology teachers, among other things. The dissolution of Czechoslovakia gave both countries the opportunity to change the mentioned unfavourable conditions of geology education through curriculum reforms. They could enhance the position of geosciences, suitably modify the content of education, and influence the perception of geosciences.

Method

This study primarily focused on the analysis of the structure and content of Czech and Slovak curricular documents (hereafter: CZC and SKC, respectively) concerning geology (the inclusion of geological content, the scope of the subject matter, recommended teaching methods, etc.). Its goal was to perform an extensive analysis and subsequent comparison of selected curricular documents for lower secondary education, ISCED 2 level, according to which the current educational system is implemented. The Framework for Educational Programme for Basic Education (MŠMT, 2021) represented the basic set for content analysis in Czechia. The New State Educational Programme for the First Stage of the Primary School (ŠPÚ, 2015) represented the basic set for Slovakia. Older versions of CZC and SKC were also examined (MŠMT, 2017; ŠPÚ, 2009).

Content analysis was employed for comparing the above-mentioned curricular documents. The selection of the required concepts (learning outcomes, subject matter, time allocation, thematic scope etc.) resulted from the research of individual documents emphasising the teaching and manner of inclusion of geology content in the relevant country. When analysing obligatory learning outcomes, a deductive approach framed by the Revised Bloom's Taxonomy (RBT) was applied to classify their requirements (Anderson et al., 2001). The RBT consists of two dimensions: cognitive processes (six levels labelled Remember, Understand, Apply, Analyse, Evaluate, and Create); and types of knowledge (Factual, Conceptual, Procedural and Metacognitive). Thus, each learning outcome can be evaluated from two views: the cognitive process required (expressed by a verb) and the type of knowledge developed (expressed by a noun). The original paper by Anderson et al. (2001) provides

theoretical background and concrete examples of how to use the taxonomy in research. According to Káčovský et al. (2021), the learning outcomes were analysed during the multilevel coding process using RBT, and the specific cognitive processes for metacognitive learning outcomes were not specified. The educational content of geology was examined in several main topics: the Earth's formation and structure, mineralogy and petrology, endogenous and exogenous geological processes, development of the Earth's crust, evolution, environment formation and protection. Further, the organisational aspect of teaching, specifically the inclusion of geological subject matter, the range of geology content in elementary schools, and recommended teaching methods and equipment, were monitored and compared.

Unlike SKC, CZC does not tie the sequencing of educational content to a particular year of study. Therefore, an online poll was conducted to examine the current state of geology education at the ISCED 2 level in Czechia. The whole questionnaire focused on the current situation of teaching geology in the nation; questions were asked about the experience and opinions of geology teachers, for example, pupils' attitude to geology, the extent of CZC, or the quality of available teaching materials. Because the poll was not carried out in Slovakia, a comparison of these questions is impossible for now. This study presents only the data related to the organisational structure of geology teaching in Czechia (time allocation, year of study, inclusion of geology etc.) in order to compare the current situation with Slovakia and SKC, respectively. A total of 342 completed questionnaires were acquired, and 304 respondents/teachers were included in the survey as they answered that they were taught geology.

The content analysis of CZC and SKC, supplemented by the opinions of Czech teachers, led to the evaluation of the geology education strategies in Czechia and Slovakia. Subsequently, general recommendations were formulated that should increase the interest in geology. The study draws on previously published results by Jedličková et al. (2019).

Results

The current position of geology within CZC and SKC

To address our first research question, we researched CZC and SKC with a focus on the occurrence of geological topics within both documents (i.e., the inclusion of geological topics within concrete educational areas or school subjects, time allocation, and cross-curricular relationships). Czech and Slovak education systems have corresponding organisational conditions for the allocation of geology. Lower secondary CZC and SKC (ISCED 2 level) similarly

place geology education in the area of Humans and Nature, namely the subject of Biology and the educational field of Inanimate Nature. Other subjects in this educational area (e.g., Geography, Chemistry, Physics) also marginally touch geological topics (specifically the Earth's formation, mineralogy, and internal geological processes).

