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Research Article

Metacognition and Lexical Complexity in Sketch Mapping – A Secondary Analysis of Think-Aloud Protocols and Sketch Maps

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Abstract: Metacognition, encompassing students' awareness of their knowledge, regulation of actions, and experiences, is fundamental to both geography education and lifelong learning. Language is key to externalizing internal processes and enabling interaction within a geography classroom. However, there remains a distinct gap in research specifically focusing on students' abilities in metacognition and language while solving geographical tasks. Therefore, the present study aims to address this gap by researching the role of metacognition and its alignment with lexical complexity and geographical performance in sketch mapping. To achieve this, a qualitative research design was developed. Ten upper secondary students participated in think-aloud protocols while sketching maps of a predefined route within the school area. This methodological approach allowed for an in-depth exploration of how upper secondary students employed metacognitive strategies and exhibited lexical complexity during sketch mapping. The results show a high degree of heterogeneity in metacognitive use, lexical complexity, and sketch map proficiency among participants. Findings indicate that participants' use of metacognition is significantly aligned with lexical complexity in think-aloud protocols, as well as their performance on sketch maps. Implications for geography education practice are provided at the end of the paper.

Keywords: metacognition; lexical complexity; think-aloud protocols; sketch maps; qualitative research

Highlights:

- Conceptualization of metacognition and lexical complexity in the context of geography education related to sketch mapping.
- Highlighting alignments of metacognition, lexical complexity, and map skills through participants' quoted statements and their sketch maps.
- Deriving implications of results in the context of language-aware geography education through macro-scaffolding.

1. Introduction

Geography education is key to nurturing students' awareness of geographical learning and empowering them to think and act as responsible citizens when it comes to spatial issues of human-environment relations from a local to global scale (German Geographical Society, 2012; Rawling, 2022). Geographical thinking and knowledge provide the basis for promoting the development of informed and engaged citizenship among students. By fostering an understanding of key geographical concepts (e.g., concepts of space), geographical working methods (e.g., map work) and practice, and the ability to apply this knowledge to real-world issues, students become better equipped to critically analyze and engage with their surroundings as informed citizens (Rawling, 2022). This aims at acquiring geographical knowledge and understanding beyond factual world knowledge (Firth, 2011; Puttick & Cullinane, 2021; Rawling, 2022). Thus, geographical learning, knowledge, and skill production require fostering an awareness of one's thinking at a meta-level. This awareness, that is, metacognition, enables students to shape their lives, assess situations, and make decisions, contributing to pivotal lifelong learning (Brown, 1987; Flavell, 1979; Hasselhorn & Labuhn, 2008; Lane et al., 2019; van der Graaf et al., 2023). However, metacognition in geography education has rarely been studied, with only a few exceptions demonstrating its positive impact on enhancing the learning processes related to argumentation (Gebele et al., 2022; Heuzeroth & Budke, 2021). There is evidence from other disciplines, for example, mathematics and science education, on the importance of metacognitive abilities, which are regarded as the main predictors of academic performance and achievements (Meijer et al., 2006; Veenman et al., 2006). Students' awareness of thinking, the awareness of strategies and how and when to regulate them facilitate the acquisition of knowledge and skills (Meijer et al., 2006; Pintrich, 2002; Schraw & Dennison, 1994; van der Graaf et al., 2023; Veenman & van Cleef, 2019). To the best of our knowledge, there is a distinct research gap when it comes to generating further evidence on the role and importance of metacognition in geography education. Moreover, metacognition also plays a pivotal role in fostering geographical language use and language awareness, which is important because language and thought are interrelated and language is key to enabling communication about thoughts and geographical content knowledge while enabling teaching and student participation (Alexander, 2018). Language-aware geography education is an approach that underscores the explicit teaching of awareness regarding

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language in geography, providing the basis for ensuring comprehensive access to geographic knowledge and the cultivation of disciplinary language skills (Hammond & Gibbons, 2005; Morawski & Budke, 2017; Prediger & Pöhler, 2015). Language use in geography education at the word level has greater complexity, that is, lexical complexity, than everyday language (Schleppegrell, 2004). This level of lexical complexity is highly interrelated with the level of conceptual understanding (Gallagher & Leahy, 2019; Heine et al., 2018). Therefore, linguists argue that the structure of metacognitive and cognitive processes mirrors the structure of language use, hence serving as a tool for expression (Anderson & Funke, 2007).

In light of the recent focus on the role of metacognition in geography education, the study conducts a secondary analysis of Heidari et al. (2024). The present secondary analysis provides further insights into the role of metacognition and its alignment with lexical complexity and geographical performance. Geographical performance can be represented through tasks connected to maps because they represent spatial structures and processes (Kimerling et al., 2016). Additionally, the present study is the first to conceptualize metacognition, lexical complexity, and geographical skills related to maps using sketch maps and research respective alignments. Thus, a conceptual framework regarding the three strands of theory was developed and applied to the data to further investigate alignments of metacognitive use and students' lexical complexity in think-aloud protocols and, in addition, geographical performance represented by students' sketch maps. This secondary analysis will further generate evidence in the field of metacognition in geography education. This is particularly important because the literature indicates that the metacognitive abilities of students predict their linguistic and geographical performance (Anderson & Funke, 2007; Meijer et al., 2006). The implications of the current study suggest that explicit instruction to improve metacognition, such as scaffolding, could contribute to inclusive geography education settings.

