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Review Article

Utilisation of Concept Maps in Geography Education Research: A Systematic Review

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Abstract: Concept maps are graphical representations of students' knowledge and understanding, used for the development of meaningful learning. In geographical education, they can support the visualisation of processes among Earth systems and the development of systems thinking. This systematic review examines 40 empirical studies (2003–2023), written in English and found in the Scopus and Web of Science databases. The aim of the literature review was to analyse and categorise the most common uses of concept maps in geography education research, focusing on the research, interaction and application issues of concept maps in relation to geography and the students creating them. The results show that concept maps were predominantly used as an assessment tool to reveal conceptual changes post-intervention. The most frequently mapped topic was climate change and other human–environment interactions. Concept maps were primarily used to study general pedagogical problems, less to explicitly research geographical education. This review highlights the role of concept maps in geography education, and their potential and limitations in efficient implementation.

Keywords: concept maps, geography education, systematic review, geography students, meaningful learning, systems thinking

Highlights:

- Using concept maps as a learning tool can help students develop systems and relational thinking skills.
- Concept map use can help teachers detect misconceptions and conceptual changes in student learning.
- Initial training in concept mapping and continuous feedback are major conditions for its effective use and the gain in possible benefits for geography students.

1. Introduction

Assimilating and connecting information plays a key role in studying geography, thinking geographically, and comprehending and interpreting the complicated world we live in. The list of methods and tools that can aid students in their effort to understand the world is endless, with concept maps having gradually found their place among these since at least the 1970s, when they were introduced by Joseph Novak and his team in the United States. They created concept maps with the aim of elucidating the learner's conceptual knowledge of a content domain (Novak & Cañas, 2006) and supporting meaningful learning (Ausubel, 1963). These maps, consisting of hierarchies of relationships built on concepts connected by a linking word, allow students to express and understand the connections between their existing ideas, link new ideas to prior knowledge and organise their ideas in a structure that suits them the best (Hay et al., 2008).

Earth systems and their interrelationships can be better understood through using such two-dimensional visual models (Mehren & Rempfler, 2022), in which the misconceptions of more abstract concepts can be easily diagnosed (Assaraf & Orpaz, 2010). Their inclusion in geography classrooms can support student learning and assessment (Wehry et al., 2012). Decades of education research have shown that the regular use of concept maps can help students develop higher-order thinking skills (Cañas et al., 2017), critical thinking, metacognitive reflection and creativity (Machado & Carvalho, 2020).

Geography teachers see the potential of concept maps in essay planning (O'Brien, 2002), gathering together all the pieces of the geography jigsaw, and supporting collaborative and visual learning (Leat & Chandler, 1996). However, they have also stressed the need for good instruction, otherwise their potential as a learning and assessment tool cannot be thoroughly realised and their implementation without reflection and practice will not be effective (Leat & Chandler, 1996; O'Brien, 2002).

Although the use of concept maps in geography education has been mentioned and strongly supported in several studies (Roberts, 2023), there has been no systematic analysis documenting these instances in empirical research, apart from in one conference paper (Campelo & Piconez, 2018). Consequently, it is not yet known what roles concept maps can play in geography classrooms, what benefits they provide and if this somehow differs from their use in other subjects and their specific requirements.

Therefore, in this article, the aim was to present the results of a systematic review that was carried out using articles published between 2003 and 2023 that addressed concept maps in geography education research. The main goal was to classify and analyse the most common use of concept maps in geography education research. The main variable for the analysis was the use of maps coded as either a learning or an assessment tool. This analysis focuses only on students, but across all levels of education. It was important for the selection that students were directly involved in the creation of the concept maps. For this systematic review, the following research questions (RQs) were proposed:

- **RQ1:** How are concept maps in geography education research used?
- **RQ2:** How are concept maps in geography education studied?
- **RQ3:** How are concept maps in geography education created?
- **RQ4:** What effects—positive or negative—do the use of concept maps have on geography education?

2. Theoretical background

2.1 Use of concept maps in education for student learning and assessment

Concept maps (Figure 1) have been identified as a complex and demanding tool for organising learners' knowledge and fostering their competencies (Novak & Gowin, 1984). The primary reason for concept maps is to develop meaningful learning, based on the cognitive psychological approach of Ausubel (1963). The goal of this learning is to be able to take newly obtained concepts and place them into a framework of existing knowledge in order to construct ideas and relationships between the learned items through a continuous learning process (Novak & Gowin, 1984; Ruiz-Primo & Shavelson, 1996), as opposed to the more-traditional rote learning (Novak & Cañas, 2006).

Hay et al. (2008) presented several uses of this tool, which can be summarised as representing two key categories when it comes to students as creators. First, concept maps have proven to be an effective learning tool, supporting students' learning strategies (Eggert et al., 2017; Machado & Carvalho, 2020; Namdar & Shen, 2016), and promote knowledge retention (Nesbit & Adescope, 2006). Through concept maps, students can summarise, organise and visualise relationships between complex and abstract concepts (Cañas et al., 2023). In addition to the development of cognitive and metacognitive processes, concept mapping can increase student motivation (Gurlitt & Renkl, 2010) by activating their prior knowledge. Teachers also see their potential in constructivist teaching and learning (Won et al., 2017), such as geography through enquiry (Roberts, 2023), encouraging the development of higher-order thinking skills.

Contrastingly, as an assessment tool, concept maps can provide evidence of students' learning and understanding (Ruiz-Primo & Shavelson, 1996), not only for the benefit of the teacher, but also for themselves through metacognitive reflection (Rebich & Gautier, 2005; Stevenson et al., 2017). Compared to traditional test formats, concept maps provide students with creative ways of illustrating their understanding (Cañas et al., 2023). Alone, however—as found by Conradty and Bogner (2012)—they do not provide the teacher with all the necessary information needed to determine whether the students understand the tested topic, and it was recommended to use both tests and concept maps together. Used before and after learning intervention, concept maps are useful for comparing the structure and complexity of students' understanding of a topic, as they potentially experience a conceptual change (Hay, 2007; Novak, 2005).

2.2 Using concept maps in geography education for systems thinking

One of the main goals of the geography education curriculum is to broaden students' worldviews by developing their understanding of increasing global complexity and the interaction between physical, human and environmental factors (International Geographical Union [IGU], 2016). To study this interconnection, systems thinking is offered as a pathway (Assaraf & Orion, 2005). Systems thinking can be understood as "the ability to recognise the elements and complexity of a system, to understand the interrelationships of the elements, and to appreciate the impacts of the interrelationships at the local, national and global levels" (Demssie et al., 2023, p. 264). In geography, all spheres, such as the atmosphere, hydrosphere or human settlements and population, are considered individual systems.

Systems thinking is a form of relational thinking, and according to Cox et al. (2019), it is inherently part of geographical thinking. This thinking is based on several domain concepts (e.g. Lane et al., 2019) that allow students to have a powerful and holistic way of seeing, understanding and studying the near and distant features of the globe and making connections between them (Ma & Lu, 2024). Lambert (2017) related systems thinking to an essential grammatical component (one of three, including vocabulary, grammar and enquiry) that is required for the development of geographical thinking (Bendl et al., 2024). Systems thinking can be fostered and assessed by external representations of mental models, such as concept maps (Åhlberg & Ahoranta, 2002; Mehren & Rempfler, 2022) and causal diagrams (Cox et al., 2019; Ma & Lu, 2024)—a variation of concept maps, where links are labelled with plus or minus signs (instead of linking words), depending on the relationship between the linked concepts.

