DIGITALIZATION AND GEOGRAPHY EDUCATION
A CURRICULUM ANALYSIS

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Summary: Digitalization presents many opportunities but also challenges for society. This also entails new tasks for the field of education. This article discusses how geography teaching can contribute to these opportunities and challenges from a subject- and education-specific perspective. To this end, we analyse aspects of subject-specific digitalization and terms associated with digitalization in curricular and framework requirements (n = 57 documents) for different types of schools in every German federal state. We use this to deduce the extent to which the state of subject-specific digitalization is in line with the society's requirements. In addition, we derive insights into why digitalization is critical to geography education.

Zusammenfassung: Mit der Digitalisierung sind viele Möglichkeiten, aber auch Herausforderungen für die Gesellschaft verbunden, die auch die Bildung vor neue Aufgaben stellt. Welchen Beitrag der Geographieunterricht dazu leisten kann, soll in diesem Beitrag aus einer fachdidaktischen Perspektive diskutieren werden. Dafür werden Aspekte einer fachspezifischen Digitalisierung und mit Digitalisierung verbundene Begriffe in curricularen Vorgaben (n = 57 Dokumente) der verschiedenen Schulformen der Bundesländer Deutschlands inhaltsanalytisch analysiert. Aus der Analyse soll abgeleitet werden, inwiefern der Stand der fachspezifischen Digitalisierung mit den Anforderungen der Gesellschaft einhergeht. Zudem sollen Einsichten zum Beitrag und zum Bedarf von Digitalisierung im Geographieunterricht abgeleitet werden.

Keywords: Digitalization, digital media, curriculum analysis, Germany, school geography

1 Introduction

Society and professional contexts require the use of digitalization in a variety of settings. Society's digitalization and the networking of all areas of life associated with it are central and exemplary developments in this regard. The permanent availability of data and phenomena on the Internet, such as social media, as well as developments, such as the Internet of Things (IoT), Industry 4.0, robotics, cryptocurrencies, big data and artificial intelligence, are just a few examples that will redefine many areas of life in the near future. Digitalization has long played a role in the private context: voice assistants play music, read the news aloud or adjust the lighting for us. The presence of smart technology, such as smart homes, is increasingly being observed in our lives, and innovations, such as cryptocurrencies and smart contracts, will also cause far-reaching social upheavals (WBGU 2019).

Professional requirements are also changing in parallel. Today, every profession requires digital skills: Carpenters now work with computer-assisted saws, e-commerce is part of the commercial sector and agriculture adopted autonomous machines long

ago (BMBF 2017). Certain professions are developing very specialized requirements, especially in dealing with burgeoning amounts of data, but also with regard to disruptive technologies. Concepts and terms such as big data, data competences and data literacy have emerged (Ludwig & Thiemann 2020). In a geographic context, climate modelling involves knowing what the data are about and understanding them from the moment of their creation and using them effectively (Ludwig & Thiemann 2020). The (global) networking of data, information and knowledge is growing increasingly relevant in the 21st century, as are the sharing and exchanging of them. Thus, it is unsurprising that "The Sexiest Job of the 21st Century" (Davenport & Patil 2012: 1) is closely linked to data literacy. Furthermore, VET 4.0 and knowledge regarding the Fourth Industrial Revolution, i.e. an understanding of the digital networking of machines, components and people, are increasingly significant (BMBF 2017).

While this digital transition presents many opportunities, there are also challenges, some of which remain unclear today. This was already the case before the COVID-19 crisis, which fundamentally intensified it. Future generations of students must be

prepared for these challenges in an appropriate, professional manner. This raises the question of what schools can and must do - and what geography lessons can contribute.