2. Theoretical Framework

To address the overarching research aim, three strands of theory—metacognition, lexical complexity, and geographical skills—in applying map conventions on sketch maps are at the center of the present study. Lexical complexity was conceptualized based on the morphological complexity of nouns and verbs as well as the extent of unique words, that is, vocabulary range. This conceptual framework provides the basis for a consistent understanding of the respective concepts within the study.

2.1. Conceptualizing Metacognition

First introduced in the 1970s by Flavell (1979) and further by Brown (1987), metacognition is a complex concept rooted in education psychology. It is broadly defined as knowledge and control of cognition (thinking) and its function. It is an umbrella term describing a variety of phenomena. Generally, it can be defined as an awareness of one's thinking at a meta-level (Flavell, 1979). Over time, manifold conceptualizations and taxonomies of metacognition have emerged and been applied by different scholars (Meijer et al., 2006). Despite the vast variety in conceptualizing the broad notion of metacognition, a two-component perspective has predominantly persisted, which is characterized by the ability to (1) know about cognition and (2) regulate cognition (Brown, 1987; Flavell, 1979; Schraw & Dennison, 1994). In addition, affective components regarding cognition in the form of metacognitive experience were an inherent component of the initial research on metacognition (Flavell, 1979, 1987). Thus, the conceptualization of metacognition (see Table 1) consists of three main components: metacognitive knowledge, regulation, and experience.

Metacognitive knowledge refers to knowledge about one's own or someone else's cognition. In addition to Flavell (1979) classification of metacognitive knowledge into person variables, task variables, and strategy variables, a more contemporary conceptualization of declarative, procedural, and conditional knowledge has been applied (Hasselhorn & Labuhn, 2008; Schraw & Dennison, 1994). Thus, the notion of metacognitive knowledge first includes knowledge about oneself and factual knowledge about tasks as well as strategies (declarative knowledge). Second, it consists of knowledge about how to solve tasks and how to use strategies (procedural knowledge). For instance, metacognitive knowledge is related to a student's knowledge of how their own cognitive strengths and weaknesses have an effect on the task. Third, metacognitive knowledge refers to a student's ability to know when and why to use an acquired strategy (conditional knowledge) in solving a task (Hasselhorn & Labuhn, 2008; Lane et al., 2019; Schraw & Dennison, 1994; Stephanou & Mpiontini, 2017). In geography education, metacognitive knowledge could be related to a student's awareness of their geographical understanding, which encompasses geographical practice. This includes the knowledge of working methods in geographical practice (Rawling 2022, p. 4). In the current study, knowledge of geographical practice related to working methods is particularly important because it involves acquiring map skills. In addition, it encompasses, for example, understanding map legends consisting of colors and symbols as encoded spatial information, as well as conceptual knowledge on how to decode, describe, or analyze maps. Metacognitive regulation describes the control of individual cognitive activities; it is more process oriented and is evident when students are engaged in performing tasks. The conceptualization of metacognitive regulation based on the threefold subdivision by Flavell (1979) into planning, monitoring, and evaluation has roughly persisted (Brown, 1987; Hasselhorn & Labuhn, 2008; Meijer et al., 2006; Veenman & van Cleef, 2019). Planning refers to predicting task expectations and outcomes as well as organizing individuals' strategies and learning processes beforehand. Additionally, monitoring involves an awareness regarding testing and revising during task performance. Finally, the evaluation includes individuals' checking of outcomes and applied strategies' effectiveness. These three subcomponents of metacognitive regulation form executive control processes and actions while students are engaged in and solve tasks (Brown, 1987; Hasselhorn & Labuhn, 2008; Schraw & Dennison, 1994). This active executive control function in metacognitive regulation involves self-regulation as well as self-regulated learning (Meijer et al., 2006). In geography education, metacognitive regulation could be related to the students' regulation of, for example, applying different coloring schemes and symbolization with respect to sketching different types of maps. Metacognitive experience, which is the third component, concerns students' affective response when they are engaged in cognitive activity. These are either conscious cognitive experiences (e.g., feeling of difficulty in solving a task, feeling at ease of understanding, and/or solving tasks) or conscious affective states (e.g., confusion, anxiety, curiosity, etc.). In geography education, metacognitive experience could be related to the students' experience of, for instance, feeling good at sketch mapping or feeling overwhelmed while sketching. Generally, students' interpretations and responses to affective states in metacognitive experiences grow more distinct with age (Flavell, 1987).



Components of Metacognition	Description	Subcomponents		
knowledge	knowledge about self and strategies as well as how, when and	declarative knowledge		
	why to use them, e.g., students' knowledge of, maps with legends that use colors, and symbols as encoded spatial information.	procedural knowledge		
		conditional knowledge		
regulation	executive control actions during task engagement. Regulation of,	planning		
	e.g., students' application of different coloring schemes and symbolization with respect to sketching different types of maps.	monitoring		
		evaluation		
experience	affective conscious states related to cognitive activity, e.g., stu-	conscious cognitive experience		
	dents' feelings of being good at sketch mapping or feeling over- whelmed while sketch mapping.	conscious affective states		

Table 1. Metacognition was conceptualized based on Brown (1987), Flavell (1979), and Schraw and Dennison (1994).

