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How Map Type Shapes Student Questioning: Evidence from Choropleth and Dasymetric Population Density Maps

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Abstract

Although maps are widely used in geography education, there is limited knowledge about how different types of maps influence students' engagement with spatial information. This issue is particularly relevant in secondary education, where students are still developing both map skills and the ability to formulate questions. This study addresses the gap by examining student-generated questions about two maps of world population density represented using different cartographic methods: a choropleth map and a dasymetric map. The analysis is based on 869 questions produced by 176 students in grades 6–9 of two lower-secondary schools. It investigates whether map type and students' age are related to the number of questions students ask, as well as to their content focus and cognitive demand. The results show that students generated significantly more questions for the choropleth map and that this map was also preferred by most of them. The number of questions generally increased with age/grade level. Older students more often focused on the thematic content of the maps, whereas younger students attended more to visual and representational aspects. Although most questions remained at lower cognitive levels, the dasymetric map and older students were associated with a slightly higher proportion of questions requiring more cognitively demanding processes. The study shows that map type influences not only students' work with thematic maps but also the character of their questioning.

Keywords: Student Questions, SGQ, Thematic map, Map Type, Student Inquiry, Geography Education

1. Introduction

Considering the strong educational potential of maps in school geography (e.g., Hanus and Havelková, 2019; Wiegand, 2006), there is a pertaining need to understand how students engage with visually represented spatial data. This need is reinforced by geography education research showing that map skills remain a central component of geographical literacy and that students' performance in map use is still uneven across educational contexts (Ooms et al., 2015; Karaca and Yalçınkaya, 2021; Fuchs et al., 2024). At the same time, geography teaching should help students engage critically with the

complexity of the world rather than merely reproduce established knowledge and ready-made views of space (Fatichenti and Charpentier, 2025).

Although maps are a routine part of geography instruction, students do not work with all map representations equally well (Havelková and Hanus, 2018; Korycka-Skorupa and Gołębiowska, 2020; Ooms et al., 2015; Rapp et al., 2007). More broadly, studies indicate that different representations of spatial information may place different cognitive demands on users and may therefore support map use (reading, analysis, and interpretation) unevenly (e.g., Çöltekin et al., 2018; Collins, 2018; Trifonoff, 1995). In this respect, the educational importance of map work lies not only in students' exposure to maps, but also in how particular forms of representation shape what students notice, how they interpret what they see, and what kinds of meaning they are able to construct. This argument is also consistent with the view that students decode what they see through their own analytical grids, making the critical examination of geographical representations an important educational task (Fatichenti and Charpentier, 2025). From a didactic perspective, this view is further supported by work showing that mapping practices themselves can function as meaningful learning tools, since map-making is not only representational but also processual and can support exploration, reflection, and the development of situated geographical understanding (Miles, 2024; Quatrida, 2024)

This issue is especially important in the case of thematic maps. Research suggests that thematic map use is often challenging for students and that these challenges are related, at least in part, to the visual organisation of the map and the way information is encoded (e.g. Sibrel et al., 2020; Sun and Li, 2010; Šašinka et al., 2019). Comparative studies have shown that different thematic map types do not support map-use tasks equally and that map type can affect both objective performance and subjective judgments of difficulty (Havelková and Hanus, 2018; Korycka-Skorupa and Gołębiowska, 2020; Machová et al., in print; Słomska-Przech and Gołębiowska, 2021). This is consistent with broader cartographic and geography education research arguing that thematic map types and cartographic representation methods are not simply technical devices, but are fundamental to how learners perceive geospatial patterns and relations (Schaab et al., 2022). Moreover, maps express particular interpretations of the world and influence how students understand that world and their relation to it (Quatrida, 2024). From a geography education perspective, this means that the choice of map type is not merely a technical matter of presentation but may shape how students understand the spatial data visualized. As a result, map type matters for task performance and more importantly for students' understanding geographic phenomena represented. Notwithstanding, the studies on map types have predominantly focused on usability, map-use efficiency, or preference rather than on how students cognitively engage with the represented phenomenon.

One productive way of approaching this issue is through student-generated questions (SGQs). In science education, SGQs are regarded as an important indicator of students' conceptual engagement because they reveal what they notice, what they find unclear, and how they attempt to make sense of new content (Apedoe, 2008; Chin and Brown, 2002; Chin and Osborne, 2008; Hersh and Merrow, 2005). Kastens, Zrada and Turin (2020) further suggest that visualisations, like maps, are particularly suitable stimuli for question generation because they foreground patterns, anomalies, and gaps in understanding. Flašar, Krajňáková and Hanus (2026) showed that different maps can elicit different types of student questions and that students' educational level influences whether those questions are directed more towards visual aspects or conceptual content. However, research specifically examining how map types shape SGQs in school geography remains limited. In particular, little is known about whether two common representations of the same spatial phenomenon differ in the kinds of questions they provoke in lower-secondary students.

The present study addresses this gap by investigating SGQs about two representations of world population density: a choropleth map and a dasymetric map. By focusing on the questions students generate, rather than only on their

accuracy in predefined tasks, the study offers a complementary perspective on how students engage with thematic maps and how that engagement may vary with both map type and age. More specifically, the study addresses the following research questions:

RQ1: How do different map types and students' age influence the number of SGQs?

RQ2: How do different map types and students' age influence the content focus and cognitive demand of SGQs?

