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Review Article

Future paths for GIS in K-12 education: A review of possibilities and constraints

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Abstract: Geographic information systems (GIS) have been highlighted as essential future knowledge and are increasingly integrated in people's everyday lives through applications, tracking, and global positioning systems (GPS). Still, applications and research of GIS technology for teaching and learning in kindergarten to grade 12 (K-12) education are limited. Through a scoping review of contemporary literature, this study identifies and discuss possibilities and constraints for GIS in K-12 education. Data were collected and analyzed with directed content analysis, using affordances as a theoretical lens, to identify possibilities and constraints of GIS for K-12 education. The study highlight themes of possibilities and constraints for further investigation. The possibilities of GIS for K-12 education include accessibility, transdisciplinary, and beyond classroom; and the constraints include skills and attitude, higher education and support, and teachers' knowledge. The theoretical contribution of the study is a conceptual model for how possibilities and constraints of GIS for K-12 education relates to reaching educational goals. Findings of the study have practical implications for teachers and other stakeholders on the use of GIS in K-12 classrooms. The study also provides several suggestions for future research on GIS in K-12 education.

Keywords: Geographic Information Systems; K-12 Education; Affordances; Constraints; Literature review.

Highlights:

- Possibilities and constraints for GIS for K-12 education.
- Practical implications for GIS in K-12 education.
- Needs for future research in GIS for K-12 education.

1. Introduction

Geographic information systems (GIS) began in the 1960s with numerous projects, where the Canada Geographic Information System (CGIS) can be mentioned as one of the more influential (Goodchild, 2018). As stated by Lü et al. (2019), GIS have many definitions, but they suggest a definition where geospatial, spatial, or geographic data are used in an information system that is designed to handle that data. This study place emphasis on the educational context for GIS and the possibilities and constraints for its applications in education.

GIS is an integral part of peoples' everyday life with global positioning systems (GPS), mobile tracking and applications (Osborne et al., 2020). GIS has also been highlighted in prior research as an essential knowledge for the future (Mzuza & Van Der Westhuizen, 2019). A problem that is mentioned in previous research is the low application of GIS technologies in kindergarten to grade 12 (K-12) education and teachers' lack of capacity to use the technology (Anunti, Vuopala & Rusanen, 2020; Nilsson & Bladh, 2020; Oda, Herman & Hasan, 2020; Collins & Mitchell, 2019; Mitchell et al., 2018; Hong, 2017). Further, prior research has noted that elementary education is a level of education that is less studied in relation to GIS technologies (Ribeiro, Azevedo & Osório, 2017) and that there are limited review articles with focus on the educational context in the fields of geoscience and geography (Schulze, 2021).

The limited amount of research on GIS for K-12 education and the sparsity of review studies on educational inquiry related to geoscience and geography, as mentioned above, could be considered a gap in research. The study at hand addresses this gap through a literature review of contemporary research on GIS for K-12 education and investigates the potential possibilities and constraints, guided by the theory of affordances (further described in '2 Theoretical framework'), for teaching and learning with GIS technologies. This study has practical implications for teachers and other stakeholders on how to use and integrate GIS in classroom settings to support teaching and learning. Further, the study provides several suggestions for future actions of research, based in the study's investigation of possibilities and constraints of GIS for K-12 education.

The aim of this study was to identify and discuss possibilities and constraints in contemporary literature with GIS for K-12 education. The conducted study has been guided by the following research questions:

RQ1: What are the possibilities of GIS in K-12 education?
RQ2: What are the constraints of GIS in K-12 education?

2. Theoretical framework

This study uses the theory of affordances as a theoretical lens. The concept was first coined by Gibson (Bower & Sturman, 2015) and has commonly been defined as 'action possibilities' or 'action potentials', by both Gibson (2015) and later researchers (Stendal, Thapa & Lanamäki, 2016; Bower & Sturman, 2015; Norman, 1999). However, this study applies affordances according to the further developments by Norman (2013; 1999).

Norman (1999) develops the theory by applying a designer perspective and emphasizing affordances that are perceived as possible in the design of artefacts, hence 'perceived affordances'. For Norman (2008) affordances, as intended by Gibson, simply exists, regardless of perception or knowledge by a user. For example, built-in physical affordances in a computer such as 'pointing', 'clicking', and 'touching' (Norman, 1999). While perceived affordances invite, or market, certain actions as possible and useful, for example touching a touch-sensitive computer screen (Norman, 1999).

Norman (1999) also introduces the concept of 'constraints' which relates to perceived affordances. Constraints relate to affordances in that there is a push-and-pull relationship between them, what can (affordances) and what cannot (constraints) be achieved with the artefact (Stendal, Thapa & Lanamäki, 2016; Leonardi, 2011). Norman (1999) identifies three behavioral constraints: cultural, logical, and physical. These limits what can, either real or perceived, be done with an artefact. Cultural constraints, such as where the scroll bar on a computer screen is located, are shared conventions by a group (Norman, 1999). That is, they are learned constraints and there is nothing in the artefact or design itself that requires these limitations to be there (Norman, 1999). Logical constraints are based in reasoning, such as that the only way to see more content on the computer screen is to scroll down (Norman, 1999). Lastly, physical constraints are based in the limitations of the real world. For example, the cursor cannot move outside the computer screen (Norman, 1999).