The sequencing of educational content in SKC is strictly tied to a particular year of study. Schools and teachers have no choice in this respect. In the SKC, the educational field of Inanimate Nature belongs to Biology in the 9th year of elementary school with one class per week. It is followed in the same school year by the educational field of Ecology (e.g., ecosystems, biotopes, community, species diversity, ecological balance etc.).

The CZC places the educational field of Inanimate Nature at the end of Biology, also followed by the educational field of Ecology. In line with the Czech educational system, the CZC only defines the content and allows schools to flexibly move the subject matter among school subjects or create new subjects. However, schools rarely use this opportunity. The survey showed that geology in Czechia is mostly taught in Biology classes (253 respondents, i.e., 83%). Only 9 respondents (2.9%) teach geology as a separate subject. In 22 cases (7.2%), geological topics are taught in the subject of Geography; 12 respondents (3.9%) indicated a combination of Biology and Geography. Other answers did not reach 1%; they included, for example, chemistry, science seminars, and project teaching. A total of 263 respondents (i.e., 86.5%) confirm that some geological topics are also taught in other subjects, mostly Geography. According to the survey, Czech elementary schools typically teach geology in the 9th year. A total of 285 teachers (93.7%) also stated that within the same year, the school curriculum includes other educational fields in addition to Inanimate Nature (most commonly Essentials of Ecology; 214, i.e., 70%). Five of the nine respondents who teach geology as a separate subject also mentioned the teaching of environmental science and ecology within the same year of study.

The personal opinions of the respondents on how they think geology is most appropriately taught are shown in Table 1. Most respondents are inclined to include the content of geology in the subject of Biology. From the individual answers, the most common opinion was to divide the teaching of geology between Biology and Geography.

Table 1

The personal opinions of the respondents (i.e., Czech teachers) on how they think geology is most appropriately taught. The respondents had the option to choose from a list of answers or state their individual answers.

Implementation of geology	Number of answers
In connection with Biology	130 (42.76 %)
In connection with Geography	57 (18.75 %)
As a separate subject of Geology	47 (15.46 %)
Combining geological content into a new subject (e.g., Earth Sciences)	40 (13.16 %)
Individual answers	30 (9.86 %)

The extent of the content of geology in CZC and SKC

The educational content of specific educational areas, including geology, comprises the learning outcomes and subject matter (both in CZC and SKC). The learning outcomes in CZC are called expected outcomes, while SKC defines performance standards. Both determine the criteria of the level of mastering the pupils' knowledge, skills, and abilities. The subject matter in CZC and the content-based standards in SKC determine the volume of required knowledge and skills and form an integral part of the educational content. To address the second research question, we compared the range of geological subject matter and the number of obligatory learning outcomes between the two countries under study. Also, the formulation of learning outcomes was considered with a focus on the demands on pupils.

The range of geological subject matter in CZC and SKC is largely identical. Both cover major topics in the educational field of Inanimate Nature. Specifically, they include the Earth's formation and structure, mineralogy and petrology, endogenous and exogenous geological processes, development of the Earth's crust, evolution, environment formation and protection. All the content belongs entirely to one educational field and one subject. A disproportion arises between CZC and SKC in the number of learning outcomes related to the field of Inanimate Nature: 3 vs 21, respectively.

Table 2 demonstrates clear differences between CZC and SKC in the specification of the educational content of the field of Inanimate nature. Endogenous and exogenous geological processes were selected as a model topic of the field of Inanimate nature. The subject is dynamic and considered popular with students and teachers (Dvořáčková et al., 2018). CZC defines the whole topic bluntly as 'causes and effects.' The SKC content standard, in contrast, elaborates in detail on what processes fall within the topic and specifies them. Even the topic of 'energy

sources of geological processes' is included, for example. A look at the expected outcomes shows a similar situation. CZC dedicates a single learning outcome to the whole of endo- and exogenous geology. Moreover, it only focuses on the consequences of geological phenomena and avoids the core of the issue. The list of learning outcomes of the topic in SKC names four points. The outcomes are more specific, requiring individual activity, for example, proposing a project and documenting processes and their effects. The outcomes work with the notion that the processes take place in the immediate surroundings of pupils.