Although concept maps have existed for an extended period, they are increasingly relevant to the requirements of modern geography curricula, as several countries include systems thinking in their national curriculum. By the end of Key Stage 3, English students should have "become aware of increasingly complex geographical systems in the world around them" (Department of Education, 2013, p. 2). In China, systems thinking is included in the geographical synthetic thinking that is viewed as one of four core competencies for geography students (Ma & Lu, 2024). The United States geography curriculum standards stress that, by studying natural, human and other systems, American students should be able to cultivate their geographical systems thinking (Heffron & Downs, 2012). Similarly, students in Germany are also expected to possess these skills (Mehren & Rempfler, 2022). Because concept maps help elucidate the complex relationships among geospatial concepts, thereby fostering a deeper understanding of critical geographical skills and disciplinary knowledge, they are in line with the proposed aspects of current and future global geographical curricula modelled on the GeoCapabilities (Bustin, 2019) and geo-literacy approach (García-Gonzáles et al., 2023).

3. Methods

To understand how concept maps have been used in geography and geography-related education over the last 20 years (2003–2023), this work presents a review of their use in broader and different aspects (Chang et al., 2022; Hartmeyer et al., 2018). To perform this systematic review, the principles and guidelines of the preferred reporting items for systematic reviews and meta-analyses (PRISMA), as outlined in Page et al. (2021), were adopted.

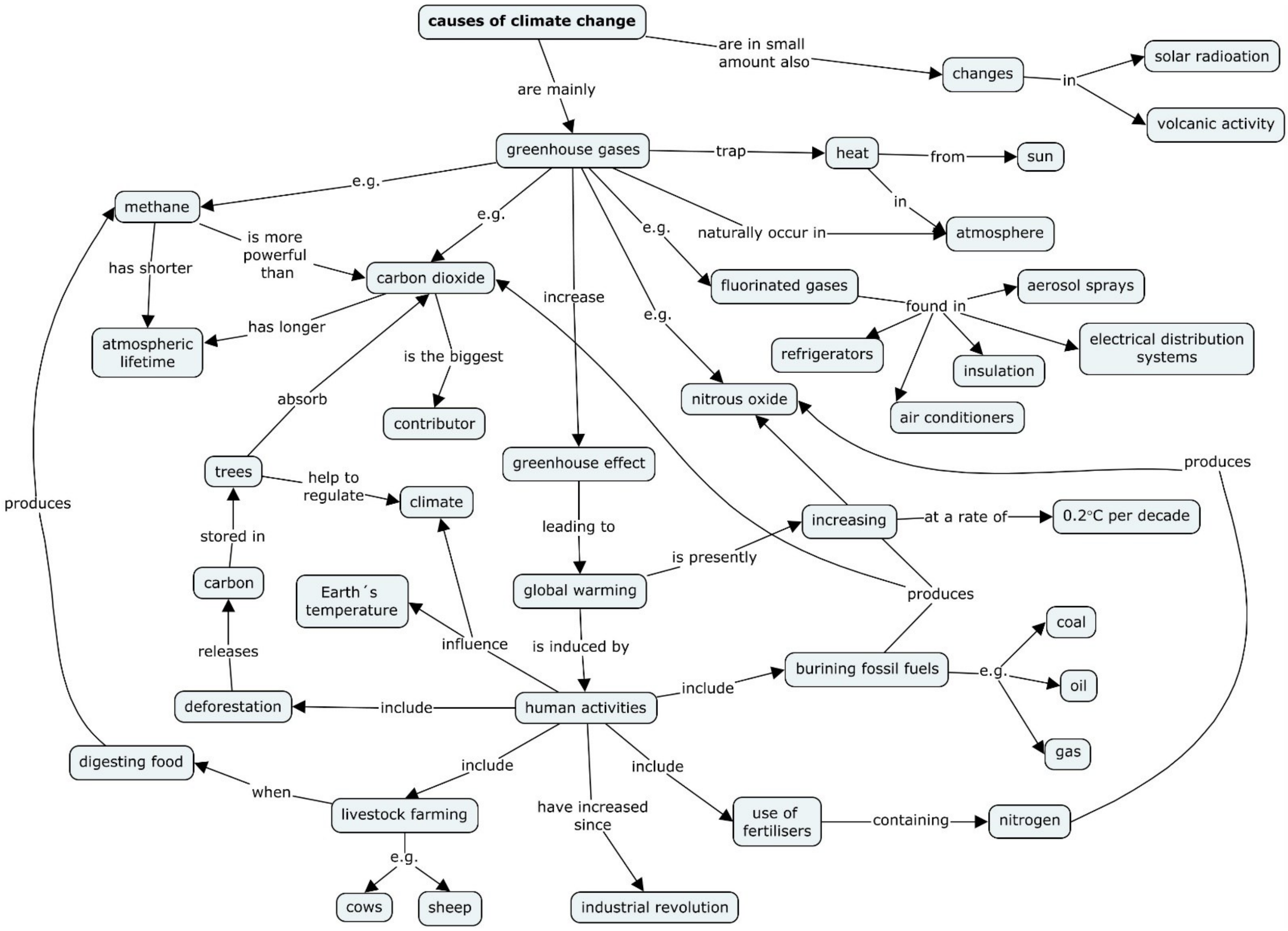

Figure 1. Example of a non-hierarchical concept map on the topic of 'causes of climate change' created by the author in CmapTools, based on the text available on the European Commission (n.d.) website.

This systematic review includes literature that was published up to March 20, 2024—the date when the online search for papers was conducted. In the search for appropriate studies, two databases were employed—the Web of Science (WoS) and Scopus. These were chosen for their broad inclusion of science articles on the topics of both pedagogy and geography. To search through the titles, abstracts and keywords assigned to the papers, the following keywords were used: ("concept map" OR "concept mapping" OR "conceptual mapping") AND ("geography" OR "science") AND ("education" OR "learning" OR "teaching" OR "school" OR "textbook"). The addition of 'conceptual mapping' was rooted in the use of this term in some theoretical papers outside of countries with English as a first language (e.g. Trahorsch et al., 2022), and 'science' was added as a reflection of discussions in Jones (2017). The last string came from personal experience and previous reviews of geography education research (e.g. Mašterová, 2023). A total of 1,983 records were obtained using this combination. To be included in the review, each study had to meet the certain criteria.

The following inclusion criteria were defined. The articles had to be written in English, published in scientific (peer-reviewed) journals, published between 2003 and 2023, empirical research, focused on all levels of education, focused on students, include the use of concept maps, include the description of concept mapping activity, be related to geography curricula (including Earth sciences and environmental education), include a description of the participants, include a thorough methodology and the purpose of the research, and include an analysis of the results and a discussion of the findings. The following exclusion criteria were defined. The article had to not be available only in part or be inaccessible, not fail to meet the quality standards of research (conference papers), not use concept maps as a pre-constructed learning material and not use concept maps as a tool for data analysis.

