International Cartographic Association
Association Cartographique Internationale

Mapping Mineral Resources: A Comparative Study of Symbology in School Atlases Over Seven Decades

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Abstract: The paper examines the evolution of symbology in mineral resource maps within Czech school atlases from 1952 to 2025. By analyzing changes in map content and symbology, the research aims to identify trends and variations in the depiction of mineral resources. The methodology includes statistical analysis of symbology, and user testing among students aged 12 to 15. The study selected atlases that represent all editions using unified symbology for mineral resource maps, focusing on eight different symbologies across 19 maps from 9 atlases. Findings reveal significant differences in symbology detail, scope, and consistency among the atlases. User testing indicated that students found chemical symbols challenging and preferred two symbologies for their comprehensibility. The research highlights the importance of systematic incorporation of map symbols into the curriculum and the crucial role of teachers in facilitating students' understanding of maps. Recommendations include improving the readability and comprehensibility of map symbols, adopting interdisciplinary approaches, and supporting inclusive education for students with learning disabilities. This study provides valuable insights into the development of map symbology in educational materials and offers practical suggestions for enhancing the effectiveness of school atlases. The findings contribute to a deeper understanding of how different approaches to map symbols influence their perception and comprehension, emphasizing the need for standardization and intuitive design in cartographic representation.

Keywords: school atlases, mineral symbology, user testing.

1. Introduction

In recent decades, cartography has undergone significant transformations that have notably influenced the design and content of school atlases. These atlases have traditionally served as a foundation for students to acquire essential geographical knowledge and deepen their understanding of the modern world (Buswell, 1935). Moreover, school atlases are pivotal in educating future generations of citizens, as they incorporate the latest advancements in cartography as a scientific discipline and technological practice. Through school atlases, students are introduced to modern methods and technologies, promoting visual learning and enhancing their ability to navigate the complexities of the information society.

One of the central components of these atlases is map symbology, which constitutes the fundamental building blocks of the map's language (Kolacny 1969). Cartographic symbols convey specific meanings and provide information about particular phenomena while simultaneously indicating their geographical locations. Aa Haeberling (2005) emphasizes these symbols are designed to be intuitive, easily recognizable, and conducive to memorization and comprehension of the information presented.

Cognitive processes in cartography, particularly perception, interpretation, and decision-making based on map symbols, are a focal point of contemporary cartographic research (Fabrikant, Hespanha, Hegarty, 2010). This research yields valuable insights into user-map interactions, laying the groundwork for designing more effective symbology systems. The evolution of map symbology not only enhances the interpretability of maps but also ensures their educational relevance and ability to address the demands of the modern information age

2. Objectives

The primary objective of this study is to analyze changes in the content of maps and the symbology used for maps of mineral resources in Czech school atlases over the past 73 years. Based on a comprehensive review of international cartographic literature focusing on cartographic semiology—with special emphasis on symbology and map legends—this research uses cartographic analysis and user testing to derive conclusions about the nature of these changes.

The analysis of symbology in selected world school atlases aims to identify differences in detail, scope, and consistency among various symbology systems. The findings may reveal which symbology is the most detailed or, conversely, the simplest, which atlases and periods exhibit the highest variability in depicting mineral resources, and whether trends exist in the development of cartographic representation of mineral resources in world school atlases.

Advances in Cartography and GIScience of the International Cartographic Association, 5, 35, 2025.
32nd International Cartographic Conference (ICC 2025), 17–22 August 2025, Vancouver, Canada. This contribution underwent double-blind peer review based on the full paper. https://doi.org/10.5194/ica-adv-5-35-2025

The study focused on symbols, symbologies, and map legends where the symbols are most readable. As noted by Barvir and Vozenilek (2020, 2021) or Ward (2002), the graphic map load makes reading and visual learning more challenging. Therefore, reading within the map field was addressed in a separate study.

These objectives bridge the theoretical analysis of symbology with its practical applicability in educational settings and the development of school atlases.

3. State-of-art

3.1 Conceptual framework

School atlases are not merely collections of maps but serve as critical educational tools. Their effectiveness hinges on the quality of map symbols, which must be clear, intuitive, and appropriate for the age and cognitive capabilities of students.