Alongside global change and sustainable development, digitalization is another cross-cutting and central challenge of our time. Greater dynamism means it will remain the task of tomorrow as well. Due to its complexity, digitalization must be recognized as a challenge for society as a whole, especially in terms of education. As a part of the latter, it should enable students to develop options for action in a rapidly changing world. One major responsibility of schools, in this regard, is to teach students digital skills. They must also impart subject-specific and interdisciplinary skills that enable students to participate in society and to make responsible decisions. Thus, students need instruction in both subject-specific knowledge and methods as well as interdisciplinary working techniques, which is also reflected in the demands of cross-cutting issues, for example, in the sense of digital education (KMK 2016) or digitalization. This mandate for professionalization includes teaching digital skills in order to gain the greatest possible self-directed and goal-oriented access to the world and its development while still in school. Such digital skills can be subject-related, such as geomedia. Since demands in the working environment are also changing rapidly, schools must prepare for a changing (professional) world, which is increasingly being shaped by digitalization. At the same time, students must be prepared for lifelong learning (KMK 2016). These current social objectives are also shifting the focus of educational processes. Ultimately, digitalization requirements are a far-reaching and central task of education. Yet, digitalization in the education sector is lagging behind the societal objectives, which can be related to both pedagogical areas and institutional framework conditions (EICKELMANN et al. 2019a). For example, the 2018 International Computer and Information Literacy Study (ICILS) showed that there is a need for training in IT equipment, such as computers and mobile devices, and that students need greater access to WLAN or digital tools (EICKELMANN et al. 2019b).

Geography is influenced by digital technology, and this connection appeared shortly after the development of the first computer (ASH et al. 2018). Digital technology enabled, for example, quantitative modelling, such as the creation of climate or landscape models, as well as geographic information systems (GIS), remote sensing and digital mapping (e.g. TOBLER 1959, HAGGETT 1966, ASH et al. 2018).

When confronting the major challenges of global change, such as climate change, globalization and migration, as well as sustainable social transformation, digitalization is still to be understood as a fundamental development for geography as a discipline (HGD 2020). Digital information technology and the handling of digital data and information, as well as computer-based knowledge and algorithms, increasingly determine private and social areas along with professional knowledge processes (HGD 2020), and this is thus a task for education and geography as a school subject.

The question arises as to the extent to which geography teaching meets these requirements and what it can contribute. Curricular requirements are normative guidelines for teaching; gaps in these requirements impact education significantly. Here, the guiding principle is the extent to which there is a discrepancy between what is written in curricula and the social and professional requirements.

This article aims to analyse digitalization in subject-specific curricular guidelines and frameworks. It is not primarily about working out potentials, but instead about analysing current curricular requirements. We do not claim completeness, especially since websites and documents themselves are subject to constant change. Rather, the aim is to point out fundamental structural and developmental lines. The guiding question is the following:

Which aspects of subject-specific digitalization are included in geographical school curricula and frameworks? Furthermore, we analyse the guiding question in a differentiated manner based on the following research questions:

- What content is used in the context of subject-specific digitalization?
- Which working methods or skills are named in the context of subject-specific digitalization?
- Which subject learning approaches and concepts are applied?

In order to answer the research questions, we conduct a content analysis of the terms associated with digitalization. To this end, we first examine the literature to derive terms central to the broad field of digitalization. We summarize them as a matrix, which we use to analyse digitalization within curricular and framework requirements. From the analysis, we derive the extent to which the state of subject-specific digitalization is in line with society's requirements. Finally, we derive insights into the contribution of and the need for digitalization in geography teaching.

2 Theoretical basis

2.1 Digitalization and the field of geography education

Digitalization is significantly influenced by technology, social developments and transformations and determines professional knowledge processes as well as educational processes (e.g. ALLERT & RICHTER 2017, HGD 2020, STALDER 2021). STALDER (2021: 3) initially compares the term digitalization with the process of "transforming an analogue medium into a digital one." For STALDER (2021: 4), it is a process within which the foundations are established for the development of new forms of action, but also new forms of perception and new patterns of thought. He distinguishes between digitality and digitalization; digitalization refers to the technical phenomenon of converting analogue information into digital information, while digitality refers to the lifeworld significance of digitalization, the phenomenon of virtuality (2021: 4). He compares digitalization to building an infrastructure that includes both the technology and the ability and learning processes to use the technology (2021: 4). In this article, we will focus on these basic requirements.