The distribution of learning outcomes based on RBT to show the different demands of learning outcomes on pupils within CZC and SKC is presented in Table 3. Due to a low number of learning outcomes related to geology in CZC, it is almost impossible to compare it with the level of the type of knowledge required by SKC. Regardless, neither curriculum defines any learning outcomes requiring factual knowledge. Conceptual and procedural knowledge are required to the same extent within the SKC.

Table 2

The differences in the education content definitions between the CZC and SKC modelled on the topic of 'exogenous and endogenous geological processes part of the subject field Inanimate nature.'

		Subject matter	Learning outcomes
ENDOGENOUS AND EXOGENOUS GEOLOGY	CZECH CURRICULUM (CZC)	- External and internal geological processes – causes and consequences	<i>The pupil is able to:</i> - distinguish between the consequences of endogenic and exogenic geological processes, including the geological rock and water cycles
	SLOVAK CURRICULUM (SKC)	- Geological processes internal, external - Energy sources of geological processes - Igneous and volcanic activity, earthquakes, rock transformation - Mechanical and chemical weathering - Geological factors, disruptive and creative activity - Disruption, transfer, settling, consolidation - Karst, surface, and underground karst formations	<i>The pupil is able to:</i> - justify the influence of geological processes on the shapes of the Earth's surface, on the life of organisms, - document catastrophic geological processes in the world and in Slovakia and their consequences, - design a project to learn about the attractions of inanimate nature in Slovakia, - explain the origin and occurrence of karst and karst formations.

Note. Adapted from MŠMT, 2021; ŠPÚ, 2015.

Table 3

Number of learning outcomes of CZC and SKC requiring the corresponding combination of type of knowledge (Factual, Conceptual, Procedural and Metacognitive) and cognitive process (Remember, Understand, Apply, Analyse, Evaluate and Create), based on Revised Bloom Taxonomy (RBT) (Anderson et al., 2001). As one learning outcome of CZC contains two different active verbs, it was evaluated using RBT twice (although the total amount of learning outcomes is 3).

CZECH CURRICULUM (CZC)				SLOVAK CURRICULUM (SKC)			
F	C	P	M	F	C	P	M
remember				remember			
understand	1	1		understand	4	1	
apply				apply		3	
analyse	1		1	analyse	2		3
evaluate				evaluate	2	1	
create				create	1	4	

Teaching methods suitable for geology classes recommended in CZC and SKC

In this section, we describe the results of the content analysis used to address the third research question. SKC defines recommended teaching methods in the educational area of Humans and Nature. It lists practical and research activities, observation, and mainly interdisciplinarity. SKC determines educational strategies even at the level of biology as a subject. The formulations of individual performance standards reflect them. It is mainly based on constructivism and the idea that pupils actively construct or make their own knowledge and that reality is determined by their experiences. The teacher is only a kind of mentor in the whole educational process. The learning outcomes of the field of Inanimate nature require practical education, observation, experiments, field trips, working with information, and similar elements.

CZC defines recommended teaching methods only generally in the characteristics of the whole area of Humans and Nature. It generally outlines a brief demand for developing critical thinking and using research methods in classes. Pupils should learn experimenting skills in their study of all subjects of natural sciences. The need for proper work with information is merely implied. CZC does not recommend any teaching methods at the level of subjects, educational fields or learning outcomes.

As digital competence is one of the seven Key Competences for Life-long Learning defined by the European Parliament and the Council (2006), we also researched whether the learning outcomes promote the use of ICT among teachers and pupils. We found that in both CZC and SKC, no mention is made of the role of ICT in natural science subjects.

Discussion

Problems in teaching geological topics at the secondary and tertiary levels arise worldwide. Universities produce fewer expert geologists, and secondary education lacks qualified teachers. Students show little acceptance towards the field in the long term (Lewis & Baker, 2010). The lack of interest may realistically bring negative consequences to society (Arthurs, 2019). To understand the persistent issues of geology, new questions must be asked, and the whole area must be examined from various perspectives. What should science teachers know about the Earth? What represents a sufficient conceptual and educational framework for geology education? How should the national curriculum implement geology education? What support do current teachers need?