Most of the articles were found in the WoS (1,087 records), followed by Scopus with 896 records. However, only 566 texts from the WoS and 522 texts from Scopus were written in English, published as journal articles and fitted the 2003–2023 publication range. Furthermore, the filter bar in Scopus allowed the exclusion of 276 texts that belonged to subject areas not relevant to geography, Earth, social, educational or environmental sciences. Subsequently, another 322 texts were filtered this way in the WoS.

After combing the list for duplicates, 412 records remained on the list. These were considered for their relevance to the studied topic. Their titles, abstracts and keywords were scanned to see if concept maps were mentioned in relation to geography or geography-related education, and if they met the chosen inclusion or exclusion criteria.

The scope for the search was extended beyond the school subject of geography because the content of this science discipline is interdisciplinary (Solem & Boehm, 2018) and oftentimes taught in the larger block of so-called natural sciences, together with, for example, physics, chemistry and biology, and social sciences, including history and citizen science. The relevance of the topic (of created concept maps and their used in

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research) to the geography curriculum was judged based on the discussions presented in the *International Charter on Geographic Education* (IGU, 2016) and *The Handbook of Secondary Geography* (Jones, 2017), along with the author's rich personal experience with the Czech and Slovak national geographic curricula at all levels of education.

Among the 412 articles scanned, from the abstract of a dozen of articles, it was evident that the authors used mind maps rather than concept maps, which seem to get mixed up quite often (Davies, 2010). Unlike concept maps, mind maps do not use linking words, and concepts can repeat. Also commonly, concept maps have rather been used as an analytical tool for investigating data gathered by interview, the content analysis of textbooks (Trahorsch et al., 2022) or from classroom observations.

As Figure 2 indicates, 77 articles were grouped for the last round of elimination. After reading the first ten of these, a set of items was prepared for coding. This list was derived from a similar tool used by Chang et al. (2022) and Hartmeyer et al. (2018), modified through the entire coding process to accommodate the needs of the set RQs. After becoming familiarised with all the roles of the concept maps used in the texts, these were categorised for the sake of clarity, as described by Hay et al. (2008), under two major headings—a learning tool and an assessment tool. After the remaining 77 articles had been thoroughly read and coded, 37 were found not meet the set criteria. Papers were considered of high quality if all the dimensions defined in Appendix A were located, whereas those that satisfied less than two dimensions in the 'Application issues' were removed. Those articles containing thorough descriptions and discussions on learning interventions were considered of the highest quality for their potential in future implementation.

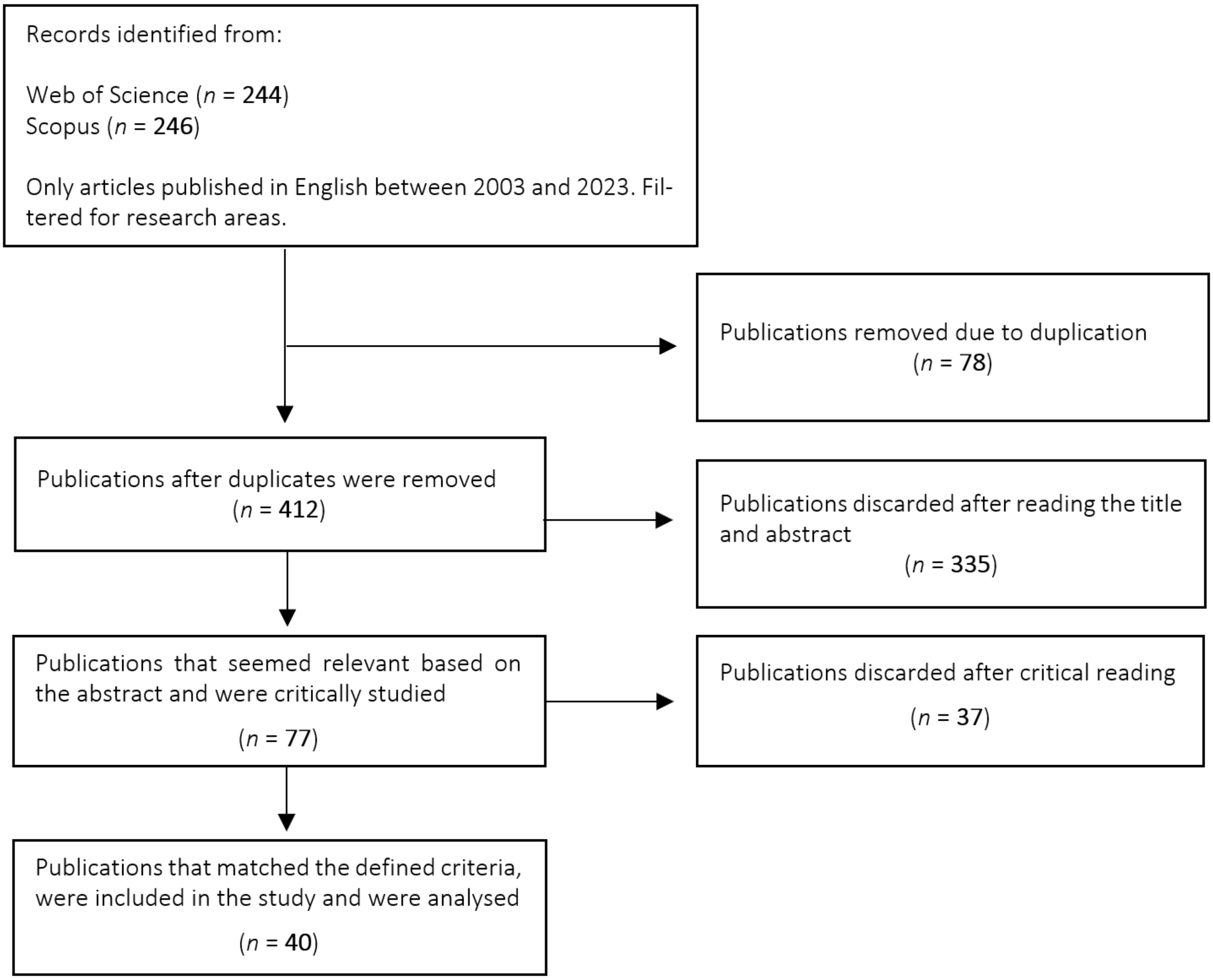

Figure 2. PRISMA scheme for the article search in the databases.

The extracted information was coded twice, in two phases. In the first phase, more-detailed descriptions of the coded items were written, and in the second phase, the qualitative data were converted by thematic analysis (Naeem et al., 2023) into more generalised codes, the units of quantitative data being unified (in the same columns). Therefore, new columns appended with 'TA' (thematic analysis) were created, including the roles of concept maps TA, aims of research TA, format characteristics TA and advantage of concept maps TA. The final classification of codes and their description are presented in Appendix A.

The concept map topics were categorised based on a deductive approach, which started by sorting the topics into four already existing categories (Jones, 2017) based on the description of the topic and the related learning intervention by the authors, continuing with an inductive approach after several topics could not match with either category, requiring two new ones to be created.