In studies of design and educational technologies' possibilities and constraints, the theory of affordances is well-established. Antonenko, Dawson and Sahay (2017) highlight the importance of being aware of the connections that exists between educational technologies' affordances and the users' educational needs. To achieve alignment between users of educational technology and the technologies' affordances, a more user-centered design of educational technology needs to be applied (Antonenko, Dawson & Sahay, 2017). Besides being used to guide design, affordances have been used to examine the educational possibilities and constraints of existing technology, not primarily intended for educational use. In a study by Xue and Churchill (2019), the potential educational affordances of a social media application are examined. The study found that categories such as resource sharing, collaboration, community building, evaluation and feedback are potential affordances of social media applications in educational setting (Xue & Churchill, 2019). Given prior research shows a limited use and study of GIS technologies in K-12 education, the theory of affordances is deemed an appropriate theoretical lens for this study.

3. Method

This study was conducted as a scoping review, analyzing 27 research papers published between 2017 and 2022 (Table 1). Munn et al. (2018) highlight that the scoping review is an appropriate approach when the goal of the literature review is to provide an overview rather than seeking answer to a specific question, as is often done in a systematic review. The aim of this study, to identify and discuss possibilities and constraints in contemporary literature with GIS for K-12 education, was considered in alignment with a scoping review. Further, Davis, Drey and Gould (2009) notes that a strength with scoping reviews is that they can be used to draw the essence out of a body of knowledge, that is diverse, developmental, and creative, which has been an important aspect of data collection and analysis in this study.

3.1. Data collection

Data were collected and identified through a literature search on Google Scholar. An aggregation of databases, accessed through the University library of University of Gävle, was used to access papers that were not Open Access. The search was conducted in late 2022 with search set to include published articles from 2017 and onwards. The initial search identified 17 300 potentially relevant papers with the following search query:

> *("geographic information system" OR "GIS" OR "Geospatial science") AND ("k-12" OR "kindergarten" OR "primary school" OR "primary education" OR "elementary school" OR "elementary education" OR "secondary school" OR "secondary education")*

This could be compared to Web of Science and Scopus were the same search string and years for publication identified 147 (Web of Science) and 233 (Scopus) potentially relevant papers. The wider range of Google Scholar made it interesting as the main search engine for this study, since it was able to detect more potentially relevant papers. However, as noted by Harzing (2020), searches in Google Scholar may also include handbooks, editorial notes, library guides and other non-scholarly works. This could partly explain the higher number of identified papers for Google Scholar. However, of the 27 selected research papers for the study (further described below), 4 were not searchable in either Web of Science or Scopus: Ribeiro, Azeve-do and Osório (2017), Tarisayi (2018), Nilsson and Bladh (2020), and Nilsson and Bladh (2022); and additional 4 were not searchable in Web of Science but could be found in Scopus: Gal (2019), Anunti, Vuopala and Rusanen (2020), Intzidou et al. (2021), and McKenzie, Cook and Roulston (2022).

Through a deductive-inductive approach, forward searches, and the idea of data saturation (further described in '3.2 Data analysis'), about 60 research papers were examined through Google Scholar before data saturation was decided and 27 research papers were selected for inclusion in the study (Table 1). The criteria used for selecting research papers to be included in the study were to encompass the aim, research questions, and theoretical lens of the study. First, content of the research papers should relate to the context of K-12 education (which is addressed in the aim and research questions of this study). This could for example be through studies on teaching and learning practices in K-12 classrooms. However, studies with K-12 students and K-12 teachers in other contexts could also be of interests, such as teacher training, professional development, and primary and secondary teacher education. Second, content of the research papers should relate to Geographic Information System (GIS) or Geospatial Science (which is addressed in the aim and research questions of this study). Third, content of the research papers should highlight possibilities and/or constraints of GIS relevant for the context of K-12 education (which is addressed in the aim, research questions, and theoretical lens of this study). Only when all three of these criteria are meet should a research paper be selected for inclusion in the study.

The selected research papers were published in 17 different journals with 'Journal of Geography' being the most common (n=5), followed by 'International Research in Geographical and Environmental Education' in second place (n=3). The remaining journals had 1 or 2 selected papers each and can be found in Table 1. The selected papers for the study have an even year distribution. The most common years of publication for the selected papers in the study were 2017, 2018 and 2020 with 5 publications each. The other years (2019, 2021 and 2022) had 4 publications each.

Table 1. Included papers ordered by publication year.