Cartographers and geography educators continue to focus on improving school atlases, emphasizing map symbology for several reasons. These symbols play a vital role in facilitating the visual processing of information. Modern research in cognitive cartography, psychology, and neuroscience demonstrates that visual information is processed faster and more efficiently than textual data, e.g. Beitlova et al. (2021) or Krassanakis, Filippakopoulou and Nakos (2016). Based on these findings, researchers aim to enhance the design of symbols to support better memorization, understanding, and application of geographic data (Vozenilek, Morkesova and Vondrakova, 2014).

The evolution of geoinformation technologies and interactive maps has also led to substantial changes in atlas cartography. School atlases have adapted to these changes, with their authors striving to integrate digital approaches (e.g., Konicek et al., 2024). Scientific studies on map symbol design ensure that these symbols remain readable and comprehensible in digital environments across various devices.

In an era prioritizing inclusivity, school atlases also play an important role in fostering gender and cultural sensitivity in cartography. This includes tailoring symbols to be accessible to users with specific needs, such as individuals with visual impairments. Research, therefore, focuses on developing symbols that are accessible even to marginalized user groups, including those with visual disabilities (Vozenilek, Michalik, Vondrakova et al., 2014).

3.2 Symbology in Czech School Atlases

The introduction of a systematic symbology for mineral resources marked a significant milestone in the creation and interpretation of economic maps. This study investigates these changes, emphasizing the development of content and symbology for economic maps in school atlases worldwide. The goal is to provide a comprehensive overview of how cartographic semiology has evolved over time and the factors driving these changes. The results of this study may contribute to a deeper understanding of current cartographic trends and their impact on the educational process.

The history and development of Czech school atlases are closely tied to the progress of cartography and education in the Czech lands. Early school atlases emerged during the Czech National Revival in the mid-19th century, focusing on fostering patriotism and providing basic geographical information about the Czech lands and surrounding regions. Significant advancements included atlases by Václav Merklas, published under the auspices of the Czech patriotic organization Matice česká.

After the establishment of Czechoslovakia in 1918, school atlases reflected new state boundaries and the growing demand for quality geographical education. The first atlas featuring a thematic economic map (a 1:90,000,000 world map in Grinten projection) was the School Geographical Atlas by Šalamon and Kuchař from 1952. During socialism (1948–1989), school atlases were ideologically adapted to emphasize planned economies, heavy industries, alliances of socialist countries, and the significance of the Soviet Union.

Following the fall of communism in late 1989, atlases were updated to reflect objectivity and openness to an international context. New thematic maps focused on ecology, globalization, and the European Union, but the symbology remained unchanged until 2004. Digital atlases and interactive mapping platforms were also introduced.

Contemporary Czech school atlases with mandatory endorsements by the Ministry of Education are published by three Czech cartographic publishers. These atlases use new technologies for both printed school atlases and their web-based interactive counterparts.

4. Methodology

4.1 Selection of Atlases

The analysis of the content and symbology of mineral resource maps in Czech school atlases of the world was based on traditional methodological concepts, e.g. Wright (1942) and Williams (1971). The atlases were selected that represent all editions using a unified symbology for mineral resource maps from 1952 to 2025.

The list of selected atlases (Table 1) includes not only the basic identification details of individual atlases but also notes on the symbology for mineral resources and its validity in subsequent editions. This selection enables the examination of continuity or discontinuity in the evolution of symbology and its impact on visual learning, e.g. Jenks (1973).

The selection process aimed to represent all editions that utilized the same symbology for mineral resource maps. For each group of atlases with similar symbology, representative examples were chosen to best characterize the respective period or series of editions. This approach simplifies the analysis, allowing a focus on the main changes in cartographic representation without the need to include every edition. Otherwise, the number of analyzed atlases would increase to 44.