4. Results

The in-depth review of the final 40 papers revealed trends and gaps in the use of concept maps in geography education research over the last two decades. Table 1 presents an overview of all the papers included in the systematic review. The next section presents general information on the published articles, with subsequent sections addressing the answers to three of the RQs regarding the research, interaction and application issues of the studied topic.

The systematic review found 13 countries in which concept maps in geography education were being used in research. The most productive country was, by far, the United States (20 articles, 50%), followed by Taiwan and the United Kingdom (both 3, 7.5%). Australia, Germany, Israel and Spain were all represented by two articles (all four 5%). One article each came from Greece, Ireland, Portugal, Singapore, The Netherlands and Turkey (all six 2.5%).

Figure 3 illustrates the frequency of the research on concept maps in geography education in the selected period of 2003–2023. The years 2003, 2004 and 2006 are not present in the selection. The number of studies peaked in the years 2011, 2016 and 2017, with four articles each. Six times, there was only one study published per year. Figure 3 distinguishes between articles that used concept maps as either learning or assessment tools, or both. There seems to be no pattern, most of the time the categories being balanced.

Table 1. Summary of results for each review article

Publication	Country	Aim	Respondents	Design	Use of CM	Topic	Training
Akbaş and Gençtürk (2011)	Turkey	Cognition	90 lower secondary education students	Mixed (quasi-experiment)	Learning tool	Physical geography	S
Allen and Barbour (2016)	USA, Colorado	Cognition, affect	10 undergraduate students	Mixed	Assessment tool	Regional geography	S
Allen and Lukinbeal (2011)	USA, Colorado	Cognition	571 lower secondary education and undergraduate students	Mixed (quasi-experiment)	Assessment tool	Physical geography	NM
Assaraf and Orion (2005)	Israel	Cognition	70 lower secondary education students	Mixed	Both	Man and environment	S
Assarf and Orpaz (2010)	Israel	Cognition	21 lower secondary education students	Mixed	Assessment tool	Man and environment	S
Bulunuz and Jarrett (2009)	USA, Georgia	Cognition	52 undergraduate students	Quantitative	Learning tool	Physical geography	D
Chang et al. (2017)	Republic of China, Taiwan	Cognition	85 lower secondary education students	Quantitative (quasi-experiment)	Learning tool	Regional geography	D
Chin et al. (2010)	USA, California	Cognition	58 lower secondary education students	Mixed (quasi-experiment)	Both	Climate change	NE
Eggert et al. (2017)	Germany	Cognition, affect	158 higher secondary education students	Quantitative (quasi-experiment)	Learning tool	Physical geography	NM
Endreny (2010)	USA, New York	Cognition	33 primary education students	Qualitative (action)	Assessment tool	Physical geography	S
Englebrecht et al. (2005)	USA, Michigan	Cognition	35 undergraduate students	Mixed	Assessment tool	Physical geography	S

Erdimez et al. (2017)	USA, Arizona	Cognition	23 primary education students	Mixed	Assessment tool	Physical geography	S
Gillies et al. (2015)	Australia, Queensland	Cognition	248 lower secondary education students	Mixed (experiment)	Assessment tool	Physical geography	NM
Hwang and Chang (2020)	Republic of China, Taiwan	Cognition, affect	101 primary education students	Mixed (quasi-experiment)	Both	Physical geography	NM
Jeong et al. (2022)	USA, North Carolina	Cognition, affect	156 undergraduate students	Mixed	Assessment tool	Physical geography	S
Karkdijk et al. (2019)	The Netherlands	Cognition	205 higher secondary education students	Mixed	Learning tool	Man and environment	N
Kwon and Cifuentes (2007)	USA, Texas	Cognition, affect	161 lower secondary education students	Mixed (quasi-experiment)	Learning tool	Physical geography	D
Marzetta et al. (2018)	USA, Colorado	Cognition, affect	25 primary education students	Mixed	Assessment tool	Man and environment	TE
Morfidi et al. (2018)	Greece	Cognition, affect	30 primary education students	Quantitative (experiment)	Learning tool	Physical geography	S
Morgan et al. (2022)	USA, Florida	Cognition	20 graduate students	Qualitative (case study)	Both	Technology and methodologies	S
Namdar and Shen (2016)	USA, Florida	Cognition	20 graduate students	Qualitative	Learning tool	Man and environment	S
Oberman (2023)	Ireland	Cognition, affect	24 primary education students	Mixed	Assessment tool	Physical geography	S
Oda (2016)	USA, California	Cognition, affect	12 undergraduate students	Mixed	Assessment tool	Technology and methodologies	D
Oliver (2009)	USA, North Carolina	Cognition, affect	74 lower secondary education students	Mixed	Both	Physical geography	D
Pontes-Pedrajas and Varo-Martínez (2014)	Spain	Cognition, affect	69 graduate students	Qualitative	Learning tool	Education	S
Proctor and Bernstein (2013)	USA, Oregon	Affect, cognition	23 undergraduate students	Mixed (action)	Learning tool	Man and environment	N
Rebich and Gautier (2005)	USA, California	Cognition	17 undergraduate students	Mixed	Assessment tool	Physical geography	D
Reitano an Green (2012)	Australia	Cognition, affect	6 graduate students	Mixed	Assessment tool	Education	S
Renshaw and Wood (2011)	United Kingdom	Affect	8 lower secondary education students	Qualitative (case study)	Learning tool	Physical geography	NM

Romero et al. (2017)	Spain	Cognition, affect	42 lower secondary education students	Quantitative	Learning tool	Physical geography	D
Schuster et al. (2008)	USA, Indiana	Cognition, affect	9 higher secondary education students	Mixed	Assessment tool	Physical geography	S
Sellmann et al. (2008)	Germany, Bavaria	Cognition	124 higher secondary education students	Mixed (quasi-experiment)	Assessment tool	Physical geography	S
Seow (2016)	Singapore	Affect	4 graduate students	Qualitative	Assessment tool	Education	S
Smithwick et al. (2018)	USA, Pennsylvania	Cognition, affect	190 undergraduate students	Mixed	Assessment tool	Man and environment	NM
Stewart (2012)	United Kingdom	Cognition, affect	69 undergraduate students	Mixed (quasi-experiment)	Learning tool	Physical geography	NM
Vasconcelos et al. (2020)	Portugal	Cognition	83 lower secondary education students	Qualitative	Assessment tool	Physical geography	NM
Walshe (2008)	United Kingdom	Cognition, affect	27 lower secondary education students	Mixed (case study)	Assessment tool	Man and environment	NM
Wehry et al. (2012)	USA, Florida	Cognition	69 lower secondary education students	Mixed	Assessment tool	Human geography	NE
Yang and Wang (2013)	Republic of China, Taiwan	Cognition	49 primary education students	Mixed (quasi-experiment)	Learning tool	Physical geography	S
Zimmerman et al. (2011)	USA, Arizona	Cognition	50 primary education students	Quantitative	Assessment tool	Physical geography	D

Note: CM = concept map; D = more-detailed training; N = no training; NE = no training due to previous experience; NM = no mention of training; S = short training; TE = previous experience plus retraining.