Year	Author(s)	Title	Published in
2017	Fleischmann, E. M. L., & Van der Westhuizen, C. P.	The Interactive-GIS-Tutor (IGIST): An option for GIS teaching in resource-poor South African schools	*South African Geographical Journal = Suid-Afrikaanse Geografiese Tydskrif*
2017	Hong, J. E.	Designing GIS learning materials for K–12 teachers	*Technology, Pedagogy and Education*
2017	Millsaps, L. T., & Harrington, J. A.	A time-Sensitive Framework for Including Geographic Information Systems (GIS) in Professional Development Activities for Classroom Teachers	*Journal of Geography*
2017	Ribeiro, V., Azevedo, L., & Osório, A.	Teaching and learning with geotechnologies on primary education: Students' perceptions	*EAI Endorsed Transactions on e-Learning*
2017	Walshe, N.	Developing trainee teacher practice with geographical information systems (GIS)	*Journal of Geography in Higher Education*
2018	Hong, J. E., & Melville, A.	Training Social Studies Teachers to Develop Inquiry-Based GIS Lessons	*Journal of Geography*
2018	Mitchell, J. T., Roy, G., Fritch, S., & Wood, B.	GIS professional development for teachers: Lessons learned from high-needs schools	*Cartography and Geographic Information Science*
2018	Tarisayi, K.	Lessons for GIS Implementation in Zimbabwe from the South African Experiences	*Alternation Special Edition*
2018	Wu, L., Li, L., Liu, H., Cheng, X., & Zhu, T.	Application of ArcGIS in Geography Teaching of Secondary School: A Case Study in the Practice of Map Teaching	*Wireless Personal Communications*
2018	Zwartjes, L.	Developing geospatial thinking learning lines in secondary education: The Gi learner project	*European Journal of Geography*
2019	Collins, L., & Mitchell, J. T.	Teacher training in GIS: what is needed for long-term success?	*International Research in Geographical and Environmental Education*
2019	Egiebor, E. E., & Foster, E. J.	Students' Perceptions of Their Engagement Using GIS-Story Maps	*Journal of Geography*
2019	Gal, A.	Fifth Graders' Perceptions of Mobile Phones and GIS Technology	*International Journal of Evaluation and Research in Education*
2019	Mzuza, M. K., & Van Der Westhuizen, C. P.	Review on the state of GIS application in secondary schools in the southern African region	*South African Geographical Journal = Suid-Afrikaanse Geografiese Tydskrif*
2020	Anunti, H., Vuopala, E., & Rusanen, J.	A Portfolio Model for the Teaching and Learning of GIS Competencies in an Upper Secondary School: A Case Study from a Finnish Geomedia Course	*Review of International Geographical Education Online*
2020	De Miguel González, R., & De Lázaro Torres, M. L.	WebGIS Implementation and Effectiveness in Secondary Education Using the Digital Atlas for Schools	*Journal of Geography*
2020	Mzuza, M. K., & Van der Westhuizen, C.	Inclusion of GIS in student teacher training and its significance in higher education in southern African countries	*International Research in Geographical and Environmental Education*
2020	Nilsson, S., & Bladh, G.	Going Digital? Geography Education in Swedish Secondary School	*Nordidactica: Journal of Humanities and Social Science Education*
2020	Oda, K., Herman, T., & Hasan, A.	Properties and impacts of TPACK-based GIS professional development for in-service teachers	*International Research in Geographical and Environmental Education*
2021	DeMers, M. N., Kerski, J. J., & Sroka, C. J.	The Teachers Teaching Teachers GIS Institute: Assessing the Effectiveness of a GIS Professional Development Institute	*Annals of the American Association of Geographers*
2021	Intzidou, G., Lambrinos, N., Tourtouras, C., & Seroglou, F.	Metadata: A pedagogical tool for the teaching of map projections in Elementary School	*European Journal of Geography*
2021	Ridha, S., & Kamil, P. A.	The Problems of Teaching Geospatial Technology in Developing Countries: Concepts, Curriculum, and Implementation in Indonesia	*Journal of Geography*

2021	Schulze, U.	"GIS works!"—But why, how, and for whom? Findings from a systematic review	*Transactions in GIS*
2022	Buzo-Sánchez, I. J., Mínguez, C., & De Lázaro-Torres, M. L.	Expert perspectives on GIS use in Spanish geographic education	*International Journal of Digital Earth*
2022	McKenzie, P., Cook, S., & Roulston, S.	Learners as Teachers—Teachers as Learners: A Collaborative Approach to Develop Skills in GIS Education	*The Geography Teacher*
2022	Nilsson, S., & Bladh, G.	Thinking Geographically? Secondary Teachers' Curriculum Thinking when Using Subject-Specific Digital Tools	*Nordidactica: Journal of Humanities and Social Science Education*
2022	Vojteková, J., Žoncová, M., Tirpáková, A., & Vojtek, M.	Evaluation of story maps by future geography teachers	*Journal of Geography in Higher Education*

3.2. Data analysis

The analysis process in this study draws on the analysis method of directed content analysis and the idea of data saturation. No tools such as Computer-Assisted Qualitative Data Analysis Software (CAQDAS) was used for the analysis, instead codes and categories were collected in a spreadsheet document. Directed content analysis is described by Hsieh and Shannon (2005) as a method for analysis that uses theory or previous research to focus the investigation. This is also commonly referred to as a deductive approach to coding (Elo & Kyngäs, 2008; Hsieh & Shannon, 2005) and could be considered a more structured approach to coding compared to conventional or inductive content analysis (Humble & Mozelius, 2022; Hickey & Kipping, 1996). Assarroudi et al. (2018) suggest 16 steps for conducting a study with directed content analysis, of which the last 9 steps relate to the analysis phase and are used as inspiration for the analysis in this study. The 9 steps are:

1. Develop formative categorization matrix
2. Define categories and subcategories
3. Determine coding rules
4. Pre-test categorization matrix
5. Chose and specify anchor samples
6. Perform analysis
7. Inductive abstraction
8. Establish links
9. Report steps of analysis and findings

Data saturation can be described as the point in analysis when adding new data will not lead to new discoveries related to the study's aim and research question (Lowe et al., 2018; Saunders et al., 2018). Previous research has highlighted that it can be difficult to determine when data saturation occurs (Lowe et al., 2018; Saunders et al., 2018). In this study, new data have been added to the analysis after the point of data saturation as an extra step of precaution to not miss new important information. The principle of data saturation was first applied in the analysis (and selection process) of papers identified through the initial search query at Google Scholar. A total of 50 papers were analyzed, of which 23 were selected for inclusion after the initial search, before data saturation was decided. Data saturation was then applied again when forward searches were conducted via Google Scholar on the more well-cited papers that had previously been selected for inclusion. This resulted in additional 4 papers, of about 10 examined, being selected for inclusion before data saturation once again was decided, bringing the total of included papers to 27.