The study brings together two strands of research: research on students' use of thematic maps and research on SGQs as indicators of cognitive engagement, learning and inquiry (Chin and Osborne, 2008; Hanus and Havelková, 2019; Kastens et al., 2020). The theoretical background therefore first outlines the role of map type in students' engagement and then considers SGQs as a meaningful lens for examining how students interpret and respond to visual geographic representations.

2. Effect of map type on the level of map use in education

Maps are central to progressive geography education because they support students in identifying spatial patterns, analysing distributions, and interpreting relationships between geographic phenomena (MacEachren, 1995). In school settings, therefore, map use should not be limited to locating places or decoding symbols; it should also involve more complex processes of their analysis and interpretation (Hanus and Havelková, 2019; Wiegand, 2006).

Research suggests that students' success in working with maps is shaped by multiple influences, including student characteristics, instructional conditions, and the characteristics of the map itself. A systematic review by Havelková and Hanus (2019) identified map type (cartographic methods of representation more generally) among the main map-related factors affecting map use level.

This is especially important in relation to thematic cartography. Different thematic maps may represent same or similar data while relying on different visual cartographic principles, which means that students must understand not only the geographic phenomenon but also the cartographic method used to represent it (Slocum et al., 2013). This finding is supported by Beitlová, Popelka and Voženílek (2020), who conclude that thematic map use is cognitively demanding and that the design of the map affects students' level of map use. Moreover, the use of quantitative thematic maps (incl. choropleth and dasymetric maps) is dependent on mathematical literacy so students with lower mathematical literacy may struggle understanding and using them (Hanus et al., 2021). This is supported by the empirical evidence that students experienced greater difficulty with maps using quantitative mapping methods than with qualitative representations (Havelková and Hanus, 2019).

Moreover, even among quantitative thematic maps, differences in cartographic representation can lead to varying interpretive demands for students. For instance, choropleth and dasymetric maps, while both intended for depicting phenomenon density, present the information in distinct ways that may, among others, affect how students understand spatial patterns. Choropleth maps display aggregated values within predefined areal, usually administrative, units by using a colour or shading scheme. They therefore communicate average values for those units rather than the internal spatial distribution of the phenomenon (Slocum et al., 2013). Dasymetric maps address this limitation by creating internally homogeneous zones based on ancillary data.

Although dasymetric maps offer clear advantages in representing the phenomenon more accurately, students in school settings are much more likely to encounter choropleth maps in textbooks and atlases (Havelková and Hanus, 2018). This frequent exposure may contribute to lower familiarity and understanding of the dasymetric method. Moreover, the characteristics of dasymetric maps might make them cognitively more demanding for students, as they must attend carefully to spatial variation and cannot rely on familiar territorial anchors. The educational relevance of this difference lies in the fact that students do not necessarily transfer understanding automatically across map

types. Students need to be introduced to differences between maps; otherwise, they may master a skill with one type of map but fail with another (MacEachren, 1995).

3. Student-generated questions

SGQs are widely regarded as an important component of learning because they position students as active participants in knowledge construction rather than passive recipients of information (Apedoe, 2008; Hersh and Merrow, 2005; Kastens et al., 2020). In science education, questioning has long been understood as central to inquiry, conceptual development, and critical reasoning, and SGQs have therefore been treated as a potentially valuable resource for both learning and teaching (Cuccio-Schirripa and Steiner, 2000; Chin and Brown, 2002; Chin and Osborne, 2008). Rather than merely reflecting gaps in knowledge, students' questions can reveal what they notice, what they find problematic, and how they attempt to make sense of new information.

A key contribution of the SGQ is the instructional shift from focusing primarily on teachers' questions to recognising the pedagogical significance of questions posed by students themselves. Chin and Osborne (2008) argue that students' questions can direct learning, stimulate discussion, support self-evaluation of understanding, and increase motivation and interest in a topic. In parallel, Chin and Brown (2002) show that the process of generating questions can itself be a meaningful learning activity because it requires students to identify uncertainty, connect ideas, and formulate lines of inquiry. From this perspective, SGQs are not only a product of learning but also a mechanism through which learning develops. The benefits of SGQs depend on the learning environment, the quality of guidance provided, and the extent to which student questioning is integrated into classroom practice rather than treated as an isolated activity (Chin and Osborne, 2008). Additionally, students' questions often remain superficial or non-investigable unless teachers provide scaffolding and a classroom culture that values questioning (Dah et al., 2023).

However, without providing stimuli, students do not typically ask many questions spontaneously (Chin and Osborne, 2008; Graesser and Person, 1994). Within geography and geoscience education, this issue is especially important because maps, diagrams, and other spatial visualisations frequently hold a potential to serve as such stimuli for questioning and inquiry. Kastens, Zrada and Turrin (2020) argue that data visualisations can stimulate questioning by drawing attention to patterns, anomalies, and gaps in understanding. In this sense, SGQs offer a useful lens for examining how students engage with geographic visualizations, especially maps. They make visible not only what students know, but also what aspects of maps attract attention and what kind of reasoning it provokes. Flašar, Krajňáková and Hanus (2026) found that different geological maps elicited different types of SGQs and that educational level shaped their focus: younger students attended more to visual and descriptive aspects, whereas older students asked more (although still limited) conceptual and content-related questions. This finding is vital for geography education because it suggests that SGQs are sensitive to both the characteristics of the stimulus and the characteristics of the learner. As a result, analysing students' questions may help reveal how maps are being understood in classroom contexts and what kinds of support students need to move from noticing geographical features to interpreting spatial distribution and thinking geographically.