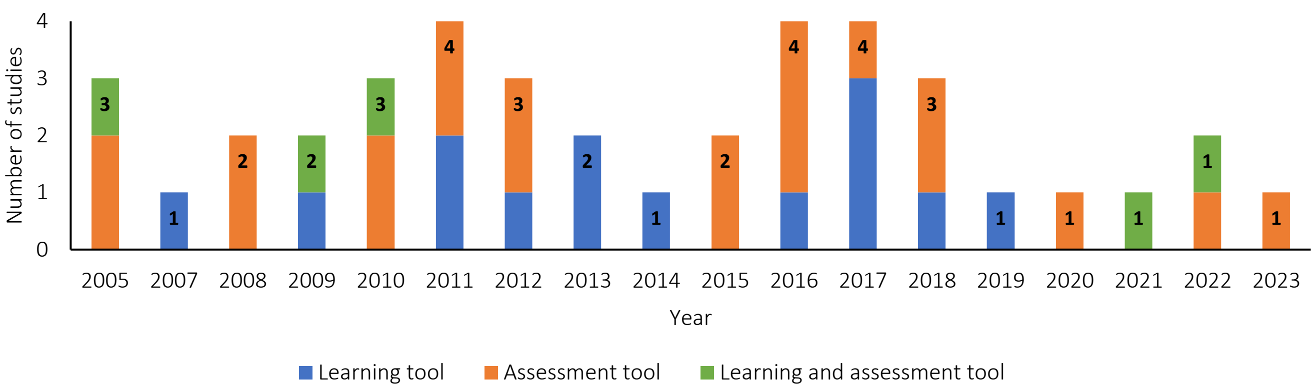

Figure 3. Time distribution for the use of concept maps in geography education research.

4.1 How are concept maps in geography education research used?

Between 2003 and 2023, assessment tools accounted for the majority role of concept maps in geography education research (21 articles, 52.5%), followed by learning tools (14, 35%) and a combination of both (5, 12.5%). This indicates that most of the research used concept maps to evaluate learning achievement, conceptual change or learning strategies.

4.1.1 Geographical thinking

Only three studies (Karkdijk et al., 2019; Renshaw & Wood, 2011; Stewart, 2012) applied concept maps solely as a learning tool to support geographical thinking skills. In one example, on the causes of landslides, Stewart (2012) wanted to see if using concept maps helped undergraduate students to foster Earth systems thinking skills on the studied issue. After an academic year of engaging in concept mapping activities, the complexity of the student work had increased, albeit with no effect on enhancing their overall performance. Nevertheless, the students expressed the usefulness of concept maps in synthesising and relating information. In the second case, Karkdijk et al. (2019) asked high schoolers to solve two mysteries, set in Rio de Janeiro and Jakarta, in order to exercise and assess their geographical relational thinking. Through their use of concept maps, the students were able to find more-complex and less-abstract relationships between natural and social elements, but only a minority of them showed higher relational levels. These Danish authors were inspired by previous research by Reseshaw and Wood (2011), who had their students investigate global physical systems through relationships between the atmosphere, oceans, volcanoes and glaciers. Studying whether concept maps can help students understand the physical world more holistically and critically, they achieved positive results.

Investigating whether students already had the skills needed for the study of global issues by employing concept maps as an assessment tool was the goal of another four papers (Assaraf & Orion, 2005; Assaraf & Orpaz, 2010; Jeong et al. 2022; Vasconcelos et al., 2020). The results show that, over the time of the intervention, the students improved in linking the components of the water cycle (Assaraf & Orion, 2005), watershed system (Jeong et al., 2022) and factors effecting life at the poles (Assaraf & Orpaz, 2010). However, several misconceptions persisted in all these studies, and Vasconcelos et al. (2020) reported on the lowest fulfilment of the assigned task. The students were able enough to complete some of the maps on the rock cycle, food chain, water cycle or carbon cycle, but they were unable to connect the elements of these submaps to the atmosphere, biosphere and hydrosphere.

4.1.2 Conceptual understanding and change

The majority of the reviewed studies used concept maps to improve or assess students' understanding of geographical phenomena. Knowledge tests in all four cases that used concept maps as learning tools proved that employing them can result in positive conceptual change and the elimination of misconceptions regarding air pressure (Akbaş & Gençtürk, 2011) as well as promoting a positive conceptual understanding of climate change (Eggert et al., 2017), several physical geography processes (Bulunuz & Jarrett, 2009) and local phenomena, such as the geology of Yehliu Geopark, Taiwan (Hwang & Chang, 2020).

A quarter of all the studies used concept maps to determine if, after a specially designed intervention, students achieved a conceptual change in their understanding of geographical topics. Comparing concept maps from before and after the intervention, the students' understanding of geology (Englebrecht et al., 2005), climate change (Rebich & Gautier, 2005; Sellmann et al., 2015), watersheds (Endreny, 2010), Earth materials (Zimmerman et al., 2011), effective geography teaching (Reitano & Green, 2012) and geospatial concepts (Oda, 2016) increased.

4.1.3 Concept map strategy

About a quarter of the studies focused primarily on concept maps as a strategy for learning and assessment, with the geographical topics only aiding in the research. The authors compared concept maps based on their form (Erdimez et al., 2017; Morgan et al., 2022), media (Chin et al., 2010; Mordifi et al., 2018) and scaffolding (Eggert et al., 2017), trying to determine which types of concept maps were more suitable for student learning, as was common for the articles on concept mapping.

Mordifi et al. (2018) concluded that the use of multimedia in concept maps did not give students advantages in learning. Erdimez et al. (2017) proved a common claim, that creating concept maps required students to use higher-order thinking skills. The claim that concept maps created by groups demonstrated better quality was also strongly supported in three articles (Chang et al., 2017; Kwon & Cifuentes, 2007; Pontes-Pedrajas & Varo-Martínez, 2014). Eggert et al. (2016) tried to finally answer the question on the types of scaffolding needed and its impact on the quality of concept maps, but their results did not show any impact on the gain of factual knowledge, and the discussion continues. The studies also focused on the student assessment of this strategy, such as Proctor and Bernstein (2013), whose students expressed positive affection towards concept maps because they were mostly not challenging for them and helped them with understanding relationships between environmental issues.

4.1.4 Assessing interventions

Concept maps were also used as assessment tools in other contexts, but this was not as frequent as other categories and so they were grouped together here. Generally, concept maps were used to assess the effectiveness of a newly designed intervention. Marzetta et al. (2018) found that concept maps being indifferent to the language abilities of the students equitably elicited science understanding. Oberman (2023) proved that children could express the complexity of climate change through their concept maps. Allen and Barbour (2016) saw a changed understanding of Morocco after visiting that country through those students' concept maps. Using concept maps to measure the effectiveness of a teaching method showed Allen and Lukinbeal (2011) and Gilles et al. (2015) that new practical exercises helped students to understand weathering processes and natural disasters, respectively, while Smithwick et al. (2018) explored the positive effect of interactive videos on the understanding of park conservation.

4.2 How are concept maps studied in geography education?

4.2.1 Research methods

Mixed methods were the most used type of data (27 articles, 67.5%), followed by qualitative methods (7, 17.5%) and quantitative methods (6, 15%). Most of the articles applied a non-experimental design methodology (28, 70%), followed by a quasi-experimental (10, 25%) and an experimental (2, 5%) design methodology. In six cases, concept maps were employed as a learning tool in quasi-experiments (Akbaş & Gençtürk, 2011; Chang et al., 2017; Eggert et al., 2017; Kwon & Cifuentes, 2007; Stewart, 2012; Yang and Wang, 2013), twice as an assessment tool (Allen & Lukinbeal, 2011; Sellmann et al., 2008) and twice as both (Chin et al., 2010; Hwang & Chang, 2020).