As a first step of analysis a categorization matrix was developed in a spreadsheet document with two main categories (based in the theoretical framework): 'affordances' and 'constraints'. The categories were defined (step 2) according to the theory of affordances, especially the concepts of perceived affordances and constraints as they are described in the theoretical framework-section. The definition of affordances and constraints were also important in deciding the coding rules (step 3). However, the coding rules also incorporated that the selected codes should relate affordances and/or constraints of GIS to K-12 education.

Pre-testing of the categorization matrix (step 4) was an integrated part of the analysis since data collection were performed simultaneously as the data analysis, where the categorization matrix was continuously tested as the data collection and analysis progressed. The coding rules were also important for which papers to include in the study (further described in '3.1 Data collection'). Similar to defining categories in the categorization matrix, previous research on affordances were used to specify anchor samples (step 5) of affordances and constraints for the analysis. The analysis (step 6) was then performed with a deductive-inductive approach. First, codes were identified, selected, and moved to the categorization matrix based on the coding rules, which in turn were based on the theoretical framework (deductive coding approach). Each code was placed under the category of affordances, constraints, or uncertain (for later categorization). Each new code added to the categorization matrix was also compared to and potentially clustered with prior codes in the categorization matrix based on similarities and differences. This was conducted inductively, and new codes could either support existing clusters (subcategories), form new ones, or re-arrange the existing. This was repeated until data saturation was decided, according to the description above.

The main analysis produced 33 clusters or subcategories, 12 of which were placed under affordances, 6 under constraints, and 15 uncertain. Uncertain clusters could for example be subcategories that were difficult to categorize because they included both affordances and constraints. To reduce the number of subcategories and include the uncertain codes and clusters, inductive abstraction (step 7) was used. Codes and clusters were compared and merged based on similarities and differences. Previous codes and clusters that were similar to each other were merged into new subcategories, while differences between the previous codes and clusters were used to make distinct new subcategories with minimal overlap. This produced 12 new subcategories replacing the previous 33, with 7 under affordances and 5 under constraints. The new subcategories are displayed in Figure 1 (presented in the next section).

As part of the clustering of new subcategories, the papers (from which the codes were retrieved) were revisited to select material to reference in the presentation of results and establish links between categories and the material. This was also important for deciding appropriate names for the new subcategories. Names for the subcategories were decided to summarize the content of codes and clusters. A challenge when deciding names for categories and subcategories in an analysis is that they may become vague for the reader. To minimize the potential effect of vagueness in subcategories' names, all subcategories are further described and exemplified when presented in '4. Analysis and results'. Lastly (step 9), the processes of data collection and analysis have been described in this section ('3 Method') and in section '4. Analysis and results' the findings of the study are presented according to the categories and subcategories produced from the analysis.

4. Analysis and results

The analysis of the included research papers in the literature review identified several possibilities and constraints for GIS in K-12 education. These are displayed in Figure 1, with percentages for support in the included papers, and presented in more detail in subheadings '4.1 Possibilities' and '4.2 Constraints'.

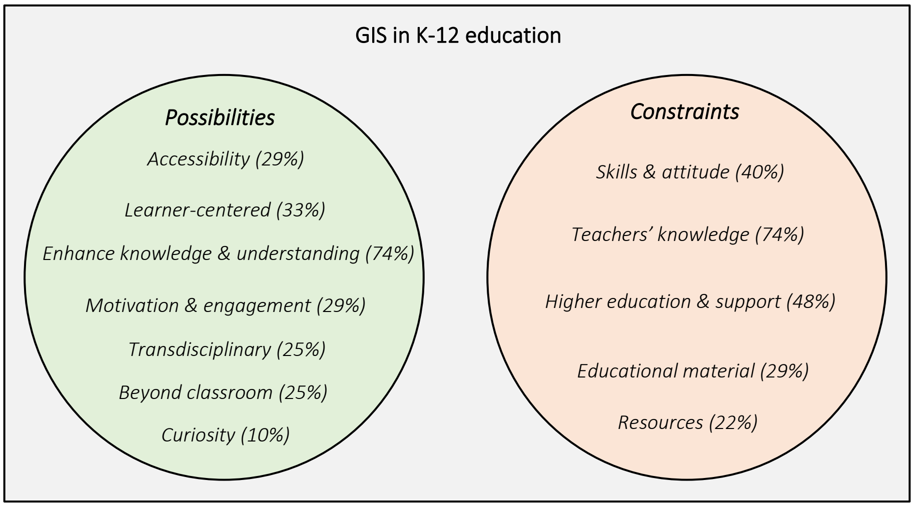

Figure 1. Possibilities and constraints of GIS in K-12 education.