4. Methodology

4.1 Research design

This study employed a quantitative cross-sectional research design based on questionnaire data to investigate SGQs about two thematic maps of world population density. The research focused on how the map type and students' age relate to the number and structure of questions formulated by students when working with maps. As each student worked with two maps representing the same phenomenon using different cartographic methods, the design also allowed a within-subject comparison of SGQs across two cartographic representations.

The analysis focused on two independent variables: the map type used in the map (choropleth vs. dasymetric map), and students' age, operationalised as grade level. Three dependent variables were examined: the number of SGQs, the content focus of the questions, and the cognitive demand of the questions.

4.2 Research sample

The study involved 176 students from two public lower-secondary schools in Prague, Czechia, attending grades 6 to 9 (aged 11–16). The schools were selected purposively: besides being located in the same Prague district, they differed in the time allocation for geography, the distribution of geography content across grades, and the teaching materials used. The sample included 96 girls and 80 boys in multiple classes from each grade level, representing a diverse group of students within each school. Teachers were involved mainly in organisational support, especially for administering the questionnaires in their classes with no additional interventions.

Participation was voluntary, and all responses were collected anonymously. The study was conducted in accordance with institutional research ethics guidelines and approved by the institutional ethics committee.

4.3 Research materials

Data were collected using a questionnaire specifically designed for this study and inspired by research tools used in related studies (Flašar et al., 2026). It included two thematic maps of world population density, each represented using a different cartographic method: a choropleth map and a dasymetric map (adapted from a commonly used Czech school atlas; Hanus and Šídlo, 2011). The choice of population density was motivated by the fact that the topic is familiar in school geography and that the atlas offered the same phenomenon represented by two different cartographic methods. The choropleth map displayed population density aggregated by administrative units (specifically individual world countries), whereas the dasymetric map depicted density independently of administrative boundaries, using spatial units derived from the phenomenon's distribution. Both maps used intervals and a colour scale to display the values of the population density.

The questionnaire provided spaces for students to record questions about each map and a final item asking which map they considered more suitable for representing population density and identification of its spatial pattern. Background information (gender, grade, and school of students) was collected in a separate section of the questionnaire.

4.4 Data collection

Data were collected in two stages: a pilot study followed by the main study. The pilot study involved 40 students (19 from grade 7 and 21 from grade 9) who were not later included in the main sample. Its purpose was to validate the questionnaire, the understandability of the instructions, and the feasibility of the research procedure. Based on the pilot results, minor adjustments were made to the questionnaire.

The main study was conducted during regular geography lessons, with students completing the questionnaire individually. They first examined each map and wrote down any questions that came to their mind in the provided spaces. After generating questions for both maps, students completed the background section and indicated which of the two maps they considered more suitable for representing the population density and its spatial patterns in the world.

4.5 Data processing

After the questionnaires were collected, all responses were digitised for analysis. Each question formulated by the students was recorded and linked to the corresponding map. SGQs were then categorised according to two analytical frameworks: content focus and cognitive demand.

The categorisation of SGQs was conducted by the first author of the study using the predefined coding scheme developed by the authors. During the coding process, each question was examined and assigned to the

Category	Subcategory	Examples of SGQs
Map	Map face	Where is Egypt?
	Legend	What does the colour white mean?
	Others	How come there's no year listed?
Data and map creation	Data	Why is this [map] not up to date?
	Map creation and selection of its content	Why is Antarctica missing?
Thematic content (population density)	Population density values	Which country has the highest population density?
	Spatial distribution	Is it more populated along rivers or in deserts and plateaus?
	Explanations and causes of differences	Why is North Africa almost uninhabited?
	Chronology	What has changed in population density from 2017 to 2025?
	Terminology	And what is density?
	Others	Why don't they populate Africa?
Map utility	–	What is this map for?
Others	Questions without any links to a map	Why don't rivers flow there? [Sahara circled]
	Nonsenses	I don't know anything, why do I have to write this?

Table 1. Classification of SGQs with examples. Source: Authors' elaboration.

category that best corresponded to its meaning and the cognitive processes required to answer it. In cases where the categorisation of a question was unclear, the question was re-examined by two researchers and categorized after reaching an agreement. This procedure ensured a consistent and systematic classifycation of SGQs throughout the dataset.

4.5.1 Content focus classification

First, the questions were analysed according to their content focus. The classification of student questions by content focus was adapted from the frameworks of Flašar et al. (2026) and Kastens et al. (2020). The classification primarily distinguished questions focusing on the thematic phenomenon represented in the map, the map representation itself, the data and map creation, and map utility (see Table 1). Some subcategories were adjusted to reflect differences in research focus. When a question contained multiple elements from different categories, it was assigned into all of them.

4.5.2. Cognitive demand classification

In addition to content focus, each question was analysed in terms of its cognitive demand. The classification drew on the Cognitive Process dimension of the Revised Bloom's Taxonomy. For analytical purposes, questions were grouped into three broad levels of cognitive demand: those primarily requiring remembering or understanding; those requiring applying or analysing; and those requiring evaluating or creating.