2.2. Conceptualizing Lexical Complexity

The role of language in geography education is highly important because it serves as both a means of learning and tool for thinking. Thinking forms the basis for psychological development and is articulated through language (Alexander, 2018; van der Veer & Zavershneva, 2018; Vygotsky, 1987). According to Vygotsky (1987), there is an interrelation between internal representations of meanings and the phonologically externalized use of language. In geography education, this means that internal geographical thoughts and content knowledge are expressed through language. Hence, language use in the classroom goes beyond teacher talk, for example, instruction, and instead encompasses a dialogic interaction between teachers and students as well as among students themselves, for example, group work (Alexander, 2018). These interactions enable and shape thinking and learning (Alexander, 2018). Therefore, language is central to geography education, with language and content acquisition being highly intertwined (Engelen & Budke, 2021). German large-scale assessment studies have highlighted that language proficiency is an indicator of educational success, especially in science (Lorenz et al., 2023; Wendt et al. 2020). However, students' language proficiency is heterogeneous and based on language skills acquired outside of schools because of their coincidental linguistic backgrounds, upbringing, socialization, and linguistic predisposition. The language expected in schools, especially disciplinary language, to access geographical content has a much greater complexity and level of abstraction than everyday language (Dal, 2006; Gallagher & Leahy, 2019; Snow & Uccelli, 2009). Students' language proficiency is important for grasping geographical concepts and actively communicating concepts in a spoken or written format. Thus, language proficiency is essential for effective participation in the classroom.

Disciplinary language in subjects such as science and geography is characterized by linguistic features that contribute to complexity, including abstractness, lexical variety, and density at the word, sentence, and text levels (Schleppegrell, 2004; Snow & Uccelli, 2009). Of particular importance is the word level because it grants access to an understanding of geographical concepts, for example, abstract geographical processes or phenomena (Gallagher & Leahy, 2019). Thus, students' proficiency in academic language at the word level is crucial for accessing knowledge and participating in the classroom (Kirk, 1995; Robinson, 2005). Thus, the word level of language in educational settings exhibits significantly greater complexity than words connected to everyday language. This lexical complexity is conceptualized based on linguistic features that contribute to its complexity. For the German language, morphological characteristics and processes are very important for indicating lexical complexity, and these involve alterations of words based on derived forms. In Table 2, types of morphological features are illustrated, for example, affixes (such as prefixes and suffixes) as well as nominalizations and compounds, all of which contribute to complexity at the word level (Halliday, 1999; Heine et al., 2018; Schleppegrell, 2004). The German language is characterized by morphological features that contribute to greater lexical complexity, particularly in terms of noun and verb usage (Heine et al., 2018). The use of nominalizations, for example, evaporation, demonstrates greater lexical complexity than verbs because these typically describe processes. As a result, nominalized forms include the semantic features of both processes and concepts, thereby further enhancing lexical complexity. Furthermore, this complexity associated with nominalizations is connected to the notion of extending grammatical categories (see Table 2). The processing and use of a diverse range of structurally complex words demand greater (meta-)cognitive resources. In particular, this processing relies on lexical complexity and density that are primarily linked to students' language proficiency, which is accessed from their working memory, which has limited capacity (Anderson & Funke, 2007; Heine et al., 2018). To conceptualize the lexical complexity of language use, the framework proposed by Heine et al. (2018) was used, which outlines three levels of difficulty regarding the morphology of nouns and verbs (see Table 2). For the purpose of the current study, the existing framework (Tab. 2) was developed to focus on three complexity levels of the main word groups, nouns and verbs because they are pivotal in representing lexical complexity in geography education. The criteria associated with these word groups are primarily grounded in the morphology of the German language at the word level.

Furthermore, alongside the levels of morphological complexity at the word level, unique words to assess the vocabulary range employed within the think-aloud protocols were analyzed. This identification of unique words was initially grounded in the concept of lexical diversity, which involved calculating the ratio of the number of different words (types) to the total number of words (tokens), thereby representing a quotient (Johansson, 2008; Kettunen, 2014). By quantifying word usage, calculating lexical diversity can provide insights into the breadth of vocabulary. To determine the number of unique words indicative of the vocabulary range within a think-aloud protocol, the lexical diversity was multiplied by the total number of words within the protocol.



Table 2. The morphological complexity of Nouns and Verbs was conceptually adapted based on Heine et al. (2018) and Matthews (2014).

Lexical Complexity at the Word Level	Criteria	Levels of Complexity from Low to High				
		low medium		high		
Nouns	structural, morphological form regard- ing the level of complexity of com- pounds	no compound	compound	complex compound		
Verbs	structural, morphological form of de- rived verb formation	no affix	affix (prefix, suffix)	affix and nominalization		

2.3. Conceptualizing Map Conventions on Sketch Maps

In geography education, maps are key methods for spatial representations of geographical information regarding human—environment relationships. Maps portray simplified, leveled, and scaled parts of the earth's surface and its related spatial information (Kimerling et al., 2016; Kohlstock, 2018). Moreover, maps are considered noncontinuous texts (OECD, 2000). Unlike descriptive texts, maps are depictive, presenting spatial information through icons that share inherent structural similarities corresponding to specific spatial features.