4.1. Possibilities

The possibilities of GIS in K-12 education that were identified in the literature review have been clustered in the following categories: accessibility (supported by 29% of included papers), learner-centered (supported by 33% of included papers), enhance knowledge & understanding (supported by 74% of included papers), motivation & engagement (supported by 29% of included papers), transdisciplinary (supported by 25% of included papers), beyond classroom (supported by 25% of included papers), and curiosity (supported by 10% of included papers).

Concerning using GIS to enhance knowledge and understanding, research papers support that this can be achieved in many subjects (Ribeiro, Azevedo & Osório, 2017) such as social studies (Egiebor & Foster, 2019) and especially in geography (De Miguel González & De Lázaro Torres, 2020; Mzuza & Van Der Westhuizen, 2019; Zwartjes, 2018; Fleischmann & Van der Westhuizen, 2017). GIS technologies can for example promote geographical literacy, systems thinking, critical thinking, and spatial thinking among K-12 students (Buzo-Sánchez, Mínguez & De Lázaro-Torres, 2022; DeMers, Kerski & Sroka, 2021; Intzidou et al., 2021; Oda, Herman & Hasan, 2020; Gal, 2019; Millsaps & Harrington, 2017). Further, applying GIS technologies in classrooms provides teaching and learning methods to geography that are modern and gives teachers the opportunity to develop new learning activities that are innovative, active, fun, and effective (Ridha & Kamil, 2021; Wu et al., 2018).

GIS is also highlighted in research to promote teaching and learning activities that are learner-centered (Mzuza & Van der Westhuizen, 2020; Gal, 2019; Ribeiro, Azevedo & Osório, 2017; Walshe, 2017), active (Buzo-Sánchez, Mínguez & De Lázaro-Torres, 2022; Ridha & Kamil, 2021; Ribeiro, Azevedo & Osório, 2017), experimental (Buzo-Sánchez, Mínguez & De Lázaro-Torres, 2022), innovative (Ridha & Kamil, 2021), constructivist (Ribeiro, Azevedo & Osório, 2017), effective (Ridha & Kamil, 2021), inquiry-based (Mzuza & Van der Westhuizen, 2020), and fun (Ridha & Kamil, 2021) where the teacher can become more of a mentor (Gal, 2019). Research also highlights the opportunity of using GIS to move away from textbooks and instead activate students in the learning process through research and curiosity (Egiebor, E. E., & Foster, E. J. 2019).

Research highlights that an advantage with GIS and mobile learning (m-learning) is that they provide accessibility in, for example, that the teacher can bring technologies, that previously were only accessible for researchers, to the students and outside the classroom (Intzidou et al., 2021; Nilsson & Bladh, 2020; Hong, 2017). It is further highlighted that GIS material can often be customized for different content, classrooms, skill-levels, and collaborative work (De Miguel González & De Lázaro Torres, 2020; Hong, 2017; Millsaps & Harrington, 2017). Research also highlights that GIS and web technologies are among the most transformative, and exciting, changes to teaching and learning institutions of any level, giving educators the opportunity to integrate GIS with real-world data (DeMers, Kerski & Sroka, 2021). With the rise of m-learning, especially smartphones and tablets, accessibility should be one of the key opportunities for GIS in K-12 education. Still, research note that m-learning and GIS technology are rarely implemented in elementary education (Schulze, 2021; Gal, 2019).

Regarding using GIS to facilitate motivation and engagement, research state that teaching and learning can be enhanced by GIS in several subjects but that it can also motivate students to learn through new learning experiences and opportunities that are fun and of interest for students (Ridha & Kamil, 2021; Anunti, Vuopala & Rusanen, 2020; Hong & Melville, 2018; Mitchell, Roy, Fritch & Wood, 2018; Ribeiro, Azevedo & Osório, 2017). A common GIS environment that is reported to facilitate motivation and engagement among students is the web-based ArcGIS Online (Egiebor & Foster, 2019; Gal, 2019). Previous research further highlights that students' interest for and motivation in geography as a subject can be increased by applying digital geography (De Miguel González & De Lázaro Torres, 2020).

Research further highlights that GIS technologies by being a more active method for teaching and learning activities, compared to the traditional textbook, can spark curiosity among students (Egiebor & Foster, 2019). Students' curiosity can for example be triggered by the visualization aspect of GIS where information can be displayed in a novel way which allows students to ask questions about the representations in the visualization and view the subject content in a new way (Egiebor & Foster, 2019; Ribeiro, Azevedo & Osório, 2017). Further, GIS technologies often allow for interactivity with the content that is being displayed which together with being perceived as a new and innovative technology can spark curiosity among student (Intzidou et al., 2021; Egiebor & Foster, 2019).

Concerning using GIS for transdisciplinary work in education, research emphasis the possibilities of using GIS to promote learning and exploration that are interdisciplinary and not restricted by boundaries of single subjects (De Miguel González & De Lázaro Torres, 2020; Gal, 2019; Mitchell et al., 2018; Ribeiro, Azevedo & Osório, 2017). Further, research highlights that GIS can be used for collaborative work between students and teachers that enables group learning and knowledge for real world applications (DeMers, Kerski & Sroka, 2021; De Miguel González & De Lázaro Torres, 2020; Gal, 2019; Hong & Melville, 2018; Ribeiro, Azevedo & Osório, 2017).