Year	Title in the original language [Czech] *Translated title in English*	Authors or Editors	Comments	Symbology code	Atlas code for reference in the text
1952	Školní zeměpisný atlas, 2. vydání *School Geographical Atlas, 2nd edition*	Šalamon, Kuchař	only 2 maps of the economy with features for mining resources valid until 1958, 7th edition	SALA	SZA1956
1959	Školní zeměpisný atlas světa, 1. vydání *School Geographical Atlas of the World, 1st edition*	Vokálek	only 3 maps of the economy with features for mining resources (different from each other) valid until 1961, 3th edition	VOKA1	SZAS1959
1962	Školní zeměpisný atlas světa, 4. vydání *School Geographical Atlas of the World, 4th edition*	Vokálek	the set of hand-held economic maps of the continents (5 maps, since 1963 6 maps) valid until 1968, 9th edition	VOKA2	SZAS1962
1970	Atlas světa, 1. vydání *Atlas of the World, 1st edition*	Vokálek	systematic concept of the Unified System of School Cartographic Aids (symbology by Koláčný) valid until 1987, 13th edition	KOLA	AS1970
1989	Školní atlas světa, 1. vydání *School Atlas of the World, 1st edition*	Klímová	still symbology by Koláčný valid until 2003, 7th edition	KOLA	SAS1989
2000	Školní atlas dnešního světa, 1. vydání *School Atlas of the Today's World, 1st edition*	Bičík	new symbology valid until 2018	KARA	TERR2000
2004	Školní atlas světa, 1. vydání *School Atlas of the World, 1st edition*	Petrunčík	new symbology valid until 2025, 5th edition	PETR	SAS2004
2004	Školní atlas světa, 1. vydání *School Atlas of the World, 1st edition*	Šára	new symbology valid until 2025	SARA	SHOC2004
2019	Školní atlas dnešního světa, 2. vydání *School Atlas of the Today's World, 2nd edition*	Hanus	new symbology valid until 2025	HANU	TERR2019

Table 1. List of selected school atlases representing symbologies.

The selection prioritized symbology rather than individual atlases, identifying eight different symbologies within the selected atlases. The analysis included symbologies from a total of 19 maps of the world, Asia, and the Americas.

The mineral resource maps in the selected atlases exhibited significant differences, particularly in the scope of the areas depicted (ranging from continents to entire world maps) and in map scales (ranging from 1:80,000,000 to 1:145,000,000).

4.2 Statistical Analyses of Symbologies

Various indicators were selected for the statistical analysis of symbology for mineral resources. The description of the basic characteristics of symbology included the total number of mineral resource groups for each symbology, the range of category counts (including the minimum, maximum, average, and median number of categories within a group), as well as the variance and standard deviation of category counts. These indicators facilitated the analysis of variability among individual groups.

A frequency overview of all mineral resources included in the symbology was created based on the list of resources from each symbology. In accordance with the studies of Dvorský et al (2009) and Gleicher (2017), a comparison of symbology across atlases was conducted using a category diversity index. For each group, the relative frequency of categories was calculated against the total number of elements in the most extensive symbology of the selected atlases. To compare the number of mineral resource groups across atlases, relative change (percentage difference) was employed.

4.3 User Testing

User testing of symbology was conducted among students to determine how easily and accurately they could interpret symbols from various symbologies. The objectives of the testing were to identify:

a) which symbologies were more comprehensible and intuitive for students,

b) how effectively students could read and interpret information from maps, and

c) what challenges they encountered when working with symbols or groups of symbols.

The target group consisted of individuals aged 12 to 15, for whom the atlases are designed and who already have experience with maps. Testing was carried out via a web-based questionnaire and in-person during geography lessons in school classrooms. A total of 273 students participated in the web-based questionnaire, and 64 students were tested directly in classrooms.

Google Forms was used for creating the questionnaire due to its capabilities for generating text-based and tabular documents as well as forms. These were utilized in the design of the questionnaire. Responses were recorded in a file that was subsequently exported to XLS format. However, since Google Forms does not allow direct image uploads, the source code of the generated HTML page was modified. For clarity, the questionnaire was divided into several pages.

Consultations with teachers revealed that completing questionnaires during geography lessons posed certain challenges and physical questionnaires were used only during interviews with teachers and selected students as part of qualitative research. The online survey was conducted between December 2023 and October 2024. Respondents were asked to indicate their gender, school grade, and relationship to maps (on a scale of 1–5).

The questionnaire included two slides, each accompanied by a set of three tasks (Table 2). On the first slide, identical symbols were excluded from the symbologies SALA, VOKA2, KOLA, PETR, HANU, KARA, and SARA. At the end of the rows, symbols deemed unsuitable by teachers were placed, including brown coal (HANU), mercury (SARA), tin (PETR), uranium (KARA), mica (KOLA), asbestos (VOKA2), silver (VOKA1), and rock salt (SALA). For the second task, multiple responses were allowed.