Maps are basically characterized by a plan view, a scaled minimization, a generalization, an orientation, and the leveling of the surface's geoid (Kohlstock, 2018; Tomlinson et al., 2012). Acquiring map skills is an indispensable component of geography education and consists of students' geographical skills related to map conventions, especially regarding reading, describing and analyzing maps, reflecting upon map content selection, and including illustrations and sketch mapping. These map skills determine students' geographical performance in geography education (Dunn, 2011; Gersmehl & Andrews, 1986). Sketch maps are more simplified and generalized representations of spatial structures than maps and do not strive for exact accuracy of scale, content, or orientation (Frank et al., 2010). Nevertheless, sketch maps remain a significant tool for illustrating the externalized cognitive perception of students' mental maps of environments, specifically showcasing students' capacity to apply map conventions (von Stülpnagel & Frankenstein, 2015). In addition, the information from sketch maps can provide more detailed information about students' map skills than regular knowledge tests. Thus, individuals' levels of proficiency in terms of map skills become evident through the use of sketched maps (Gieseking, 2013). In addition to filling in spatial information on blank maps, sketch maps hold significant value in evaluating students' understanding of previously described map conventions and cartographic illustration techniques, including graphic and coloring schemes (Dunn, 2011; Gieseking, 2013).

Based on the preceding conceptual framework, the derived research questions aimed to assess the alignment of metacognition and lexical complexity in think-aloud protocols as well as geographical performance in sketch maps. To gain further insights into this topic, the following key research questions frame the study:

- RQ1: To what degree is metacognition represented in think-aloud protocols while sketch mapping?
- RQ2: How do metacognition and lexical complexity in think-aloud protocols align with geographical abilities in the sketch maps of upper secondary students?

Addressing the respective research questions within the study contributes to generating sound evidence as well as narrowing the research desideratum with respect to alignments between the metacognition, lexical complexity, and geographical abilities of students in geography education classrooms. This is important because the evidence on these topics would be the first to increase the importance of the role of metacognition in geography education, especially in a language-aware geography education setting.

3. Method

3.1. Participants

Ten upper secondary students with an average age of 17.1 years (SD = 0.3) from the same grammar school in Northern Germany participated in the study. Convenience sampling was applied so that the first 10 responding participants were included. An equal representation of five female and five male participants is evident. The participants indicated that they had been born in Germany and mainly spoke German at home. School grades in the subject of geography, German, and math ranged from very good to poor performance. This contributed to high heterogeneity regarding the overall academic performance in school within the sample.

3.2. Research Design

In the present study, upper secondary students (ISCED III) had to sketch free-hand maps of a familiar route to their school while simultaneously thinking aloud (for more details, see Heidari et al., 2024). The purpose of the map was to be given to an exchange student to find the way to school from a particular orientation point. Sketch mapping is a free-form task that provides insights into students' individual map skills when representing a particular part of space (Apostolopoulou & Klonari, 2022). In fact, the sketched map serves as an evaluation tool for assessing individuals' levels of proficiency regarding implemented map conventions on sketch maps (Blades, 1990; Metz, 1990; Wise & Kon, 1990). There is no free-hand sketched map that can be drawn in the exact same way twice, hence contributing to its reliability. The thinking aloud method is the only approach for ensuring access to students' (meta-)cognitive processes while they are engaged in a geographical task (Veenman & van Cleef, 2019). As the concurrent verbalization of students' ongoing thoughts during actual performance contributed to the highest validity, the research design was developed accordingly (Cox et al., 2020; Ericsson & Simon, 1998). However, because thinking aloud is a highly unfamiliar task format, the students first watched a simulation video of the researcher thinking aloud and engaged in a practice exercise in thinking aloud while solving a crossword puzzle. After completing the practice and actual task, the participants were asked to provide sociodemographic data. All participants



individually completed the tasks in the same classroom setting. All of the thinking aloud was automatically recorded, and the sketch maps were digitized through the uniform use of a digital pen and paper.

3.3. Data Analysis

Transcriptions of the think-aloud protocol were transcribed based on McLellan et al. (2003), and the digitized sketched maps were uploaded to MAXQDA for coding. The applied segmentation structured the transcripts into sentences (thought units) that were completed with a full stop. The previously described conceptual framework regarding metacognition and lexical complexity, including the morphological complexity of nouns and verbs, served as a concept-driven coding scheme, per Mayring (2015), and was applied to the generated qualitative data of the think-aloud transcripts. First, the absolute frequencies of metacognitive activity of the individual participants were coded based on the predefined scheme (see Table 1). Because metacognitive components of knowledge, regulation, and experience interrelate, metacognition was holistically coded within the think-aloud protocol. In addition, the relative frequencies of metacognition were determined for each participant based on the coding segments (sentences) within the think-aloud protocols. The summarized results were evenly distributed into high (40–68%), medium (30–39%), and low (0–29%) groups.