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4.2.2 Research foci

As for research foci, the cognition aspect accounted for exactly half the studies. Almost every study paid attention to the learning achievement of their students, with three-quarters of these looking for signs of conceptual change, which meant testing their students before and after an intervention. Only two studies were not interested in assessing the learning achievements of students, rather exploring only their attitudes towards studied issues (Renshaw & Wood, 2011; Seow, 2016), therefore focusing on affect. Almost half (18 articles, 45%) of the 40 articles combined these two aspects.

4.2.3 Participants

Regarding the participants, the majority of concept maps in geography education research concerned lower secondary education students (13 articles, 32.5%), followed by undergraduates (10, 25%) and primary education students (8, 20%). The least attention was paid to the higher secondary education and graduate students (both 4, 10%). In one case (Allen & Lukinbeal, 2011), the research focused on both lower secondary education students and undergraduates together in one sample. On average, 78 students were included in a sample group per study, the median being 49.5. A minimum of four students was used in one study (Seow, 2016) and a maximum of 571 students in another (Allen & Lukinbeal, 2011).

4.3 How are concept maps created in geography education?

4.3.1 Collaboration

In every study, it was always made clear whether the students had created the concept maps on their own or had worked in pairs or groups. Most of the students created their maps on their own (28 articles, 70%), four times (10%) they worked in pairs or in groups, and in six cases (15%), these two methods of map creation were combined.

4.3.2 Type of response mode (media)

It was also noted in the studies whether the students created their concept maps using a pen and pencil (i.e. manually, on paper) or using software (i.e. digitally). More than half (25 articles, 62.5%) of the maps were drawn by hand, with a dozen articles (30%) indicating digital forms through software (e.g. cMapTools, Xmind, Inspiration). Once, students were provided with both manual and digital tools.

4.3.3 Type of scaffolding

The third aspect concerning the form of the maps was the level of scaffolding, meaning how independent or restricted the students were in their options and creations. Most articles adopted a low-directed mapping scaffolding (23 articles, 57.5%) because this guaranteed the learners the greatest autonomy. The others used medium-directed mapping (8, 20%) and high-directed mapping (5, 12.5%), where the demand for higher-order thinking skills was supposedly decreased (Erdimez et al., 2017). Two studies (Eggert et al., 2016; Wehry et al., 2012) compared all three options, albeit coming to no conclusions, all options somewhat benefitting the students.

4.3.4 Concept map topics

The students had to visualise 41 unique geography topics in their concept maps. These could be divided into six categories, with physical geography being represented by almost half of them (18 articles, 43.9%). As can be seen in Table 2, topics related to education, human geography and technology and methodologies were the least common (all three 2, 4.9%). Climate change appeared six times, taking first place as the most common topic (Chin et al., 2010; Eggert et al., 2017; Oberman, 2023; Rebich & Gautier, 2005; Schuster et al., 2008; Sellmann et al., 2015). Some articles covered a broader topic, such as Europe (Chang et al., 2017) and geology (Englebrecht et al., 2005), whereas others focused on a specific location and phenomenon (Hwang & Chang, 2020). Through concept maps, Seow (2016) and Reitano and Green (2012) asked pre-service teachers to map their attitudes and understanding of what it took to teach geography.

Researchers mostly (17, 42.5%) chose a concept map topic related to the content of the designed intervention that was in line with the curriculum the students at the time of the study usually covered with their teachers (e.g. Hwang & Chang, 2021; Vasconcelos et al., 2020). The concept map topics chosen for studies carried out in higher education institutions (11, 27.5%) were based on the content of the lectures and laboratory classes that were part of the relevant courses (e.g. Jeong et al., 2022; Morgan et al., 2022). The third group of authors (7, 14.5%) picked the topics in relation to the pedagogical problem being studied—for example, relational thinking in the case of Kardijk et al. (2019) and misconceptions in Yang and Wang (2013) and Sellman et al. (2015)—that were supposed to reveal the problem through the created maps. Five authors (Assarf & Orpaz, 2010; Bulunuz & Jarrett, 2009; Eggert et al., 2017; Endreny, 2010; Namdar & Shen, 2016) were more detailed in their reasoning behind the chosen topics.

Table 2. Frequency of concept map topics assigned to students in articles

Category	Topic frequency (*n* = 41)	Topics
Physical geography	18 (43.9%)	Reasons for wind (3), rock cycle (2), Earth materials (2), moon phases (2), atmosphere (1), geology (1), ice (1), oceans (1), reasons for seasons (1), volcanoes (1), erosion (1), weathering (1), changing Earth (1), water cycle (1), Yehliu geology (1), soil formation (1), soil erosion (1)
Man and environment	12 (29.3%)	Climate change (6), ecosystem relationships (3), earthquakes (3), food chain (2), conservation of soil (1), sustainable tourism (1), conservation of parks (1), nuclear energy (1), carbon cycle (1), rain (1), landslide (1), solar radiation (1)

Regional geography	5 (12.2%)	Life at the poles (1), Morocco (1), Europe (1), Jakarta (1), Rio de Janeiro (1)
Human geography	2 (4.9%)	Human geography (1), landmarks (1)
Education	2 (4.9%)	Geography education (2), environmental education (1)
Technology and methodologies	2 (4.9%)	WebGIS (1), geospatial concepts (1)

Note: Numbers indicate the frequency of mapping tasks for each topic, with an article possibly containing more than one mapping task topic.

4.4 What positive effect does the use of concept maps in geography education have on students?

The most mentioned advantage of concept maps was their potential to elicit student understanding of the studied topic (Allen & Lukinbeal, 2011; Assaraf & Orion, 2005; Oda, 2016; Reitano & Green, 2012; Schuster et al., 2008; Sellmann et al., 2015; Seow, 2016; Walshe, 2008; Wehry et al., 2012) and to diagnose common misconceptions (Englebrecht et al., 2005; Gillies et al., 2015; Rebich & Gautier, 2005). In all these cases, however, the results were not compared with other methods of assessment, meaning the benefits of concept maps over traditional multiple-choice tests were not supported, nor their reliability (Endreny, 2010).

The second most-praised benefit of using concept maps was their ability to visualise, organise and integrate gained knowledge (Assarf & Orpaz, 2010; Chin et al., 2010; Hwang & Chang, 2021; Namdar & Shen, 2016; Oberman, 2023; Proctor & Bernstein, 2013; Renshaw & Wood, 2011; Romero et al., 2017; Stewart, 2012). During their geography classes (i.e. lectures, enquiry lessons, fields trips), the students worked with several types of data, texts and maps that provided them with new information that they had to piece together in order to obtain a complete picture of the problem at hand (Zimmerman et al., 2011). Through this process, the students could see the gaps in their knowledge and build a coherent knowledge structure (Eggert et al., 2017).