4.6 Data analysis

The data were analysed using descriptive and inferential statistics. Descriptive statistics were used to summarise the total number of SGQs and to calculate the average number of questions per student. The distribution of questions across maps, content categories, and cognitive categories was also examined.

For the inferential statistical analysis, null hypotheses based on the proposed research questions were formulated (Table 2). The statistical tests used for the hypothesis testing were selected based on the data type of the dependent and independent variables. Non-parametric tests were intentionally used due to the nature of the data. The level of significance was set at 0.05 for the hypothesis testing, and Bonferroni correction was applied to adjust the significance level during pairwise comparisons. The analysis was conducted using IBM SPSS Statistics.

The number of SGQs does not depend on the map type.	Wilcoxon signed-rank test
The number of SGQs in content categories does not depend on the map type.	
The number of SGQs in cognitive demand categories does not depend on the map type.	
The number of SGQs does not depend on the students' age (grade).	Kruskal–Wallis test (Dunn's test)
The number of SGQs in content categories does not depend on the students' age (grade).	
The number of SGQs in cognitive demand categories does not depend on the students' age (grade).	

Table 2. The formulated null hypotheses and the chosen test statistics. Source: Authors' elaboration.

5. Results

The study involved 176 lower-secondary school students, who together generated 869 SGQs related to two thematic maps of world population density. Only one student did not formulate any question. The maximum number of questions generated by a single student was 17 questions, consisting of nine questions related to the choropleth map and eight questions related to the dasymetric map. The average number of questions generated per student was 4.9.

The analysis of the content focus of the questions showed that students most frequently formulated questions related to the main thematic content of the maps, namely population density. Questions belonging to this category focused directly on the spatial distribution of population density or on characteristics of the phenomenon represented in the map such as the values, distribution, causes of differences, or basic terminology connected with population density. Figure 1 presents both the absolute number of questions and their distribution across the designated content categories and selected subcategories. It shows clearly that questions related to the thematic content of the maps were by far the most frequent, whereas questions focused on map utility or uncategorizable questions were relatively rare. In addition to questions related to the thematic phenomenon, students also formulated questions related to map representation and its creation. These questions referred, for example, to elements of the map or to the way the information was visualized in the map, including the legend, colours, or the construction and content selection of the map itself.

The cognitive demand of SGQs was evaluated using three categories derived from the Revised Bloom's Taxonomy. The analysis showed that most questions belonged to the lowest cognitive category. Overall, 82.5% of all questions were classified in the first category (remembering and understanding). Questions belonging to the second category (applying and analysing) accounted for 15.2% of all questions, while questions in the third category (evaluating and creating) represented 2.4% of the total number of questions.

5.1 Effects of map type and age on the number of SGQs

The first research question examined how the map type and students' age influence the number of SGQs about maps of world population density.

5.1.1 Map type

The map type significantly influenced the number of questions generated by students. Out of the total 869 questions, 503 questions referred to the choropleth map, whereas 366 questions referred to the dasymetric map.