Regarding the analyses of lexical complexity, the LATIC (Linguistic Analyzer for Text and Item Characteristics) analysis tool was applied to the transcribed think-aloud protocols. This ensured the systematic analysis and count of linguistic items of each transcript (Cruz Neri et al., 2022). In the present study, the linguistic features of nouns and verbs were at the center of interest because they were further analyzed for their linguistic complexity based on morphology. Respective levels of complexity (low, medium, high) based on the predefined conceptual framework (see Table 2) were assigned to nouns and verbs. To investigate the overall morphological complexity of nouns and verbs, the coding results were summarized as high, medium, or low. Moreover, the lexical diversity or type-token ratio was calculated by LATIC based on the number of unique words divided by the number of total words for each participant's think-aloud transcript. This lexical diversity was then multiplied by the number of total words in the think-aloud protocols to investigate the extent of unique words, that is, vocabulary range, used within the think-aloud protocol. These results were also grouped into high, medium, and low groups.

Finally, the overall performance of implementing map conventions on sketch maps was assessed based on German school grades, here ranging from very good, good, medium to poor. An independent geography teacher working at the grammar school where the study was conducted served as an interrater. The interrater reliability was $\kappa = 0.8$, indicating almost perfect agreement (Brennan & Prediger, 1981). Discrepancies were resolved through discussion.

4. Results

4.1. Representation of Metacognition in Think-Aloud Protocols while Sketch Mapping (RQ1)

The representation of metacognition in think-aloud protocols was analyzed by examining both the absolute frequency of coding units and their relative frequency within the segments of each participant's think-aloud protocol (see Table 3). The participants were judged to have exhibited metacognition in the low (e.g., Student 7: 7; 26%), medium (e.g., Student 5: 22; 32%), and high ranges (e.g., Student 2: 42; 50%). In Table 3, the participants are listed in chronological order according to their use of metacognition, here categorized as high, medium, or low. In general, the participants within the sample showed high heterogeneity and variety of use. To address the first research question, the exemplary representations of the metacognition of low- and high-performing individuals will be contrasted in the following section. Figure 1 shows examples of low and high metacognition within the think-aloud protocols of Student 7 (n = 7; 26%) and Student 1 (n = 31; 68%). The boxes in Figure 1 depict the number of words in the think-aloud protocol. Purple boxes represent words as components of coding units related to metacognition while gray boxes represent all other words in the think-aloud protocol. The representation of metacognition by Student 7, which is displayed in the left column in Figure 1, shows a low representation and density of metacognition within the think-aloud protocol. Moreover, this participant showed not only a relatively minor representation of metacognition as well as a selective prevalence but also short units of metacognition, as displayed by the following quotes from the think-aloud protocol of Student 7: "It is difficult to add details [...] That is not size-accurate now." The first quote refers to the participant's awareness, including cognitive experiences, with respect to task difficulty. Furthermore, the participants checked the outcomes following the sketch mapping, so the quotation included minor awareness of knowledge regarding the map-related scale and proportion represented. Within the sample of the present study, those participants who used metacognition at a low range showed less variety, comparably short units and low density of metacognition than the medium- and high-performing participants.

In contrast to the low-performing students, Student 1 showed a high representation of metacognition use within the think-aloud protocol (n = 31; 68%). The results displayed in Figure 1 (right column) emphasize the participants' representation of metacognition within the sample, including lengthier metacognitive units as well as a high density of metacognitive representations. Exemplary quotes from Student 1 indicate this representation of metacognition within the think-aloud protocol: "I'm just trying to imagine it a bit directly how I approach it [...] I'm trying truly hard to visualize what I actually see every morning."

Mainly, the student referred to the planning of creating a coherent scale for the respective sketch map. Further exem-plary quotes from the think-aloud protocol of Student 1 showed metacognitive use, particularly regarding regulation and experience, when a scale was produced on the sketched map. This awareness of interrelated executive control actions as well as affective components of awareness with respect to task difficulty for the student can be seen in the following quote: "Therefore, if I now imagine this path is one centimeter wide, then I just think about how wide the path is; it is not 20 meters wide, but the new building is definitely wider. Um, I think I will just write one centimeter, that is difficult, I will just write 30 meters and that would be 3000 centimeters."

Other than Student 1, Student 2 also showed a high representation of metacognition within the think-aloud protocol (n = 42; 50%). A high variety and density of coding units also appeared. The following quotes from Student 2 highlight this representation: "Well, I would start by making the layout of the map."

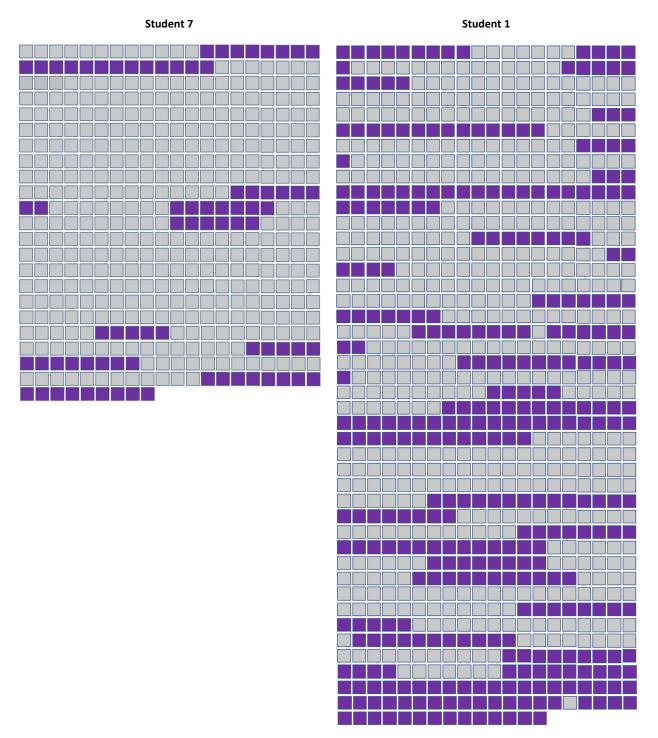
This quote from Student 2 indicates an awareness of which executive controls actions to apply during the planning phase before starting the sketch mapping process to represent a given route. This notion is further supported by the following quotes: "I'm trying to structure things out first, just to have a good idea of how I envision the map now because I do not have it in my head as clearly anymore [...] I'm just trying to visualize the terrain from above right now."