The presented research analyses two examples of the curriculum documents (CZC and SKC) with respect to geology at the ISCED 2 level, identifying the possible key factors modulating the general attitudes towards geoscience. Geology deserves attention in the extent and content of the curriculum, didactical aspects, teaching forms, and interdisciplinary links to other natural sciences. Understanding these factors could assist the effort to reverse the current situation and to elaborate educational practices that highlight the values of the geosciences among pupils, students, and teachers.

The position of geology among other science disciplines

The multidisciplinary character of natural sciences is mentioned, especially with regard to the emergence of boundary disciplines (e.g., Wake, 2000), but the integrated education of natural sciences remains rare in Europe (Eurydice, 2011). Also, geology as a boundary discipline faces the ever-present question of the integration level. If geology cannot be taught fully integrated into a complex subject of geoscience, the merger of geology and physical geography should be considered, as is the case in most European countries (Fermeli et al., 2011; Jedličková et al., 2019). Physical geography usually describes and explains basically the Earth's shapes that arise from endogenous or exogenous geological processes and links them with the environment, human influence on the environment, renewable and non-renewable natural resources, agriculture, spatial planning, and other disciplines.

According to Adetunji et al. (2018), geosciences face a more difficult challenge than other science disciplines due to students' scant exposure to geosciences in their early educational period. The absence of a complex concept of geoscience teaching and the inclusion of geology in other subjects causes the *de facto* subordination of geology. Sections of geology are often ignored or explained superficially (Brajković et al., 2018; Meléndez et al., 2007). The decreasing volume of geological content in comparison to other subjects and its reduction in the secondary school curriculum and at universities is causing serious concerns among the geological community (Arthurs, 2019; Meléndez, 2006, 2007).

The historical context of geology education in Czechia and Slovakia demonstrates that the position of geosciences has never been sufficiently strong. Practically any educational revision resulted in a content exclusion of geology, and the inferior role of geology remains apparent. Integrating geology into biology in Czechia and Slovakia emerges from a tradition attempting to capture the links between live and inanimate nature in the geological past. Including the complete content of the educational unit Inanimate Nature in a single subject and year allows a complex syllabus of the field within the ISCED 2 level. We consider this approach preferable to fragmenting the geological content among different subjects, so it is not recognised as geology. However, some negative trends arose from the content analysis of curricular documents of both countries, for example, the low time allocation for the subject of Biology in the ninth year of study and the inclusion of content from another educational field, most commonly Ecology, in the same year. This further reduces the time for teaching the field of Inanimate Nature and Geology.

The adequacy of the scope of the educational content and teaching methods

Geology education in Czechia and Slovakia emerges from the traditional structure of the field. Individual branches (mineralogy, petrography, endogenous and exogenous geological processes, etc.) appear seemingly independently within the curriculum. Pauk (1979) indicated many deficiencies in this type of arrangement. It hinders cross-curricular relationships, such as the relationship between geological processes and the origin of minerals and rocks, and tends towards overwhelming with separate facts. It does not develop geological (i.e., spatiotemporal) thinking of pupils. This concept also makes the continuous modernisation of educational content and teaching aids difficult for teachers (Pauk, 1979, p. 22).

The more theory geology classes provide to pupils, the lower the possibility of individual and discovery activities (Pauk, 1979). Overly theoretical

content leads to presentation without cooperating with pupils and to knowledge memorising. The inappropriate content and range of curriculum results in a negative attitude towards the field. Czech teachers report pupils' lack of interest in geology, in line with the worldwide trend (Fermeli et al., 2015; Lewis, 2008; Meléndez et al., 2007). The cause is mostly seen in the oversized geology curriculum, uninteresting content for pupils, and overly abstract, theoretical, and impractical knowledge (King, 2012). The Czech in-service teachers, who responded to the survey, considered the neutral or negative pupils' attitude to geology to be because pupils learn the content but fail to see a clear personal benefit for the future. They also stated that pupils come to classes with a certain aversion to the subject of geology. Moreover, the teachers themselves are supposedly not passionate about teaching geology, and thus they do not have the capacity to motivate pupils. Dvořáková et al. (2019) state that Czech university students of the biology and geography teaching study programmes take as little as one semester of geology in some cases. This is far too little for future biology or geography teachers to develop a positive relationship with the subject. It fails to prepare teachers capable of efficiently explaining the complex links between inanimate nature, animate nature and human beings and to motivate the building of positive attitudes to inanimate nature.