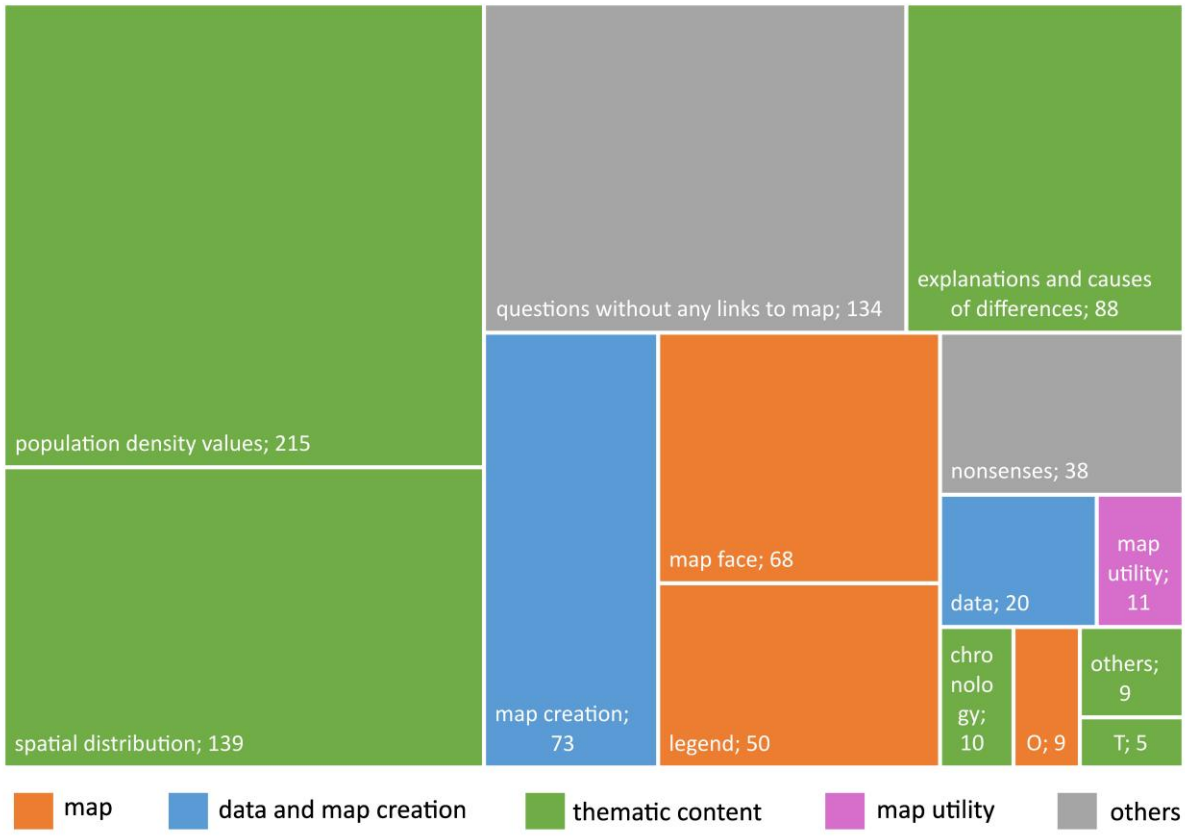

Figure 1. Distribution and number of questions in the designated content categories.
Note: Abbreviations: O – others, T – terminology. Source: Authors' elaboration.

Almost all (175) students generated at least one question for the choropleth map. In contrast, 20 students did not formulate any question for the dasymetric map. On average, students generated 2.8 questions for the choropleth map and 2.1 questions for the dasymetric map (Figure 2). This difference was statistically significant ($z = -7.04$, $p < 0.001$).

Students' responses to the preference question in the questionnaire showed a similar pattern. When asked which map would be more suitable for describing the spatial distribution of world population density, 116 students selected the choropleth map, whereas 29 students selected the dasymetric map. Four students indicated that both maps were equally suitable for this task.

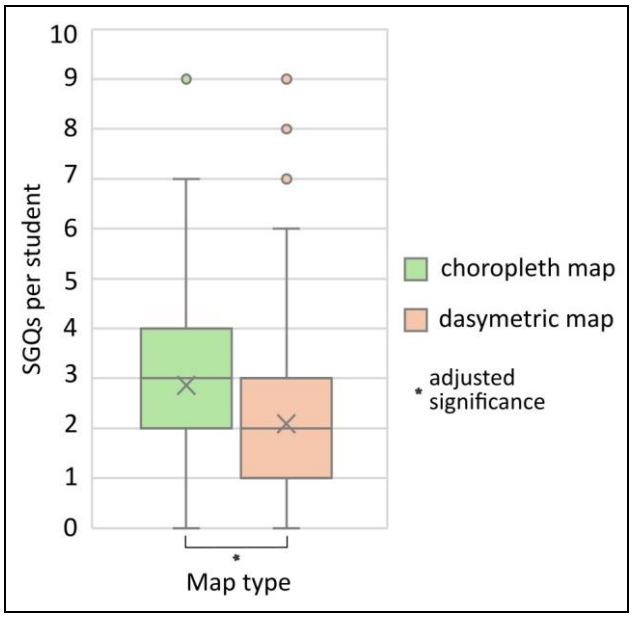

Figure 2. The number of SGQs for each map type.
Source: Authors' elaboration.

5.1.2 Students' age

Students' age was represented in the analysis by grade level (grades 6–9).

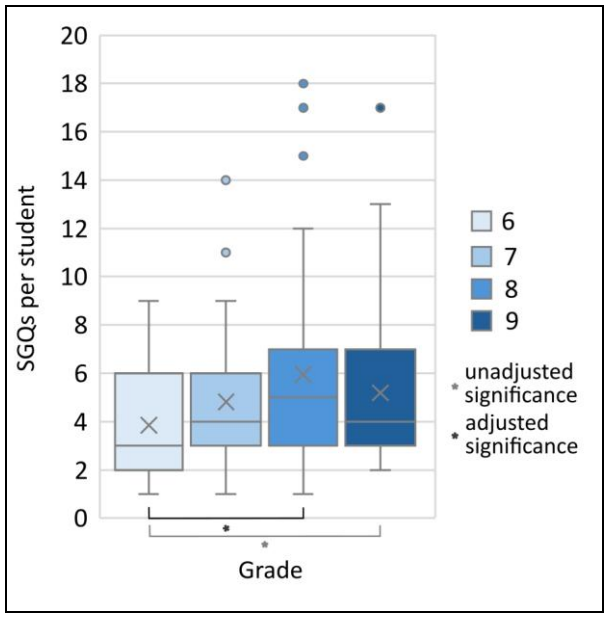

Figure 3. The number of SGQs for individual grades. Source: Authors' elaboration.

The number of SGQs was statistically significantly influenced by the grade ($\chi2(3,176) = 9.51$, $p = 0.023$). Students in higher grades tended to generate more questions than students in lower grades. However, the trend was not strictly linear (see Figure 3). Among students in grade 9, the average number of questions (5.19 per student) slightly decreased compared with students in grade 8 (5.96 per student). The increase in the number of questions was statistically significant after Bonferroni correction only between grade 6 (3.85 SGQs per student) and grade 8 ($p = 0.020$).

5.2 Effects of map type and age on the content focus and cognitive demand of SGQs

The second research question examined how the map type and students' age influence the content focus and cognitive demand of SGQs.