These quotes by Student 2 indicate a conscious understanding of map-related concepts, for example, recognizing the importance of a plan view and their awareness of strategizing their approach to sketching maps accordingly. Student 2's metacognitive experience becomes evident through their aware acknowledgment of difficulties in recalling the route needed to be sketch mapped. This representation of metacognitive experience with affective considerations demonstrates a high variety and density of metacognitive use by Student 2.

These exemplary quotes from Students 1 and 2 contribute to the results of the present study that high-performing students showed a high variety of metacognitive use, including metacognitive knowledge, regulation, and experience. In addition, the coded metacognitive units were lengthier, and the think-aloud protocols had high density and variety regarding their metacognitive representation.

Figure 1. Exemplary representation of Coding Units regarding Metacognition (n = 7) in the Think-Aloud Protocol of Student 7 (left) and Student 1 (n = 31). Source: Authors' own illustration.





Participants	Metacognition		Lexical complexity							map skills	
(n = 10)			Absolute freque				frequency of morpholog		Overall morphological complexity of nouns and verbs	Absolute frequency unique words	(very good, good, me-
	absolute frequency of coding units	relative frequency of coding units	low	medium	high	low	medium	high			dium, poor)
Student 1	31	68%***	79**	23***	1**	82**	30***	0*	medium	270.92**	very good
Student 2	42	50%***	139***	22***	1**	176***	35***	1**	high	335.25***	very good
Student 3	50	40%***	148***	24***	7***	186***	39***	3***	high	372.72***	very good
Student 4	38	35%**	86**	9**	0*	88**	29***	0*	medium	271.08**	medium
Student 5	22	32%**	131***	9**	0*	135***	19**	0*	medium	279.5**	medium
Student 6	9	19%*	51*	4*	0*	99*	14**	0*	low	149.52**	poor
Student 7	7	26%*	44*	0*	0*	39*	16**	0*	low	163.08**	poor
Student 8	0	0%*	31*	2*	0*	19*	6*	0*	low	82.44*	poor
Student 9	0	0%*	16*	4*	0*	23*	9*	0*	low	90.4*	poor
Student 10	12	28%*	35*	17**	0*	55*	10*	2**	low	154.77**	good

Table 3. Results of Assessing Metacognition, Lexical Complexity in Think-Aloud Protocols and Map Skills in Sketch Maps.

Note. *reflects low performance; **reflects medium performance; ***reflects high performance.

4.1. Alignment of Metacognition and Lexical Complexity in Think-Aloud Protocols with Geographical Abilities in Sketch Maps of Upper Secondary Students (RQ2)

The findings of the present study, as illustrated in Table 3, highlight that, in addition to the metacognition described previously, the representation of lexical complexity in think-aloud protocols and geographical map skills on sketch maps highly varied among the participants of the present study.

4.1.1. Lexical Complexity

Lexical complexity is illustrated based on the absolute frequency of the morphology of nouns and verbs in the low, medium, and high ranges. These were summarized into an overall morphological complexity. To address the second research question, the exemplary assessment results of metacognition, lexical complexity, and map skills by low- and high-performance participants are displayed below. For instance, Student 9 primarily demonstrated a low level of morphological complexity in nouns (16) and verbs (23), minor morphological complexity in nouns (4) and verbs (9) at a medium level, and no morphological complexity at a high level, resulting in an overall morphological complexity at a low range. In contrast, Student 3 showed the highest morphological complexity, resulting in morphological complexity of nouns (148) and verbs (186) at a low range, medium-range morphological complexity of nouns (24) and verbs (39), and even a representation of high-range morphological complexity in nouns (7) and verbs (3). This prevalence of the respective morphological complexity of Student 3 resulted in an overall high range of morphological complexity. In addition to the morphological complexity, Table 3 shows the absolute frequency of unique word counts resembling the vocabulary range. Student 9 demonstrated a low-range unique word count (90) while Student 3, on the other hand, used 388 unique words within the thinkaloud protocol, indicating a high vocabulary range.