On the second slide, four selected sets of symbols from Figure 2 were presented.

Slide		Task	
S1	Symbols from the symbologies VOKA2, KOLA, PETR, HANU, KARA, and SARA.	T1	Which symbols would you choose for natural gas, silver, and asphalt?
		T2	Select symbols for gold, oil, uranium, lead, and diamonds.
		T3	For which mineral resources do you believe the symbols at the end of the rows were created?
S2	Sets of symbols for iron ore, copper, zinc, and manganese (from Figure 2).	T4	Choose the most suitable symbol from each set.
		T5	Select the least suitable symbol from each set.
		T6	Identify the symbols used for iron ore, copper, zinc, and manganese in the atlas you use in geography lessons.

Table 2. Slides with tasks for user testing

The time allocated for completing the tasks was not limited. The following metrics were monitored:

- Accuracy of responses: Number of tasks correctly completed by each student.
- Time required: The duration taken to complete the tasks.
- Symbol preferences: Identification of the most and least favorable symbols.

Upon completing the testing, subjective feedback was collected from students. They were asked how easy it was to work with the map, which symbologies they found the most comprehensible or the most complex, and what challenges they encountered during testing.

Following Brychtova, Popelka, and Vozenilek (2012), the collected responses were evaluated using quantitative analysis, while subjective feedback was analyzed qualitatively.

5. Results

5.1 Number of Symbols and Symbol Groups in Map Legends

A total of 46 mineral resources were identified in 19 map legends containing eight symbologies (see Figure 1). With one exception (TERR2019), resources were not organized into thematic groups with headings. They were mostly arranged based on visual similarity under general headings such as "Mining" or its variants ("Mining of Mineral Resources," "Mining of Resources of Global Significance," "Occurrence and Mining of Mineral Resources," "Mineral Resources"). In one case, an incorrect heading, "Mining of Minerals," was used, which included coal and oil—both of which are not minerals.

Although symbols in the map legends were not explicitly grouped into logical categories, some groupings could be inferred based on the syntactic aspects of the symbols:

- SALA: Ores and minerals were represented using alphanumeric symbols (chemical notations), while fuels, non-ores, and other resources were depicted with geometric symbols.
- VOKA1: All resources were represented using geometric symbols.
- VOKA2: Similar to SALA, ores and minerals were depicted with chemical notations, further divided into three groups by color differentiation; fuels, non-ores, and other resources were again shown with geometric symbols.

 https://doi.org/10.5194/ica-adv-5-35-2025 |

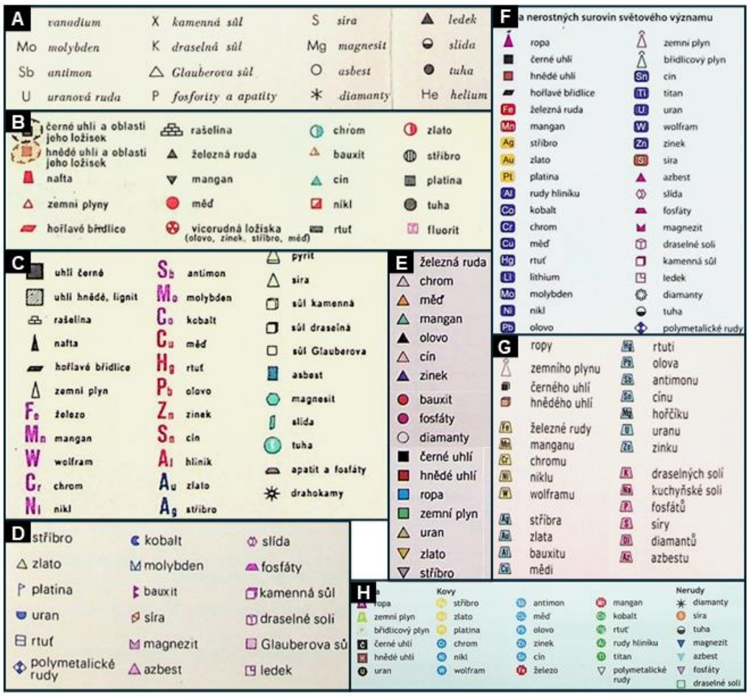

Figure 1. Examples of symbologies from map legends: A – SALA, B – VOKA1, C – VOKA2, D – KOLA, E – KARA, F – PETR, G – SARA, H – HANU (codes defined in Table 1).