Students must receive an education that allows them to live independently and responsibly in a digital world (KMK 2016). The Standing Conference of the Ministers of Education and Cultural Affairs of the states in the Federal Republic of Germany classify digital skills into six competence areas (KMK 2016). These areas describe general and cross-curricular skills in a digital world: digital literacy, media and methodological competence, data literacy (e.g. PRYOR & DONELLY 2009, KOLTAY 2014) and information literacy (MENTHE & HÜFNER 2019).

The ICILS (EICKELMAN et al. 2019a) shows that less than one quarter of eighth grade students achieved the first two of the five levels of competency; only 1.9% achieved the highest level of competency, level V (EICKELMANN et al. 2019a). As a result, researchers conclude that a significant proportion of secondary school students lack the computer-related skills needed to participate in society successfully (FRAILLON et al. 2019). In the classroom, 60.2% of teachers in Germany report using digital media at least weekly (EICKELMAN 2019a). The students' perspective reveals that teachers (of all subjects) in Germany use digital media with below-average frequency compared to other countries.

Promoting digital skills is a cross-curricular issue. To frame the relationship between geography and the digital, ASH et al., for example, propose a threefold categorization: "geographies produced *through*, produced *by*, and *of* the digital" (2018: 27).

The German Association of Geography Education (Hochschulverband für Geographiedidaktik, HGD) also describes digitalization with regard to a broad subject-specific understanding. They propose ten perspectives of a "geography education under the conditions of digitalization" (HGD 2020: 5). The perspectives include the following: (1) an awareness of the fact that digitalization conveys guidelines for sustainable digitalization, (2) dealing with digital geoinformation as a cultural technique, (3) skills and knowledge in the context of geomedia, (4) participation in social changes by means of digital geomedia, (5) the effect of the geoinformation industry and other non-commercial platforms on life and privacy, (6) changes in the professional world due to digitalization, (7) understanding digitally shaped lifeworlds in their spatiality in a multitheoretical way, (8) the importance of artificial intelligence for the construction of identity and social realities through geomedia, (9) using open educational resources (OER) to design collaborative digital geomedial learning environments and (10) encouraging teachers to engage with the possibilities of digitalization regarding the subject and to understand this professionalization as appropriate geographical transmission in the age of digitalization (HGD 2020).

OTTO (2018) clarifies the relationship under a converging perspective by stating that digitalization for geography education can be understood in two ways and that digital skills and technologies are necessary for both:
1) Learning with digital media and tools
2) Designing digital teaching and learning concepts.

2.2 Digitalization classifications and terms in geography education

Numerous classification systems have been proposed for digital skills and media in the field of geography education. From these theoretical classifications, the main categories for the analysis grid are later derived (see 3.2).

Hardware and technology are a prerequisite for digitalization in today's society. Technical devices are a part of everyday life in the private and professional world. In geography education, established digital devices are computers, digital blackboards (e.g. dis-

plays, smartboards, interactive boards) and mobile devices. Mobile devices, such as tablets or mobile phones, are used in the corresponding learning settings, which are extended through the use of GPS (devices) navigation devices for mobile learning, for example (e.g. DITTER et al. 2012, KRAUTTER 2015).

The potential of these digital devices is unfolded through software. Geographical education makes use of various software, digital tools and digital media. Here, KRAUTTER (2015) differentiates between interdisciplinary software and geographical software. The following terms are relevant in digital teaching: simulations and animations, mobile learning, ePortfolios, virtual reality (VR), geographic information systems (GIS), WebGIS, digital maps (work), digital globes, remote sensing and satellite images (KRAUTTER 2015, DITTER et al. 2012, SIEGMUND & MICHEL 2013). For the field of GIS, diverse and elaborate concepts are available, especially for secondary education (e.g. HÖHNLE et al. 2014, KERSKI 2003, 2021) and for teacher training (e.g. SCHULZE et al. 2013). The impact of digital tools on learning has been empirically tested. CARRERA et al. (2018) investigate the motivation and usability of augmented reality (AR) as a tool for relief modelling with tablets among students. AR refers to a reality, in which virtual components augment physical-tangible elements (KOCH 2017, JEKKERBLUEHILL & OHL 2018). The results of the study by CARRERA et al. (2018) reveal this technology to be a motivational tool for 3D visualization. Yet, these digital methods and visualizations have seldom been reappraised and transferred to school geography lessons, if at all. One notable exception here is the AR sandbox used in geography lessons (JEKKERBLUEHILL & OHL 2018).