5.2.1 Content of SGQs

The distribution of questions across most of the content categories differed across age groups. This is supported by Figure 4 showing both the total number of questions in each content category and the shift in students' attention across grade levels. The most visible pattern is the increasing dominance of questions focused on the thematic content of the maps with increasing grade, whereas questions focused on map representation are more prominent in lower grades. This is confirmed by the statical tests indicating that students in higher grades formulated significantly more thematic content questions, than the students in lower grades ($\chi2(3,176) = 48.28$, $p < 0.001$). In contrast, younger students asked significantly more questions related to map representation ($\chi2(3,176) = 13.01$, $p = 0.005$). The students' age statistically significantly influenced also the number of SGQs focused on data and map creation ($\chi2(3,176) = 19.09$, $p < 0.001$). Interestingly, students in grade 6 and grade 9 generated on average more SGQs than grade 7 and 8 students, nevertheless the differences was statistically significant after Bonferroni correction only between grade 6 and 7 ($p < 0.001$) and between grade 6 and 8 ($p = 0.016$). As shown in Figure 4, questions related to map utility and other marginal categories remained comparatively infrequent in all grades.

Compared to the influence of students' age, the map type did not influence the distribution of questions across the content categories substantially. The students only generated significantly more questions related to the thematic content of the map when the population density was depicted using the choropleth method ($z = -4.18$, $p < 0.001$).

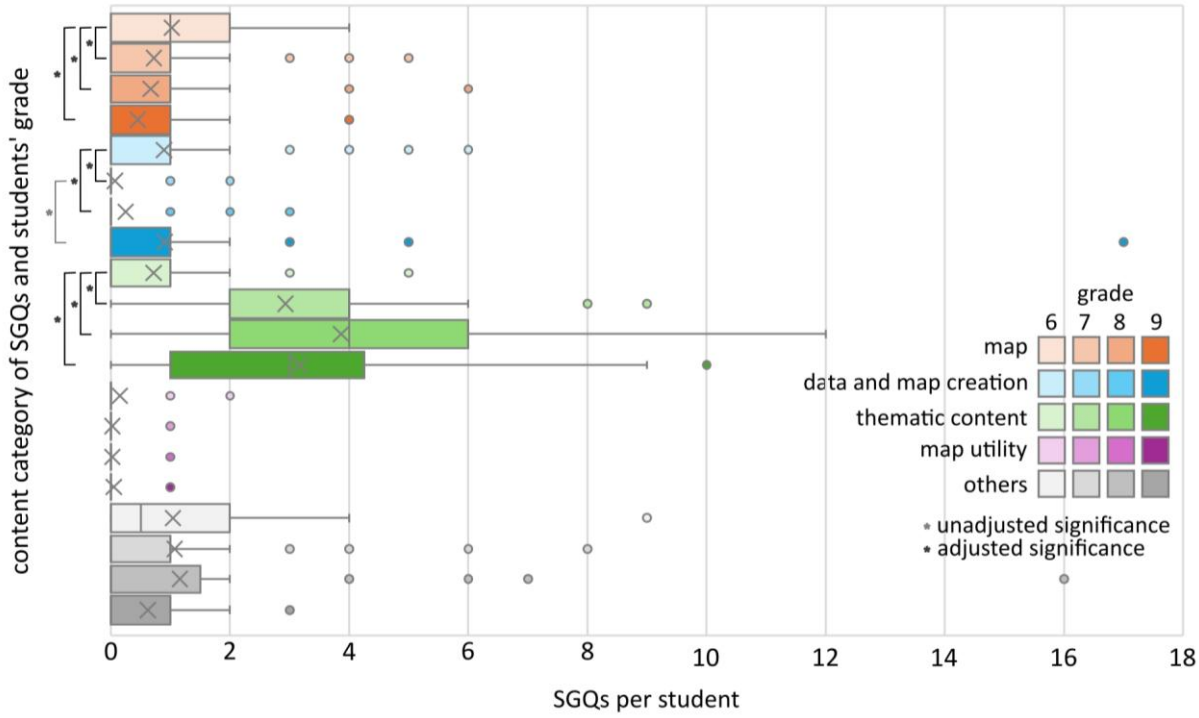

Figure 4. The number and distribution of the questions in relation to their content and the grade. Source: Authors' elaboration.

5.2.2 Cognitive demand of SGQs

When the two maps were compared, differences were observed in the distribution of cognitive categories. For the choropleth map, 84.3% of questions belonged to the lowest cognitive category, 13.2% belonged to the second category, and 2.5% belonged to the highest category. For the dasymetric map, 79.9% of questions were classified in the lowest category, 17.8% in the second category, and 2.2% in the highest category.

cognitive level	map type	SGQs per student			total
		Mdn	M	Max	
R&U	CM	2	2.32	9	408
	DM	1	1.63	7	287
A&A	CM	0	0.37	4	65
	DM	0	0.36	3	64
E&C	CM	0	0.07	2	12
	DM	0	0.05	1	8

Table 3. The descriptive statistics of SGQs by cognitive level and map type. Source: Authors' elaboration. *Note: Abbreviations: R&U – remembering and understanding, A&A – applying and analysing, E&C – evaluating and creating; Mdn – median, M – mean, Max – maximum.*

These results show that the dasymetric map was associated with a slightly higher proportion of questions belonging to the second cognitive category. Nevertheless, the map types differed significantly in the number of SGQs only in the lowest cognitive category ($z = -3.99$, $p < 0.001$), in which the students generated more questions with the choropleth map (Table 3).