4.1.2. Geographical Abilities in Implementing Map Conventions on Sketch Maps

In addition, the assessment of map skills on sketch maps showed high heterogeneity, ranging from very good to poor. Examples of an overall poor assessment regarding the representation of map skills are illustrated by Figure 2, which shows the sketch map produced by Student 7 and, in Figure 3, the sketch map produced by Student 9. In contrast, Figures 4 and 5 display the sketch maps of Students 2 and 3, indicating an overall very good assessment of the represented map skills. Moreover, the results presented in Table 3 demonstrate that the participants' level of represented metacognition use primarily served as an indicator of their overall map skills in applying map conventions on sketch maps. Moreover, the use of metacognition corresponded to the level of lexical complexity. It also indicated a tendency toward the extent of unique word use, which will be explored more below. Low-performing students who did not use metacognition (e.g., Student 9) also showed minor morphological complexity in the medium range and no morphological complexity in the high range as well as a notably low extent of unique word use within the think-aloud protocol. In addition, the sketch maps were assessed to be poor in implementing map skills with respect to applying map conventions. This finding emphasizes that participants who lacked the use of metacognition in their think-aloud protocol additionally demonstrated low lexical complexity and poor implementation of map conventions on their sketch map within the sample (see Figures 2 and 3). High-performing students who used metacognition at a high level also showed greater morphological complexity in the medium range and even minor use of morphologically complex structured metacognition at a high range in their think-aloud protocols. Additionally, these students had significantly greater unique word counts. This also contributes to the notion that metacognitive use is aligned with lexical complexity as well as performance among the participants. Exemplary for high-performing students within the sample are Students 1, 2, and 3, who used a high variety and density of metacognition. These students also showed medium or mainly high overall morphological complexity, particularly regarding the morphological derivation of verbs regarding prefixes and suffixes. Moreover, noun compounds were more frequently used in addition to verb derivations. Furthermore, the extent to which unique words represented the vocabulary range was particularly high among the participants. Moreover, their map skills in implementing map conventions on their sketch maps were primarily rated as very good. The exemplary sketch maps of Students 2 and 3, as illustrated in Figures 4 and 5, also showed greater complexity regarding the geographical skills in applying map conventions as they were rated as very good.

An exception within the sample, Student 10, showed that, despite low performance regarding metacognitive use, the geographical map skills based on the sketch map were rated as good. Additionally, this participant showed morphological complexity of nouns and verbs at a low range in the think-aloud protocol. The extent of unique words resembles the range of medium-performing participants within the sample.

Figure 2. Sketch Map of Student 7.



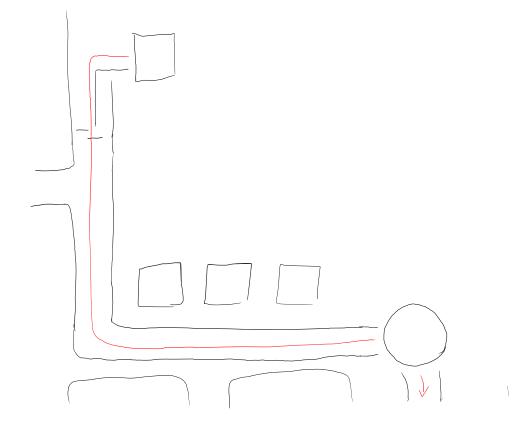
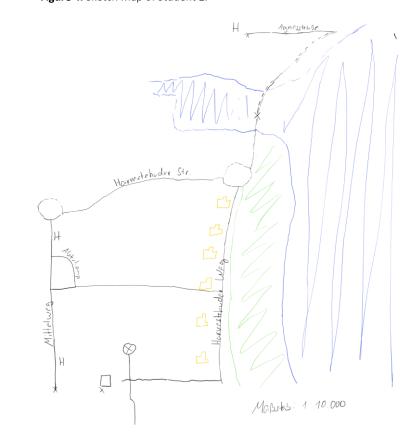




Figure 4. Sketch Map of Student 2.