The curriculum should cover the most general essentials of geosciences and be formulated accessibly, supporting demonstrations and practical use. Teachers should use examples from close surroundings and from practice and show the links to current and attractive examples (e.g., biota evolution and large extinctions). Geology should not burden pupils at the ISCED 2 level too much with regional geology. The emphasis on facts (esp. crystallography, systematic mineralogy, and petrography) should be reduced only to basics, especially at the lower secondary level and should be presented in an interactive way. More attention should be paid to the physical and chemical essence of geological processes and their links. The process should use cross-curriculum relations (e.g., crystallisation processes from chemistry or physics). Significant shifts in the subject matter of geosciences and the development of new disciplines (environmental geology, global climate processes, low-carbon energy, etc.) need to be reflected. However, geosciences worldwide are often taught by teachers trained in a completely different field or with inadequate training (e.g., Lewis & Baker, 2010), who need proper motivation. Teacher motivation based on a person's autonomous motives or based on enjoyment and interest tends to last long and proves most effective, according to the self-determination theory (Vojáčková, 2020). Any change in the curriculum or partial interventions in its form is a long-term affair. The results of Pešková et al. (2019) suggest that even a ten-year period is sufficient

to change teachers' mindsets with respect to educational change. According to their study, the reform ideas should be explained at the level of individual school subjects; for secondary school teachers, it is necessary to define the educational aims in a different way than just in the intended curriculum. The development of coherent support for geology teaching in the form of further training for teaching staff and the provision of more detailed syllabi for geology teaching seems to be a suitable solution. Pešková et al. (2019) state that teachers' voices should be heard, and they should be involved in the preparation of the reform process. This would enable the reform to respond to the teachers' specific needs and experience and support their ownership of the reform (Sandholtz, 2002).

Nevertheless, the need for restructuring geology education relates to re-assessing the educational goals in addition to other things. They should aim at forming the pupil's whole personality, practical skills, critical thinking, forming work hypotheses, and evaluating them (Rocard et al., 2007). In general, CZC does not take this direction and fails to reflect the needs. It defines the learning outcomes rather widely and generally. Current CZC still emphasises terminology, classification, and encyclopaedic knowledge. The survey among Czech in-service teachers confirmed this fact. Since 2005, when CZC was established in schools, several minor changes were provided, and in 2021 the revised CZC was issued (MŠMT, 2021). However, this revised CZC version does not differ in this respect. It only introduces the educational area of Informatics and places the development of digital literacy at the level of key competencies. As a result, learning outcomes in other educational fields of CZC were reduced. Specifically, the number of geological learning outcomes fell from six to three with the same phrasing. A comparative study of curricular documents of selected European countries points out several deficiencies of CZC in this area (Kácvský et al., 2021). The innovated 2015 version of SKC (ŠPŮ, 2009) has changed significantly compared to the original version (ŠPŮ, 2009). The educational content decreased considerably, and the original 67 learning outcomes shrank to 21 newly formulated ones, although none of the main geological topics was eliminated. The new formulation of learning outcomes focuses more on the pupils' activities and deeper understanding of natural processes, as well as on simulating scientific work, observation, perceiving relations in time and space, and interdisciplinary approach. The performance standards largely reflect the daily life and immediate surroundings of pupils.