cognitive level	grade	SGQs per student			total
		Mdn	M	Max	
R&U	6	3	2.93	9	135
	7	4	4.21	14	181
	8	3	4.82	16	217
	9	3	3.86	15	162
A&A	6	0	0.52	5	24
	7	0	0.47	4	20
	8	0	1.00	6	45
	9	0	0.95	4	40
E&C	6	0	0.17	2	8
	7	0	0.07	1	3
	8	0	0.04	1	2
	9	0	0.17	2	7

Table 4. The descriptive statistics of SGQs by cognitive level and grade. Source: Authors' elaboration. *Note: Abbreviations: see Table 3.*

Differences in cognitive demand were also observed across grade levels. Although the lowest cognitive category clearly predominated in all grades, older students produced a somewhat higher proportion of questions belonging to the second category (applying and analysing) compared with younger students. Questions belonging to the highest cognitive category (evaluating and creating) remained relatively rare across all grade levels (see Table 4). Overall, the grade level did not significantly influence the number of SGQs in any of the cognitive demand category.

6. Discussion

This study set out to examine how different types of map and students' age relate to the number, content focus, and cognitive demand of SGQs about world population density maps.

The strongest pattern concerns map type. The choropleth map elicited more questions and was more often perceived as suitable for identification of spatial patterns of the phenomenon. This suggests that it was the more immediately accessible representation for the students in this sample. That interpretation is consistent with previous research showing that map types differ in both usability and perceived difficulty (Hanus and Marada, 2016; Ishikawa, 2016; Michaelidou et al., 2004; van Dijk et al., 1994). Słomska-Przech and Gołębiowska (2021) reported that choropleth maps produced the best overall performance metrics in their comparison of thematic map types and that students also assessed them as the easiest. Their discussion further notes that earlier studies had found cases in which users preferred choropleth maps even when those maps did not produce better performance, which underlines that familiarity and perceived ease are important dimensions of map use (Słomska-Przech and Gołębiowska, 2021). This is supported by the findings of Havelková and Hanus (2018) that reveals that choropleth maps are even for many upper-secondary students challenging thematic maps to read, analyse and, especially, interpret, but, in contrast, are the most frequently used quantitative map type in Czech school atlases, thus students are familiar with them.

The result also aligns with school-based research on thematic map reading of Beitlová, Popelka and Voženílek (2020) who highlighted that thematic map tasks that appear straightforward are often not solved successfully by students. They also point to the importance of visual design features in thematic map use. In addition, Hanus, Havelková and Švubová (2021) argued that the use of quantitative thematic maps depends partly on the mathematical operations they require and explicitly noted that choropleth map can be demanding for students. Taken together, these studies support the conclusion that the lower number of questions generated for the dasymetric map may reflect lower immediate legibility rather than lower educational value of this type of map. At the same time, the findings do not suggest that the choropleth map was simply better. Although it elicited more questions overall, the dasymetric map was associated with a slightly higher proportion of questions in the applying and analysing category. This indicates that the two representations differed not only in accessibility but also in the kind of engagement they supported.

The second major finding concerns age-related differences. Older students generally generated more questions and, more importantly, were more likely to formulate questions focused on the thematic content rather than on visual or representational aspects. This closely mirrors the pattern reported by Flašar, Krajňáková and Hanus (2026), who found that younger students tended to focus on visual and descriptive aspects of maps, whereas older students asked more content-focused and conceptual questions. The consistency of this pattern across studies suggests that SGQs are sensitive to educational level and may therefore provide a useful indicator of how students at different stages engage with maps (Scardamalia and Bereiter, 1992; Costa et al., 2000).

The findings on cognitive demand also correspond to the broader SGQ literature. Most questions in the present study were located at the lowest cognitive level. Chin and Osborne (2008) noted that the educational value of student questioning does not lie simply in asking more questions, but in the quality and depth of those questions. They further highlighted that students

who ask higher-level questions tend to show stronger conceptual understanding. Similarly, Dah et al. (2023) emphasised that many students' questions do not become investigable or cognitively demanding unless questioning is explicitly scaffolded. Against this background, the predominance of low-level questions in the present study is not surprising. What is more important is that some variation in question complexity was still visible across map type and age, suggesting that both the visual stimulus and the student's educational stage matter.

The study also extends previous work on visualisations as stimuli for questioning. Kastens, Zrada and Turrin (2020) showed that data visualisations can provoke a wide range of student questions and argued that these questions provide insight into how students interpret what they see. The present study builds on that insight by showing that even when two maps represent the same phenomenon, differences in cartographic representation are associated with differences in the number and nature of students' questions. This highlights the paper's main contribution as it connects research on thematic map use with research on SGQs and shows that SGQs can be used as a meaningful lens for examining how students engage with different map types.

6.1 Educational implications

The findings of this study provide several implications for geography education, particularly regarding the use of maps as stimuli for inquiry-based learning and the role of SGQs in developing map-based understanding of geographical concepts, processes and phenomena.

Previous research has shown that visualisations such as maps can reveal patterns and relationships that encourage students to formulate questions while reading, analysing or interpreting spatial data (Kastens et al., 2020). The results of this study support this view by demonstrating that students generated a substantial number of questions when working with maps representing the spatial distribution of population density. Activities in which students explore maps and formulate their own questions may therefore provide opportunities for engaging students in processes of interpretation and inquiry rather than focusing solely on the description of spatial patterns.