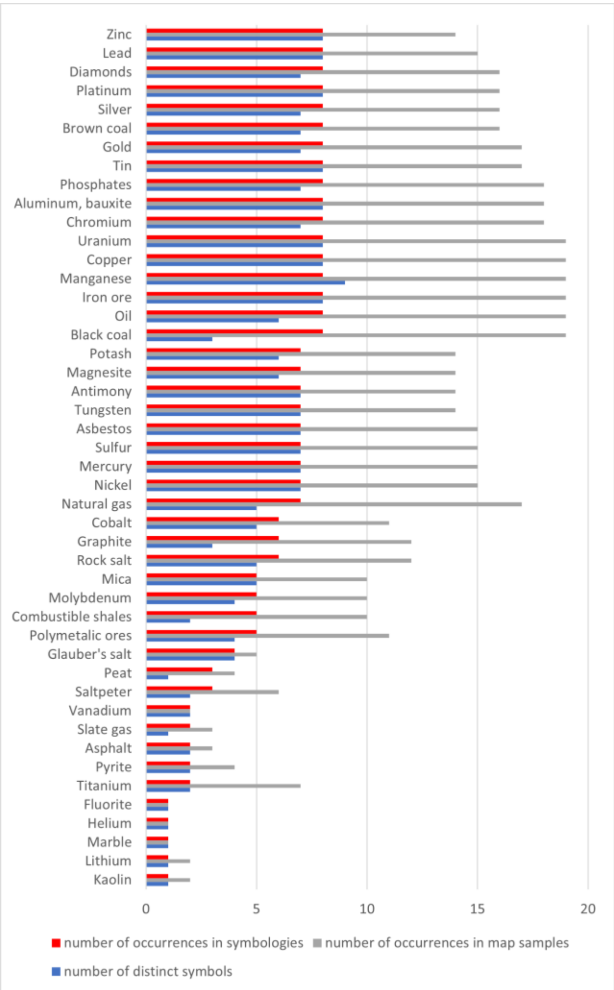

Figure 2. Frequency of occurrence of minerals in the legends of 19 map samples.

- KOLA: All resources were shown using geometric symbols mimicking chemical notations, color-coded into five groups.
- KARA: Geometric symbols were divided into four unnamed groups differentiated by shape.
- PETR: Geometric symbols were used for fuels and non-ores (consistent with KOLA symbols), while ores and minerals were represented by alphanumeric symbols (chemical notations) in square frames with colored fills, divided into four groups.
- SARA: Fuels were represented by geometric symbols, while other resources used alphanumeric symbols (chemical notations) in trapezoidal frames with colored fills, divided into three groups.
- HANU: The legend was explicitly divided into three groups (fuels, metals, non-ores). Fuels and metals were represented by alphanumeric symbols in frames of different shapes with colored fills, while non-ores were depicted using geometric symbols.

The most comprehensive legend is found in the AS1970 atlas, which includes 40 out of the 46 symbols. This legend serves as the introductory symbology for all maps of resource mining in the atlas.

5.2 Symbols for Mineral Resources

The number of changes in the symbols for mineral resources during the period 1952–2025 was examined. Although a total of eight symbologies were identified (see Table 1), the number of symbols varied among individual mineral resources—fewer for some and more for others.

Analysis of the graphical representation of symbols in these eight symbologies revealed the following findings:

- The greatest consistency in symbols was observed between the symbologies KOLA (AS1970 and AS2004) and PETR (SAS2004). This is understandable, as both symbologies originated from the same publisher, despite the significant time gap between their publication and the change in ownership triggered by political events in Czechoslovakia in 1989.
- In the VOKA1 symbology, two different symbols were used for brown coal.
- In the same symbology (VOKA1), the same symbol was used for platinum on one map and for brown coal on another.
- The same symbol was used for asphalt in the KOLA symbology and for asbestos in the PETR symbology.
- An identical symbol was used for mica in the SALA symbology and for graphite in the KOLA, PETR, and HANU symbologies.
- Shale appears in five symbologies but is represented by only two distinct symbols.
- For eight resources (iron ore, copper, uranium, aluminium/bauxite, tin, platinum, lead, and zinc), different symbols were used across all eight symbologies (see Figure 3).
- Manganese (manganese ore) is the only mineral resource that has nine different symbols across the eight symbologies. This anomaly occurred because two different symbols were used for manganese on different maps in atlases with the VOKA1 symbology (see Figure 3).