☐: Schule Ø: Sock gouse

5. Discussion

The purpose of the current study was to gain a better understanding of the role of metacognition and its alignment with the lexical complexity and geographical performance of upper secondary students. A qualitative research design based on upper secondary students' thinking aloud while sketching was developed. Metacognition and lexical complexity were investigated based on students' think-aloud protocols, and geographical skills were investigated with respect to map skills applied to drawn sketch maps. The results provide two key findings. First, the greater the use of metacognition is, the greater the variety, complexity, and density of metacognition. Second, there are alignments, especially between metacognitive use, the morphological complexity of nouns and verbs, and geographical skills. The first key finding represents the first direct demonstration that students highly draw on metacognition and that they have the ability to use a variety of metacognition strategies, such as metacognitive knowledge, regulation, and experience, while solving the task. Metacognition users, especially at a high range, represented the understanding of an active cognitive agent while being involved in sketch mapping. This enabled these students to have an awareness of knowing, regulating, and experiencing their own cognitive activity (Flavell, 1979). The finding is in accordance with the notion that metacognitive abilities facilitate further metacognitive acquisitions as well as its development (Flavell, 1987; Hasselhorn & Labuhn, 2008; Meijer et al., 2006). This is a striking finding for geography education and related research because students' awareness of cognition hints at abilities that exceed factual knowledge as well as its acquisition (Rawling, 2022). Enhancing students' awareness of how geographical knowledge is produced is particularly crucial especially connected to geographical practice, which is related to fostering geographical skills, for example, map skills. However, because students' geographical learning is characterized by an abundance of cognition, which is prone to errors, metacognitive knowledge, regulation, and experience are essential for contributing to students' development of knowledge on geographical practice toward the development of an active cognitive being regarding knowledge production (Flavell, 1987; Hasselhorn & Labuhn, 2008; Rawling, 2022). Promoting this distinct awareness of cognition within geography education provides students with access to skills, for example, map skills beyond factual learning (Firth, 2011; Flavell, 1987; Puttick & Cullinane, 2021; Rawling, 2022). Moreover, metacognition provides an essential part of geographical sense-making in geography education (Rawling, 2022), particularly when it comes to students' mental maps of the environments they are surrounded by and interacting with. Here, metacognition may play a pivotal role in geography education, particularly regarding an awareness of students' mental maps of local environments because this awareness is linked to students' geographical thinking and actions on both local and global scales (Dunn, 2011; Lane et al., 2019; Rawling, 2022; Troffa et al., 2009). Thus, the first key finding is that the greater the metacognitive ability is, the more varied, complex and frequent the different metacognitive uses. This is important because metacognitive acquisition is further eased by existing metacognitive abilities. This is crucial for geography education, particularly for contributing to students' understanding of being active cognitive agents in their lives (Flavell, 1987; Hasselhorn & Labuhn, 2008). Furthermore, this finding can help students apply their geographical knowledge to real-world issues and assess situations and decision-making on local and global scales because spatial interconnectedness, complexities, and dynamics provide the basis for geographical learning and thinking (Metoyer & Bednarz, 2017; Rawling, 2022).



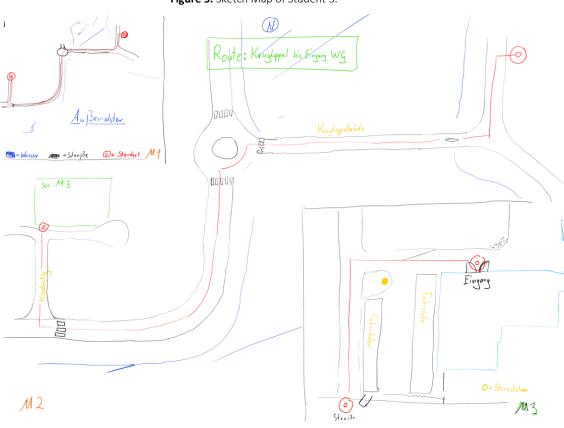


Figure 5. Sketch Map of Student 3.

5.1. Limitations

Although the present study's results clearly support the importance of metacognition in geography education, it is appropriate to recognize several potential limitations. First, the number of participants prevents the generalization of the results. These findings are the first evidence of the use of metacognition being involved in sketch mapping. Second, the homogenous age group of the students hinders the generalization of the results, especially regarding transferring the results to younger learners. Apart from the sample size and form, the conceptualization of metacognition highly varies among scholars and studies. Thus, the underlying conceptualization of metacognition within the present study was developed based on the overarching aim of the present study. This may have contributed to a selection of metacognitive components. Despite these limitations, the findings underline the pivotal role of metacognition, especially in geography education, showing how metacognitive abilities are aligned with lexical complexity and geographical performance among the participants.

6. Conclusion

In conclusion, the present study can be seen as a first step toward integrating three lines of research, metacognition, and lexical complexity in think-aloud protocols as well as map skills in implementing map conventions on sketch maps, which, to the best of our knowledge, have not been directly linked. The results have contributed to the pivotal role of metacognition in geography education and related research. In particular, the participants who were able to use metacognition at a high range showed more variety, complexity, and density regarding its use but also showed greater lexical complexity and, sometimes, a greater vocabulary range and greater geographical skill on their sketch maps. Thus, the results emphasize that metacognitive abilities align with geographical performance. Furthermore, metacognition use was linked to lexical complexity, particularly through represented morphological complexity. Although the generality of the current results must be established by future research, the present study provides the first exploratory evidence for the importance of fostering the metacognitive abilities of students in geography education. Students' awareness of their knowledge, regulation regarding executive control action in geographical tasks, and individual experience may have a positive impact on geographical learning and achievements in geography education. In geography education practice, language-aware geography education can contribute to fostering metacognition as well as language skills connected to maps and map skills in general. One approach for teachers to achieve this goal is through the implementation of macro-scaffolding (Hammond & Gibbons, 2005; Prediger & Pöhler, 2015). This approach includes the explicit instruction of metalanguage, which involves discussing the semantics of language and language choices made in subject learning (Schleppegrell, 2013). Explicit instruction in metalanguage fosters metacognition and in-depth engagement with maps in a language-aware geography classroom. For instance, students are provided with phrases in the form of questions (scaffolds) that help them identify or use geographical language elements, which are essential as externalized counterparts of geographical thinking (Rawling, 2022; Schleppegrell, 2013). Promoting an awareness of students' nature as active cognitive beings provides the basis for thinking and acting as responsible citizens regarding spatial issues of human-environment relations. Future research may contribute to the fact that fostering metacognition in geography education may further enable the acquisition of geographical knowledge and skills. Finally, emphasizing metacognition in geography education research may not only generate evidence on its role in achieving higher educational performance but may also pave the way toward lifelong education.



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