In general, the findings in Bulunuz and Jarret (2009) and Smithwrick et al. (2018) showed that concept maps helped their students to learn about the chosen topic. Their creation was considered useful by many of the students (Romero et al., 2017; Stewart, 2012), and even enjoyable (Pontes-Pedrajas & Varo-Martínez, 2014). Through exchanging and examining their ideas, students working in groups produced higher-quality concept maps than those who worked independently (Chang et al., 2017; Kwon & Cifuente, 2007; Pontes-Pedrajas & Varo-Martínez, 2014). Although the students preferred to work together (Namdar & Shen, 2016; Oliver, 2009), the results of this review indicate that students were assigned concept maps as part of group work less commonly.

Engaging in concept mapping as an appropriate active learning approach (Morgan et al., 2022), students who typically performed lower in standardised testing saw it as an effective reading strategy (Marzetta et al., 2018) that helped them understand science expository texts and recall the read information (Morfidi et al., 2018). All students were improved in their scientific explanation and writing (Yang & Wang, 2013), providing support for integrating complex systems knowledge (Jeong et al., 2022).

5. Discussion

The findings of this review point to several roles of concept maps that can lead to gains in the learning process or in the analysis of learning outcomes The findings are in line with the outcomes of previous literature reviews (Hartmeyer et al.; 2018; Chang et al.; 2022; Machado & Carvalho, 2020; Nesbit & Adescope, 2006). However, the advantages of the use of concept maps in geography and other science subjects, as stressed in this and the previous reviews, need to be viewed more critically, especially in light of the different formats and interventions they have been implemented through.

It has been acknowledged in traditional concept mapping publications that, prior to using concept maps, the learners should become acquainted with the theoretical background and practical aspects that come with this tool (Cañas et al., 2023). Learning how to properly construct concept maps is a crucial step. Without this skill, the product cannot fully reflect the learner's knowledge (Schuster et al., 2008). Despite this, the students in Kardijk et al. (2019) and Proctor and Bernstein (2013) skipped this step, diving straight into the mapping activity. Nine other studies did not provide any details on such training and instruction (see Table 1). Roughly half of the studies indicated a little time was spent on training, but no feedback was given, such that the students could benefit from gaining more experience. Aware of this importance, six studies spent more time on training (Bulunuz & Jarrett, 2009; Chang et al., 2017; Kwon & Cifuentes, 2007; Oda, 2016; Oliver, 2009; Zimmerman et al., 2011), but only two additionally provided students with feedback (Rebich & Gautier, 2005; Romero et al., 2017). Upon seeing the produced concept maps, Walshe (2008) and Zimmerman et al. (2011) noted that some initial training, such as that outlined by O'Brien (2002), could have overcome the students' lack of capability. Moreover, continuous feedback would have also been beneficial (Morgan et al., 2022). Applying these recommendations in the form of appropriately guided concept mapping sessions proved to be salutary in the case of Romero et al. (2017). Training pre- and in-service teachers should not be overlooked either because their knowledge concerning map assignments and the process of creation and analysis is the bedrock of successful implementation (Subramaniam & Harell, 2015). The last section of this paper refers to useful sources of inspiration for (potential) practitioners.

In addition to initial training, researchers and students alike were aware of the time assigned to the activity being a factor that could restrict the students' abilities in expressing their knowledge (Schuster et al. 2008; Vasconcelos et al., 2020). Some, however, believed that concept maps could be used to quickly assess complex concepts in a short time (Allen & Barbour, 2016). In addition, the structure chosen in Oliver (2009) played a part in limiting the students' efforts. The list of concepts they were provided with did not reflect their understanding of the topic and caused confusion. The scaffolding of the concept map (Hay et al., 2008) could thus be viewed as the third most important aspect, with a potentially negative effect, as well as being a factor in the research results achieved. The conclusions of previous studies have indicated that low-directed concept maps are most suitable for formative assessment (Hartmeyer et al., 2018) and for eliciting the mental models of the student, whereas providing lists of concepts is more appropriate for using concept maps in summative assessments (Cañas et al., 2023; Hay et al., 2008). From this review, it was apparent that low-directed mapping was chosen the most, although the type of scaffolding chosen depended on the aims of the learning or assessment, the time allocated for the concept mapping activity and the proficiency of the students in this activity. It is suggested that students first be introduced to fill-in-the-blank maps and then directed to progress toward maps built from scratch, which require more patience, cognitive load and time (Cañas et al., 2023; Hay, 2007; Ruiz-Primo & Shavelson, 1996).

Quite striking is the fact that meaningful learning, which is supposed to be the primary benefit of concept mapping in any subject, was not maximised, as the inventors of the tool intended (Cañas et al., 2023). This can only be achieved by giving regular feedback and revising the product, which was only done in the studies by Chin et al. (2010), Hwang and Chang (2021) and Proctor and Bernstein (2013) (see Appendix B). In these cases, group discission, peer-assessment and self-assessment, respectively, helped the students reflect on their learning and make progress. Cañas et al. (2023), with years of experience in establishing concept maps in subjects across all levels of education, stressed the importance of changing the methodology used in class, which should be based on feedback, discussion and argumentation during construction. Their suggestions showed the possible road from individual to long-term mapping, which is linked to advantages in the learning process that are included in this article.

One of the possible advantages linked to geographical education is Earth systems thinking or any aspect of geographical thinking. This, however, was only included in a handful of studies. All four domains of geographical thinking (Bendl et al., 2024), which should be the aim of geography lessons, can be found in the objectives of these articles. These included: the content dimension, fostered through key concepts, such as the interconnections that are the bedrock of the propositions in the concept maps (Assaraf & Orpaz, 2010; Assaraf & Orion, 2005); the procedural dimension, evoked through a critical selection of the concepts involved, and decision-making while establishing connections and the map structure (Vasconcelos et al., 2020); factual knowledge, practiced by marking correct linking words and including examples (Renshaw & Wood, 2011); and the affective domain that is displayed though the subjective nature of concept maps that brings forward student opinions during problem-solving (Kardijk et al., 2019). Future studies should cover all these domains at once to ultimately establish a strong link between concept maps and geographical education, as is suggested by this review. The aims of national geography curricula to equip students with systems and relational thinking (Ma & Lu, 2024) can be more efficiently achieved by being built on the premises of the results of this review.

6. Conclusions

This review reports on the numerous uses of concept maps in the context of geography education that were explored in the 40 articles. Most of these fell into the category of concept maps as an assessment tool. With these, the authors of the research wanted to test the knowledge and thinking of their students. Concept maps as a learning tool were used in 14 cases and the combination of both options was chosen five times. Supporting or analysing specific geographical skills, such as Earth systems thinking, or more general geographical thinking was present in less than one-fifth of the articles. The rest of the studies focused on more general pedagogical issues through a geography topic, and their results can be applied to other subjects as well.