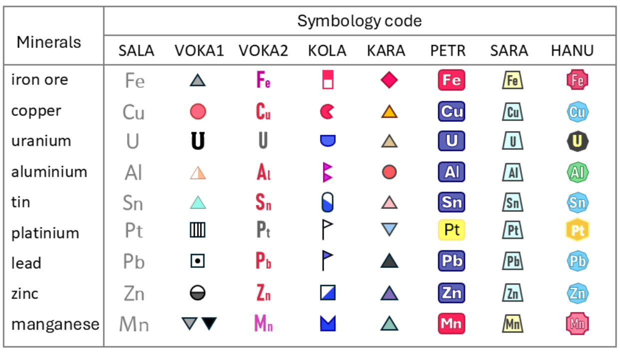

Figure 3. Differences in map symbols for selected minerals.

5.3 Student Evaluation of Symbols

The results of the web-based questionnaire, completed by 273 students aged 12 to 15 (considering incomplete responses), revealed the following findings:

- There were almost no differences in the accuracy of answers between boys and girls.
- The accuracy of responses to questions T1 and T6 improved only slightly with higher school grades.
- The success rate for correctly identifying symbols (T1) across different symbologies ranged from 26% to 42%. The highest accuracy was observed for natural gas, while the lowest was for asphalt.
- Students selected a wide variety of symbols for individual resources: 11 for gold, 20 for oil, 13 for uranium, 25 for lead, and 6 for diamonds, with no single symbol being significantly dominant.
- In Task T3, which assessed the least suitable symbols (as determined by teachers), the accuracy of responses was very low: 5% for the symbol for brown coal, 2% for mercury and tin, and 0% for all other symbols.

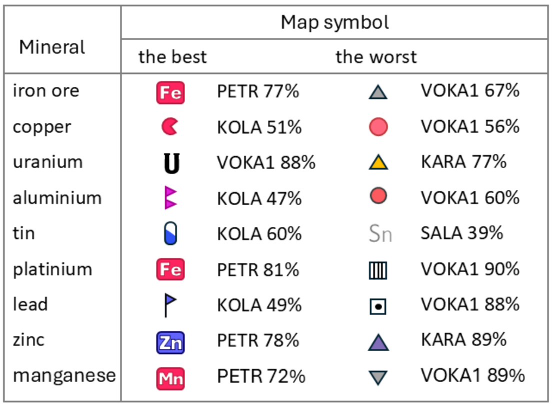

Figure 4. The best and worst map symbols for selected minerals.

- According to students and teachers, the most appropriate symbols were found in the KOLA and PETR symbologies, while the least favorably rated were the VOKA1 and KARA symbologies.
- In task T6, only 31% of students were able to identify all the symbols that were part of their school atlases.
- Students responded fairly quickly, enjoyed the testing, and showed interest in the correct solutions to the tasks.

During interviews with 64 students working with the printed questionnaire, the following emerged:

- Students are generally unaware of the informational value of maps and atlases, not only in geography lessons but also in a broader context.
- Although they were able to recognize chemical symbols in alphanumeric symbols, some students complained that in geography, they had to demonstrate knowledge from another subject.

- Many students are unfamiliar with various mineral resources; some terms they had heard of, but they lacked in-depth knowledge.
- Symbols for mineral resources are considered difficult to master.

6. Discussion

The finding that there are practically no differences between boys and girls in terms of knowledge and the ability to recognize map symbols suggests that visual learning through map symbols works uniformly regardless of gender. This conclusion is supported by other studies, such as the work of Beitlova, Popelka, and Vozenilek (2020). However, it is clear that progressive education, associated with increasing age and education level, has minimal impact on improving the correctness of answers.