Research also notes the relevance of GIS beyond the classroom, that it can prepare students for society and the challenges that it will hold (DeMers, Kerski & Sroka, 2021; De Miguel González & De Lázaro Torres, 2020; Egiebor & Foster, 2019; Hong & Melville, 2018; Ribeiro, Azevedo & Osório, 2017; Walshe, 2017). This is for example highlighted through the possibility that GIS can develop students critical thinking, support them in exploring new places realistically, and connect students' experiences to their own lives, which could prepare them for the global challenges of the future (Buzo-Sánchez, Mínguez & De Lázaro-Torres, 2022; Egiebor & Foster, 2019; Ribeiro, Azevedo & Osório, 2017).

4.2. Constraints

The constraints of GIS in K-12 education that were identified in the literature review have been clustered in the following categories: skills & attitude (supported by 40% of included papers), teachers' knowledge (supported by 74% of included papers), higher education & support (supported by 48% of included papers), educational material (supported by 29% of included papers), and resources (supported by 22% of included papers).

Research indicates that potential constraints for the application of GIS in K-12 education are related to teachers' limited knowledge in, and about, the technologies which in turn lead to a low rate of applications in classroom settings (DeMers, Kerski & Sroka, 2021; Intzidou et al., 2021; Schulze, 2021; Anunti, Vuopala & Rusanen, 2020; Nilsson & Bladh, 2020; Oda, Herman & Hasan, 2020; Collins & Mitchell, 2019; Gal, 2019; Mzuza & Van Der Westhuizen, 2019; Hong & Melville, 2018; Mitchell et al., 2018; Hong, 2017; Ribeiro, Azevedo, & Osório, 2017; Walshe, 2017). It is further emphasized that time is a constraint closely related to this, teachers need time to be familiar with technologies, to utilize them, to plan lessons for their students with GIS, and the students, in their turn, needs time to learn the tools before they can be used for teaching and learning (Collins & Mitchell, 2019; Egiebor & Foster, 2019; Gal, 2019; Mitchell et al., 2018; Tarisayi, 2018; Fleischmann & Van der Westhuizen, 2017).

Research state that GIS is not common in teacher education and professional development and when it is present it tend to be superficial, a stronger involvement from schools and school leadership is suggested for teachers to make the commitment to learn GIS technologies (Ridha & Kamil, 2021; Mzuza & Van der Westhuizen, 2020; Nilsson & Bladh, 2020; Oda, Herman & Hasan, 2020; Gal, 2019; Hong & Melville, 2018; Mitchell et al., 2018; Millsaps & Harrington, 2017; Ribeiro, Azevedo, & Osório, 2017; Walshe, 2017). Research also highlight that GIS teaching tend to have a textbook-style approach which limits the possibilities of the technologies for educational purposes (Fleischmann & Van der Westhuizen, 2017), this could be a consequence of teachers' lack of time, knowledge, and education in GIS.

Research further highlights that limited skills and negative attitudes among both students and teachers are barriers that needs to be addressed in the future regarding GIS in educational setting (Buzo-Sánchez, Mínguez & De Lázaro-Torres, 2022; Nilsson & Bladh, 2022; Ridha & Kamil, 2021; Mitchell et al., 2018; Fleischmann & Van der Westhuizen, 2017; Hong, 2017; Ribeiro, Azevedo & Osório, 2017). It is also suggested that reported limitations in GIS technologies for educational purposes could instead be concealed desires to not engage with the technology (Walshe, 2017). Teachers could for example lack sufficient expertise or knowledge in relevant technologies or be unwilling to change their teaching of subject content (Mzuza & Van Der Westhuizen, 2019). However, since GIS technologies have been developed that are web-based and more user-friendly, the barriers for integrating the technologies in K-12 education are significantly lower today (Buzo-Sánchez, Mínguez & De Lázaro-Torres, 2022; Oda, Herman, & Hasan, 2020). Some of these user-friendly GIS technologies are StoryMapJS, ArcGIS StoryMaps and Tour Builder (Vojteková et al., 2022).

Concerning educational material on GIS, research state that there is a lack of GIS materials that are curriculum-oriented, centered on the user or reusable learning objects for lesson use (McKenzie, Cook & Roulston, 2022; Fleischmann & Van der Westhuizen, 2017; Hong, 2017). This lack has been highlighted in research as a major barrier for K-12 GIS implementation (Hong & Melville, 2018). A challenge that teachers face is that many GIS technologies were not originally designed to be tools for teaching and must therefore be converted for teaching practices (Oda, Herman & Hasan, 2020). Previous research notes that many lesson materials on GIS, created by teachers, have very limited interactivity for students and are instead built on static maps (Mitchell et al., 2018). Further, the lack of curriculum-oriented GIS materials will probably remain because of shortage in the workforce of personnel with skills in both education and geospatial science (Fleischmann & Van der Westhuizen, 2017).

Research also reports on lack of resources and facilities as constraints for GIS implementation in K-12 education (Ridha & Kamil, 2021; Mzuza & Van Der Westhuizen, 2019). Prior research state that inadequate funding is a challenge for implementing GIS (Mzuza & Van Der Westhuizen, 2019; Tarisayi, 2018). It has also been highlighted that lack or limitations of resources such as teachers' time, accessibility of computers or the internet, GIS software, and data are potential constraints for the use of GIS in education (Ridha & Kamil, 2021; Collins & Mitchell, 2019; Gal, 2019).