In both of the curricula we have researched, there is a lack of emphasis on using digital technologies across science subjects. To be effective in changing environment of education, it is also required that the builders of the new education system understand the imperatives of the technologies influencing

the changes in education. NCCA (2004) presents three main frequently cited arguments for implementing digital technologies in education. The first is related to the potential benefits of ICT for teaching and learning, including possible gains in motivation, problem-solving abilities, collaborative skills, and other factors. The second rationale is based on the ubiquity of technology and the consequent need to acquire digital competence and its application in the knowledge of our society. The third related argument expresses concern about the digital divide in society. The main reasons for this gap are considered to be the lack of physical access to technology, and limited literacy, numeracy, and problem-solving skills. To be fair, we examined mainly the passages of CZC and SKC devoted to the learning outcomes, so it can be assumed that the requirement for interdisciplinary use of digital technologies might be formulated in the general passages of both curricula. However, in the context of the above-mentioned arguments, we believe that the requirement of using ICT and developing digital competence essentially needs to be formulated directly as a part of the compulsory educational content of individual subjects.

Conclusions and Recommendations

The study analysed the national curriculum documents in the Czech Republic (CZC) and the Slovak Republic (SKC) from the perspective of the scope of the educational content of geology, the formulation of learning outcomes related to this field of study, and the recommendation of appropriate teaching methods. Both countries integrate the geology curriculum at the ISCED 2 level rather unconventionally into the subject of Biology. The scope of the syllabus of geology in both countries is broad and comprehensive at the ISCED 2 level. However, due to the thematic breakdown, the individual disciplines (e.g., mineralogy, petrography, endo- and exogenous geology) are presented almost separately. This often leads to an overload of content with isolated facts. We suggest that the geology syllabus should systematically cover key global geological processes from forming of the Earth to processes in the mantle and crust, followed by an explanation of exogenous processes. The global ecosystem development should mention popular extinct organisms. Special attention should be paid to areas that teach pupils environmental protection, including the rock environment. Emphasis should be placed on the links between the development of inorganic nature and the origin and evolution of life.

The clear difference between both analysed curricula is their extent: the more detailed SKC has seven times as many geological learning outcomes as the rather brief CZC. The learning outcomes are formulated differently. Conceptual

and Procedural Knowledge are required to the same extent. CZC plays a role of a document that defines mandatory claims of education at a given level. Its formulations remain general. Therefore, they do not provide a possible source of inspiration for geology teachers. In contrast, SKC reflects the importance of using appropriate teaching methods at the level of learning outcomes. Thus, it provides teachers with appropriate support. We consider a higher proportion of problem teaching, laboratory and fieldwork, observation, and experiments in classes represents the desired tool to increase the social prestige of geology. Field trips and excursions can demonstrate geological and geomorphological phenomena and processes, aspects related to the use of landscape and its protection, the links between the bedrock and flora biodiversity, or risks related to geological processes (landslides, erosion, or flooding). It is convenient or even necessary to implement the requirements for suitable methods of teaching natural sciences into the learning outcome formulation of individual subjects. In our opinion, their general description in the generic parts of the curriculum is inadequate.

We consider ICT to be a cross-curricular component for all school subjects. Effective implementation of ICT across the curriculum is complex and involves strategic management and coordination within whole national and school policies. According to United Kingdom Department for Education (2004), it is crucial that pupils be taught the appropriate ICT capability before applying it in other subjects. Therefore, subject teachers need to know what they can reasonably expect a pupil to know, understand and be able to do. The use of ICT needs to be purposeful and carefully integrated into the subject lessons, with a clear rationale for its use. Therefore we believe that the requirement of developing digital competence needs to be formulated directly as a part of the compulsory educational content of individual subjects.

Based on the researched studies and content analysis of both curricula, there are several potential factors that influence geology education at the level of the intended curriculum. To at least partially avoid the described shortcomings resulting from the design of the national curriculum, geology education requires:

- interdisciplinary understanding and presentation as an integral part of natural sciences
- interpretation of geological knowledge in a broader context and links to everyday life
- using especially practical tasks, observation, and fieldwork
- incorporating cross-curricular demands (e.g., working with data, using ICT, conducting practical and fieldwork) explicitly into the specific learning outcomes

- supporting current teachers of geosciences and motivating them by offering them further training with various seminars, workshops, and more detailed syllabi for teaching geology. Experts in the field (i.e., didactics of geology) and teachers should participate in this training so that the support developed is maximally adapted to the target group and, at the same time, respects the professional aspect of the field.

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