Authors whose goal was to explore aspects of geographical thinking explained their choice of concept maps as a learning and assessment tool on the grounds of the visualisation of relationships between the studied elements. They viewed the concept maps as a tool suitable for studying geography based on the understanding of interrelationships between systems of the natural and social phenomena of our world. Hence, they are supposed to be useful in fostering geographical thinking, particularly relational and Earth systems thinking. The research results, albeit small in number, showed that concept maps as visual tools are suitable for this task. Through these, students can see how the elements of Earth systems, such as the atmosphere and hydrosphere, are connected through the water cycle, and the pedosphere and biosphere through the carbon or rock cycles. The level at which students can see these links depends on their level of proficiency in concept mapping and the depth of the knowledge they have gained through learning and exploring. Through concept maps, they can do more than think as geographers, they can practice their digital literacy, teamwork, critical thinking, creativity and metacognition skills, which are important parts of the competency-based education currently gaining global traction. The success of the implementation also lies in the hands of the teacher who needs to be well-trained and aware of the pitfalls of using concept maps as learning and assessment tools. Their experience with concept mapping can be seen as the next step in future research on concept maps in geography education.

6.1 Limitations of the review study

Although there was an attempt in this systematic review to capture all the important trends surrounding the research on concept maps in geography education, several limitations posed an obstacle to this aim. First, the research was limited to papers published between 2003 and 2023, which may have excluded important topics published before 2003. Second, the records were screened and articles coded by only one researcher, which may have resulted in bias. To prevent this bias, or other possible human errors, more researchers may need to be included in the review process. However, this study was part of the author's doctoral dissertation, which necessitated a single-author review. Third, the review included only articles published in English, which limited the number of studies from other countries, such as Brazil and the Baltic countries, where concept maps have a strong tradition. Fourth, the search for appropriate articles was restricted to the WoS and Scopus databases. Other options that include literature focused on pedagogical research, such as ERIC, psycINFO, psycARTICLES, EBSCO and Science Direct, were briefly looked at, but because many of the articles were duplicated, only the two broadest databases were fully interrogated. The last limitation concerns the systematic review methodology used in this work, which explored the topic from a rather more qualitative than quantitative perspective. Other literature review options include meta-analyses and bibliometric analysis, which have been applied to similar topics previously (e.g. Nesbit & Adescope, 2006; Chang & Yang, 2023). However, based on preliminary enquiry, coded data are not suitable for their purposes.

6.2 Implications of the results for geography teacher praxis

Prior teacher preparation is necessary if the use of concept maps in their classes is to be meaningful, as is the case when implementing any new pedagogical methods in one's lessons. Also, in acquiring the theoretical basics of concept mapping, they should get to practice making them as well (Moon et al., 2011; Subramaniam & Harell, 2015), using all types of response modes, mappers and formats and on multiple topics. To better guide the students, teachers must first experience the entire process on their own. This review includes articles that focused on pre-service teacher training (Bulunuz & Jarrett, 2009; Reitano & Green, 2012; Pontes-Pedrajas & Varo-Martínez, 2014; Seow, 2016), but only in the first one were the students properly trained and provided with feedback. This approach should represent the primary guidance for any teacher training in concept mapping. Once they have undergone similar instruction, they can be guided by Roberts (2023) in planning their geography lessons using concept maps. As the author points out, the use of concept maps is suitable for all stages of enquiry-based learning in geography, the teachers first need to choose the purpose of the maps and which learning outcomes they will support, and then decide on options from a spectrum of mapping activities for application. Therefore, concept maps can be paired with exercises that rely on geospatial technologies (Mašterová, 2023), both aiding in the visualisation of interconnections between geographical issues and topics. Including concept maps in the final stage of place-based education (Endreny, 2010) can help students relate more general and abstract terms to places and issues they experience firsthand, such as watersheds in an urban setting. Other aspect lies in knowing how to analyse student work and to provide feedback, which can help pupils to be better concept mappers (Cañas et al., 2023). Several scenarios of how to handle this are available in a book by Anohina-Naumeca (2024), who integrated formative assessment into concept mapping activities to support the development of students' structural knowledge. Assessing the maps can be done using marking guides (Won et. al, 2017), which can show both the teacher and student what parts of the map require revision and what misconceptions are present. To sum up, each teacher needs to find their own way of scaffolding the concept mapping activities, with the time available, learning materials, suitable topics, previous experience, and student needs in mind.

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Appendix A

Issues	Dimensions	Definition	Coding items
Interaction	Roles of concept maps TA	Describes the use of concept maps in the educational process	Assessment tool, learning tool, both
	Advantages of concept maps TA	Describes the positive effect of using concept maps on students	Cognitive (knowledge, skills), affective
Application	Type of response mode TA	Describes the form of concept maps students created	Manual, digital, both
	Mapper	Describes who created the concept maps	Individually, in groups, both
	Format characteristics TA	Describes what instructions for concept mapping the students were given	Low-directed mapping, high-directed mapping, medium-directed mapping, mixed
	Topic of concept maps	Describes the topic the students had to visualise	Technology and methodologies, physical geography, human geography, man and environment, education, regional geography
Research	Design methodology	Describes the design of the research	Experiments, quasi-experiments, non-experiments
	Types of data	Describes the types of data collected	Quantitative, qualitative, mixed method
	Research foci TA	Describes the aims of the research	Cognition: learning achievement, conceptual change, collaboration, higher-order thinking performance Affect: technology acceptance, attitude, self-efficacy, self-assessment, satisfaction, cognitive load, motivation
	Participants	Describes the students who took part in the research	Level of education according to the International Standard Classification of Education, mixed
			Number of participants

Note: If an article did not include information regarding the dimensions of the application issues, the code 'not reported' was assigned. Articles in which this code was used multiple times were approached more cautiously or excluded.

Appendix B

Signs of meaningful learning	Learning	Assessment	Both
NO – no feedback mentioned, no revision to maps	Akbaş and Gençtürk (2011); Eggert et al. (2017); Chang et al. (2017); Kardijk et al. (2019); Kwon and Cifuentes (2007); Namdar and Shen (2016); Pontes-Pedrajas and Varo-Martínez (2014); Stewart (2012); Wehry et al. (2012); Yang and Wang (2013)	Allen and Barbour (2016); Allen and Lukinbeal (2011); Endreny (2010); Englebrecht et al. (2005); Erdimez et al. (2017); Gillies et al. (2015); Jeong et al. (2022); Marzetta et al. (2018); Oberman (2023); Oda (2016); Reitano and Green (2012); Sellmann et al. (2015); Seow (2016); Smithwick et al. (2018); Vasconcelos et al. (2020); Walshe (2008); Zimmerman et al. (2011)	Assaraf and Orion (2005); Oliver (2009)
YES – students got feedback, but did not revise their maps	Bulunuz and Jarrett (2009); Morfidi et al. (2018)	Assaraf and Orpaz (2010); Schuster et al. (2008)	Morgan et al. (2022)
YES – prior knowledge tested, students got feedback throughout the course on their research and thinking, but not related to concept maps		Rebich and Gautier (2005)	
YES – text aimed at meaningful learning and they revised their maps periodically as they continued learning, no feedback mentioned	Renshaw and Wood (2011)		
YES – text aimed at meaningful learning and they were given feedback on each map, but no revisions	Romero (2017)		
YES* – students had previous experience with concept maps, all maps were revised based on group discussions			Chin et al. (2010)
YES* – students had previous experience with concept maps, got feedback regularly for each map, revised the previous maps and self-assessed their maps	Proctor and Bernstein (2013)		
YES* – peer-assessment and revision of created concept maps			Hwang and Chang (2021)

*Note: *Article contains all signs of meaningful learning, as discussed in the article.*

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