Regarding support for GIS in K-12 education, research states that effective approaches for implementing GIS in education are teacher training and professional development (Vojteková et al., 2022; DeMers, Kerski & Sroka, 2021; Oda, Herman & Hasan, 2020). However, research also notes that higher education in GIS for teacher training and professional development and the conditions for teachers to participate in such training are lacking (Buzo-Sánchez, Mínguez & De Lázaro-Torres, 2022; McKenzie, Cook & Roulston, 2022; Mzuza & Van der Westhuizen, 2020; Collins &

Mitchell, 2019; Mitchell et al., 2018; Millsaps & Harrington, 2017). Research highlights that training for teachers in GIS should focus on building community and networks, offer coaching and feedback on pedagogy and diverse content and software, and be well-structured and of appropriate time to support teachers in making the change of their teaching and learning activities (McKenzie, Cook & Roulston, 2022; Ridha & Kamil, 2021; Mzuza & Van Der Westhuizen, 2019; Mitchell et al., 2018).

5. Discussion

The results of the study have highlighted both opportunities and constraints of GIS for K-12 education, which are further discussed in this section. Regarding the identified possibilities, several of these are important for classroom practices. It is, for example, important to note that the use of GIS can enhance subject knowledge and understanding, that teachers can draw upon GIS for teaching and learning that are learner-centered, active, experimental, constructivist, and inquiry-based, and that GIS can motivate students through new, fun, and interesting learning experiences and opportunities. Regarding the identified constraints, several of these are important to consider for the implementation and use of GIS in K-12 education. For example, it is important to note that a barrier for GIS in K-12 setting is lack of education-oriented GIS materials and technologies, resources, and facilities that GIS require for successful implementation in classroom practices.

The most interesting possibilities and constraints, especially for future research, lies in the themes of Accessibility, Transdisciplinary, Beyond classroom, Teachers' knowledge, Skills and attitudes, and Higher education and support. Transdisciplinary and beyond classroom are important to address since these highlight learning and skills that are crucial for students to connect learning to their own lives and preparing them for future challenges, such as collaboration, group learning, critical thinking, and exploration, (Buzo-Sánchez, Mínguez & De Lázaro-Torres, 2022; DeMers, Kerski & Sroka, 2021; De Miguel González & De Lázaro Torres, 2020; Egiebor & Foster, 2019; Gal, 2019; Hong & Melville, 2018; Ribeiro, Azevedo & Osório, 2017).

The reported lack in teachers' knowledge and constraints for skills and attitudes (DeMers, Kerski & Sroka, 2021; Intzidou et al., 2021; Schulze, 2021; Anunti, Vuopala & Rusanen, 2020; Nilsson & Bladh, 2020; Oda, Herman & Hasan, 2020; Collins & Mitchell, 2019; Gal, 2019; Mzuza & Van Der Westhuizen, 2019; Hong & Melville, 2018; Mitchell et al., 2018; Hong, 2017; Ribeiro, Azevedo, & Osório, 2017; Walshe, 2017) are important to consider in relation to higher education and support, since professional development could play an important role in enhancing knowledge and skills and changing attitudes. However, there is much work to be done in that field since prior research has highlighted limited and superficial use of GIS in teacher education and professional development, and a need for more involvement from school leadership to emphasize its importance (Ridha & Kamil, 2021; Mzuza & Van der Westhuizen, 2020; Nilsson & Bladh, 2020; Oda, Herman & Hasan, 2020; Gal, 2019; Hong & Melville, 2018; Mitchell et al., 2018; Millsaps & Harrington, 2017; Ribeiro, Azevedo, & Osório, 2017; Walshe, 2017).

Research and development in accessibility of GIS technology could also be an important approach to address teachers' lack in knowledge, skills, and attitudes which have been highlighted in previous research. Higher education is of course important for changing attitudes and for developing knowledge and skills, but teachers (and students) also need tools to use that are accessible and engaging. Prior research has, for example, highlighted that GIS technology can provide accessibility through mobile learning, customized learning content and integration with real-world data (DeMers, Kerski & Sroka, 2021; Intzidou et al., 2021; De Miguel González & De Lázaro Torres, 2020; Nilsson & Bladh, 2020; Hong, 2017; Millsaps & Harrington, 2017). However, as noted in previous research, mobile learning and GIS technologies are not widely implemented in elementary education (Schulze, 2021; Gal, 2019), which makes this an important topic for future research.

To conclude this section, it should be noted that this study has limitations, the most obvious being a limited number of included research papers (n=27) and the generalizability of the results. However, the goal of a scoping review, compared to a systematic review, is to provide an overview rather than an answer to a specific question (Munn et al., 2018) which can be especially important if the body of knowledge is developmental, creative, and diverse (Davis, Drey & Gould, 2009). Therefore, this study should not be considered a summary of GIS in K-12 education or as a definite answer to how GIS should be applied in K-12 classroom. The study should rather be considered an overview of some important and interesting possibilities and constraints for GIS in the K-12 setting that can be drawn upon by stakeholders and further explored in future research.