Significant differences in the accuracy of determining map symbols (e.g., in task T1) are strongly influenced by the native language of the users (Czech) (Vondrakova and Vozenilek, 2016). In the case of alphanumeric symbols with chemical symbols, a difference was observed when the chemical notation corresponds to the Czech name of the mineral resource, e.g., Pt for platinum, Zn for zinc, or Mn for manganese. Conversely, for resources where the chemical notation does not correspond to the Czech name, such as Hg for mercury, Sn for tin, or Fe for iron, the accuracy of map symbol identification was significantly lower.

The low proportion of students who could identify all the symbols from the atlas used in geography lessons either suggests unclear symbol interpretation or insufficient use of the atlas in geography classes. Attention when searching for the "best" symbology should focus on the KOLA and PETR symbologies, which were rated as the most successful. The similarity in their success can be explained by the fact that the newer PETR symbology adopted some symbols from the older KOLA symbology.

Qualitative research through interviews with students emphasized the irreplaceable role of the teacher when working with maps and atlases. Students showed interest and motivation for tasks and perceived maps and atlases as undervalued sources of information with value beyond geography education. However, they still consider mastering symbols for mineral resources to be difficult, particularly in terms of memorization and interpretation. This highlights the need for stronger pedagogical support when working with maps.

Some students complained about the necessity of connecting knowledge from different subjects, specifically chemistry and geography, which they find burdensome. When chemical symbols are used in maps of mineral resources in school atlases, it creates a problem when these symbols are not taught in chemistry until later than students first encounter them on maps. This situation may lead to frustration and reduced motivation.

Insufficient knowledge of basic information about mineral resources, or only superficial awareness of them, points to the need for deeper integration of this topic into the school curriculum. A better connection between chemistry and geography teaching could facilitate students' understanding and increase their interest in this issue.

It is also essential to take into account the specific needs of students with learning disabilities, concentration issues, impaired vision, or other health disadvantages. These students may face increased difficulties in recognizing map symbols or memorizing information related to map tasks, e.g. Vozenilek, Michalik, Vondrakova and Brychtova, 2014. Educators should consider modifying teaching materials and methods to ensure accessibility for all students, such as by increasing contrast in maps, simplifying symbols, or allowing more time for tasks. Supporting an inclusive approach will ensure that these students have equal opportunities to develop their skills.

7. Conclusions

This paper analyzes changes in the symbologies of Czech school world atlases over the past 73 years, focusing on maps of mineral resources. It provides essential insight into the use of thematic maps and their symbologies in geography education at elementary schools. The identified difficulties students face in interpreting symbols and their meanings suggest the need for greater emphasis on systematically incorporating map symbols into the curriculum.

The finding that students consider mastering map symbols to be difficult highlights the importance of pedagogical support, such as through visual exercises, integration with other subjects, and the introduction of more accessible symbol systems. Maps and atlases also represent an attractive tool that can motivate students and contribute to the development of their practical skills and deeper understanding of geographic information.

The author emphasizes the crucial role of selecting suitable map symbols and their consistent interpretation for effective teaching. The low level of students' knowledge of map symbols points to the need for more frequent work with maps and atlases, which could strengthen students' ability to extract information from these sources.

For the creators of school atlases, the paper offers valuable suggestions for improving the readability and comprehensibility of map symbols. The analysis of symbologies shows that a combination of geometric and alphanumeric symbols – such as in the KOLA and PETR symbologies – is more successful with students. Logically organized legends and color differentiation can also significantly facilitate users' orientation. Suggestions to reduce students' burden, such as limiting the use of chemical symbols, provide important guidance for future atlas creation. These changes could significantly increase the effectiveness of school atlases as educational tools.

The results of the research contribute to a deeper understanding of how different approaches to map symbols influence their perception and understanding.

Identifying issues related to symbol ambiguity and interpretation highlights the need for standardization of map symbologies and the development of intuitive and easily memorable symbols. The study also highlights the importance of interdisciplinarity in cartography – the connection between chemical and geographical knowledge opens new possibilities for map creation.

The findings on students' and teachers' preferences provide a useful foundation for designing maps of mineral resources that better meet educational needs. The paper also inspires further research into cartographic visualization and its application in the educational process and other types of cartographic products than school atlases, e.g. dialect atlases (Vozenilek et al., 2022).

Acknowledgements

The article was supported by the project of the Czech Science Foundation “Identification of Barriers in the Process of Communication of Spatial Socio-Demographic Information” (Grant No. 23-06187S).