A further implication relates to the role of cartographic representation in shaping students' engagement with maps. The results indicate that the type of cartographic representation influenced the number and characteristics of the questions generated by students. Because different cartographic methods highlight different aspects of spatial data, the choice of map representation may affect the features of the map that attract students' attention during interpretation. In classroom practice, this suggests that presenting the same phenomenon using different cartographic representations may support discussion about how map design influences the interpretation of spatial information.

The findings also highlight the importance of considering students' educational level when designing map-based learning activities. Differences observed between grade levels indicate that younger students more frequently focus on the visual or representational aspects of maps rather than the thematic content represented in them. These results suggest that effective use of maps in teaching may require gradual development of students' map skills as well as familiarity with principles of cartographic visualisations.

Another implication concerns the potential use of SGQs as a source of information about students' understanding of maps or geographical content visualized. Previous studies have shown that analysing students' questions can help teachers identify areas of difficulty and aspects of content that attract students' attention (Chin and Osborne, 2008). In the context of map-based learning, the questions formulated by students may reveal how they interpret maps and which elements of the map they find unclear, challenging or noteworthy. Such questions can therefore provide teachers with insights into students' understanding of maps as spatial data visualizations.

Overall, the findings suggest that encouraging students to formulate questions while working with maps may support active engagement with spatial information. At the same time, the results indicate that both the

design of the map and the characteristics of the learners influence the nature of the questions generated during map-based learning activities (similarly Havelková, Hanus 2019).

6.2 Study limitations and implications for future research

The findings of this study should be interpreted in light of several limitations related to the research design and the scope of the analysed data. Addressing these limitations may be considered when interpreting the findings but also provide useful directions for future research on SGQs and map use in geography education.

First, the study focused on a specific group of students from selected lower-secondary school classes. Although the sample provided valuable insight into students' questioning when working with thematic maps, the findings cannot be generalised to whole school population and all educational contexts. Future studies could extend this research by including a larger and more diverse sample of schools and educational environments. Expanding the study to different educational systems or age groups would make it possible to examine whether similar patterns in SGQs emerge across different learning contexts.

Second, the study examined students' questions generated in response to a limited set of map stimuli representing a single thematic phenomenon. While this design allowed a controlled comparison between two map types, it also limits the extent to which the results can be applied to other types of maps and geographic topics. Future research could therefore investigate how students formulate questions when working with thematic maps depicting various phenomena or with other map types.

Another limitation relates to the specific learning situation in which the data were collected. The questions analysed in this study were generated during a structured research activity (although as a part of standard geographical instruction) rather than within a regular classroom inquiry process. Previous research suggests that the nature and complexity of SGQs may vary depending on the learning context and the type of stimulus used (Chin and Osborne, 2008; Kastens et al., 2020). Further studies conducted in more authentic classroom environments could therefore provide additional insight into how students formulate questions while engaging with maps during common learning activities.

Future research could also explore in greater detail the relationship between students' map skills and the characteristics of the questions they generate. Previous studies have shown that differences in map skills and prior knowledge can influence how students interpret maps and other visual representations (Hanus and Marada, 2016; Ooms et al., 2015). Investigating this relationship may contribute to a better understanding of how students' experience with maps shapes their questioning during map-based learning.

Finally, further research could examine instructional approaches that intentionally incorporate SGQs into map-based learning activities. Previous studies have highlighted the potential of student questioning to support inquiry-based learning, knowledge construction (Chin and Osborne, 2008; Kastens et al., 2020) or deep learning (Song 2016). Exploring how teaching strategies can effectively encourage and utilise SGQs in geography education may therefore represent a promising direction for future research.

7. Conclusions

This study examined how map type and students' age are related to SGQs about two maps of world population density. By comparing a choropleth map and a dasymetric map, it extended research on thematic map use by focusing not only on students' performance, but also on the questions students formulate when engaging with maps.

The findings show that map type influenced both the quantity and the character of students' questioning. The choropleth map elicited more questions overall and was preferred by most students, suggesting that it was the more immediately accessible representation for lower-secondary students. At the same time, the

dasymetric map was associated with a slightly higher proportion of questions requiring applying and analysing skills, indicating that it may prompt somewhat more cognitively demanding engagement. Students' age also mattered: older students generally generated more questions and more often focused on thematic content, whereas younger students attended more to visual and representational aspects. Across both map types, however, most questions remained at lower cognitive levels.

The main contribution of the study lies in showing that SGQs provide a productive lens for examining how students engage with thematic maps. Different map types did not only affect how many questions students asked, but also what these questions addressed and how cognitively demanding they were. In this respect, the study complements earlier research showing that map type influences map-use performance and supports the view that students' questions are a useful indicator of conceptual engagement and inquiry.

The findings have implications for geography teachers, teacher educators, and authors of teaching materials. For teachers, they suggest that thematic map selection should be considered not only in relation to content coverage but also in relation to the kinds of questions and thinking different map types are likely to support. For teacher educators, the results highlight the need to prepare future teachers to work explicitly with differences between thematic map types and to use students' questions as evidence of how maps are being understood. For authors of atlases and textbooks, the findings indicate that map type may influence whether students attend primarily to visual form or to thematic meaning.

Overall, the study suggests that thematic map types are not didactically neutral. If different map representations shape not only how students use maps but also what they ask about them, then map selection becomes an important instructional decision in geography education.

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