6. Conclusion

The aim of this study was to identify and discuss possibilities and constraints in contemporary literature with GIS for K-12 education. Through this study several possibilities and constraints for GIS in K-12 education (summarized in Figure 1) has been identified in previous research and discussed. Some of the identified possibilities, highlighted in this study, are to be expected. For example, that GIS technologies can enhance knowledge and understanding in school subjects and make teaching and learning more learner-centered and motivating for the students. Similarly, some of the identified constraints are to be expected, such as that there is insufficient access to education-oriented material and technologies relating to GIS, and that teachers and schools need more resources for successful GIS implementation in the form of time, funding, computers, software, and data. Although these are expected they are still important to consider in the continuing implementation of GIS in K-12 education and they could, for example, be further investigated through data analytics (Mitchell et al., 2018), large scale studies (Anunti, Vuopala & Rusanen, 2020; De Miguel González & De Lázaro Torres, 2020; Egiebor & Foster, 2019; Hong, 2017; Millsaps & Harrington, 2017), longitudinal studies (De Miguel González & De Lázaro Torres, 2020; Ribeiro, Azevedo & Osório, 2017), and comparative studies (Egiebor & Foster, 2019), which have been suggested by the research papers included in this study.

However, based in the findings of this review, the author believes that the following themes of possibilities and constraints with GIS for K-12 education are especially interesting for further investigation:

- Accessibility
- Skills and attitudes
- Higher education and support
- Teachers' knowledge
- Transdisciplinary
- Beyond classroom

DeMers, Kerski and Sroka (2021) state that a pressing research need is to investigate how GIS can "help fuel meaningful use of technology, integrate it with real-world investigations and data". With the background of previous research highlighting the limited application of GIS technologies in K-12 classrooms, this could provide a fruitful topic for future research, investigating, for example, how GIS technologies can be made more accessible for K-12 education. This could be studied through research approaches such as design science to develop new GIS artefacts, or action research to investigate and change educational practices. This would also provide an interesting opportunity to study different GIS technologies effect on users' skills and attitudes.

Another potentially fruitful topic for future research could be to address how higher education, for example through professional development courses, could support development of teachers' knowledge in GIS. Both support from higher education and teachers' knowledge have been highlighted in this study as constraints for GIS in K-12 education. However, this is based on how it has been reported in previous research and does not necessarily determine their roles for future implementation of GIS in K-12 education. Previous research has highlighted teacher education and professional development as limited in regard to providing teachers support in the use of GIS technologies in K-12 classrooms. This constraint could be turned into a possibility for addressing teachers' lack in knowledge, for example, through design-based research (DBR) studies on developing and evaluating meaningful and engaging teacher education courses or professional development courses in GIS.

Concerning the themes Transdisciplinary and Beyond Classroom, these could be considered educational goals of implementing GIS in K-12 education. Reaching educational goals are fundamental for teachers and other stakeholders when implementing new technologies in classroom practices. However, reaching these goals can often be hindered by constraints, related to both the technology and the context. Based on the findings of this study and the discussion above, the author suggests that the possibilities identified in relation to the new technology should be drawn upon to overcome the constraints and to reach the educational goals. This could be summarized as a conceptual model for reaching educational goals with GIS technology in K-12 education (Figure 2).

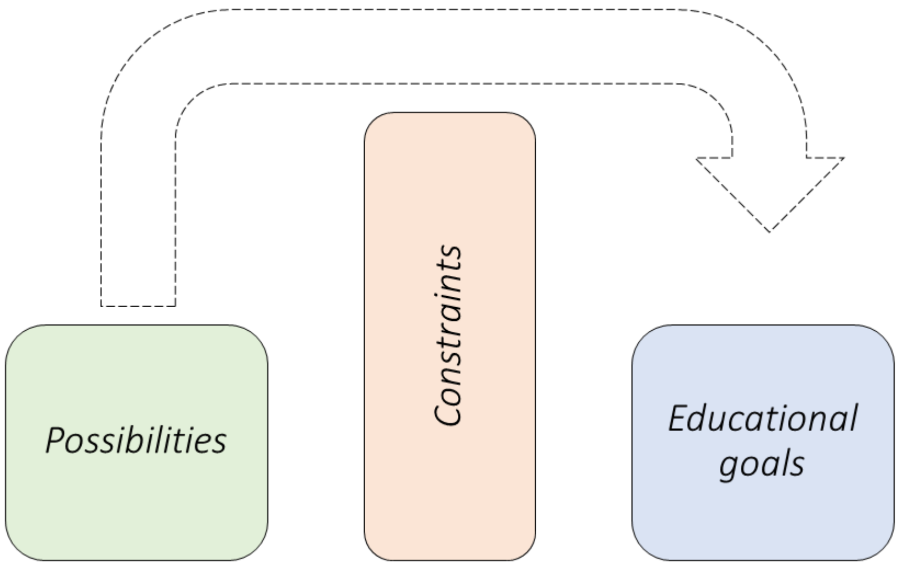

Figure 2. Conceptual model for reaching educational goals.

For classroom practices, an example could be that more accessible GIS technology will support teachers and students in overcoming the constraints related to limited skills and negative attitudes. More accessible technologies and positive attitudes towards using them in education will in turn impact more teachers seeing the benefit of applying them in classroom practices, which enables reaching the educational goal of transdisciplinary collaborations and learning. Furthermore, meaningful and engaging higher education and professional development can support teachers in overcoming the constraint of lacking sufficient knowledge in GIS for applying it in classroom practice. With support in developing knowledge about GIS and how to apply it in classroom practice, teachers will also be able to make the connections between GIS in education and GIS in the real world clear and meaningful for their students, which facilitates reaching the educational goal of beyond classroom learning.

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