8. References

Barvir, R. and Vozenilek, V. (2020). Developing Versatile Graphic Map Load Metrics. ISPRS International Journal of Geo-Information. Vol. 9, pp. 705.

Barvir, R. and Vozenilek, V. (2021). Graphic Map Load Measuring Tool – development and verification. Online. International Journal of Cartography. Vol. 7, pp. 285–303.

Beitlova, M., Popelka, S. and Vozenilek, V. (2020). Differences in Thematic Map Reading by Students and Their Geography Teacher. Online. ISPRS International Journal of Geo-Information. Vol. 9, pp. 492.

Beitlova, M., Popelka, S. Vozenilek, V. Facevicova, K., Janeckova, B.A. et al. (2021). The Importance of School World Atlases According to Czech Geography Teachers. ISPRS International Journal of Geo-Information. Vol. 10, pp. 504.

Brychtova, A., Popelka, S. and Vozenilek, V. (2012). The Analysis of Eye Movement as a Tool for Evaluation of Maps and Graphical Outputs from GIS. In: Svobodova, H. Proc., 19th International Conference on Geography and Geoinformatics: Challenge for Practise and Education. Brno, Masaryk University, pp. 154–162.

Buswell, G. T. (1935). How people look at pictures. University of Chicago Press Chicago.

Dvorsky, J, Snasel, V. and Vozenilek, V. (2009). Map Similarity Testing Using Matrix Decomposition. Online. In: Proc., International Conference on Intelligent Networking and Collaborative Systems. IEEE, pp. 290–294.

Fabrikant, S. I., Hespanha, S. R., and Hegarty, M. (2010). Cognitively inspired and perceptually salient graphic displays for efficient spatial inference making. Annals of the Association of American Geographers, Vol. 100, pp. 13–29.

Gleicher, M. (2017). Considerations for visualizing comparison. IEEE Transactions on Visualization and Computer Graphics, Vol. 24, pp. 413–423.

Haeberling, C. (2005). Cartographic design principles for 3D maps–A contribution to cartographic theory. In: Proc., 22nd International Cartographic Conference, Caruña, Spain.

Jenks, G. F. (1973). Visual integration in thematic mapping: fact or fiction? International Yearbook of Cartography, Vol. 13, pp. 27–35.

Kolacny, A. (1969). Cartographic information—a fundamental concept and term in modern cartography. The Cartographic Journal, Vol. 6, pp. 47–49.

Konicek, J., Vozenilek, V., Barvir, R. and Vondrakova, A. (2024). Quantitative Approach for Assessing Infographics in Atlas Cartography. Geographia Cassoviensis, Vol. 18, pp. 46-65.

Krassanakis, V., Filippakopoulou, V. and Nakos, B. (2016). Detection of moving point symbols on cartographic backgrounds. Journal of Eye Movement Research, Vol. 9, pp. 1–16.

Vondrakova, A. and Vozenilek, V. (2016). User Issues In Geovisualization. In: Proc., Informatics, Geoinformatics And Remote Sensing Conference. Albena, Bulgaria, pp. 599–606.

Vozenilek, V. Morkesova, P. and Vondrakova, A. (2014). Cognitive Aspects of Map Symbology in the World School Atlases. Procedia – Social and Behavioral Sciences. Vol. 112, pp. 1121–1136.

Vozenilek, V., Ireinova, M. Vondrakova, A. and Konicek, J. (2022). Mapping, synthesis and visualization of Czech dialects. International Journal of Cartography. Vol. 8, pp. 148–163.

Vozenilek, V., Michalik, J., Vondrakova, A. and Brychtova, A. (2014). Mapping and Visualisation of Activities in Special Education. Online. Procedia – Social and Behavioral Sciences. Vol. 112, pp. 1106–1120.

Ward, M. O. (2002). A taxonomy of glyph placement strategies for multidimensional data visualization. Information Visualization, Vol. 1, pp. 194–210.

Williams, L. (1971). The Role of the User in the Map Communication Process: Obtaining Information from Displays with Discrete Elements. Cartographica: The International Journal for Geographic Information and Geovisualization, Vol. 8, pp. 29–34.

Wright, J. K. (1942). Map makers are human: Comments on the subjective in maps. Geographical Review, Vol. 32, pp. 527–544.