STEINBACH (2019) differentiates types and fields of the application of digital learning products, for example, web-based learning products, digital mapping and field trip guides. Up until now, the field of media pedagogy and literacy has made the majority of theoretical, practical or empirical contributions on the use, opportunities and challenges of social media in educational contexts (e.g. ALLERT & RICHTER 2017, FOX & BIRD 2017, MOSER 2019, WAMPFLER 2013). In geography education, on the other hand, this research either does not exist or is only present with regard to selective approaches.

Apps and (software) programs are also classified as digital learning products (e.g. STEINBACH 2019). Recommendations have been made for using apps with mobile devices for geography lessons (PETER et al. 2020) or for teaching concepts with learning apps (KOTZTIN 2018). EISEN & LILLARD (2019) show positive effects of using apps in elementary school geography lessons when the learning process is integrated into social contexts. Science, e.g. citizen science projects, and spatial orientation, e.g. navigation apps, are two contexts in which apps are also used. Citizen science projects contribute to scientific knowledge, especially in the field of data collection in global change research (DICKINSON & BONNEY 2012).

In addition to digital media and programs, digitalization is also increasingly focusing on methods. For example, field trips and extracurricular work are established methods used to teach geography that could benefit from the new opportunities provided by digitalization. Researchers suggest entirely virtual (e.g. WIKTORIN 2018) or digitally enriched field trips (GRYL 2020) from a subject-didactic perspective at the research level (e.g. FRIESS et al. 2016, STAINFIELD et al. 2000) and in teaching practice (e.g. FRAEDRICH 2018).

Last but not least, geoinformation systems must be considered from the perspective of the subject. An educational concept for university teaching based on GIS skills (SCHULZE et al. 2013) suggests a possible transfer to teaching contexts.

Forms of digital communication and information platforms are not without overlap with software and digital tools. Yet, they have a special significance in the students' lifeworld and educational contexts. Examples are social media (e.g. Facebook, Instagram, Twitter), Web 2.0 (e.g. Wikipedia, YouTube), e-mail, podcasts, social networks, chats and Wiki/WikiQuest (e.g. KRAUTTER 2015, DITTER et al. 2012).

Students need to acquire the skills to use the various digital tools, methods and digital technologies appropriately (STALDER 2021). This requires appropriate digital learning concepts. Therefore, learning approaches and concepts have been discussed regarding digitalization in general, and specifically within the context of geographical education. They include e-learning formats (BRENDEL 2018, KRAUTTER 2015) and blended learning (e.g. KOLLER & SITTE 2005), as well as digital or partially digital teaching formats in the sense of online, virtual, flipped and inverted classrooms. Research has also investigated, for example, mobile learning concepts. "The established concept stands for learning and teaching with mobile devices, which has reached all educational contexts and, due to the constant technological developments, continuously challenges didactic innovations in particular" (DE WITT & GLOERFELD 2018: 1). The applications and technological foundations of mobile learning are diverse and range from practical school con-

cepts (Feulner & Ohl 2014) to knowledge about data protection and privacy (Steinhauer 2018). In a pre/post study, Chang et al. (2018) show that sixth grade students display greater learning success through mobile learning than traditional learning groups.

Current discussions also highlight skills in dealing with digital data (data literacy). This includes the ability to collect, manage, evaluate and apply data from a critical and reflective perspective (Ridsdale et al. 2015). So far, suggestions have only addressed the level of the subject sciences, e.g. climate modelling (Ludwig & Thiemann 2020), and have not been spelled out for the level of subject didactics.

Even though many insights and concepts have already been developed and discussed in the context of digitalization in recent years, it still poses a multitude of challenges and tasks from a subject-specific perspective. The following methodological approach will first help to clarify this.

3   Methods

3.1 Data collection

To address the research question, 57 curricula were analysed, including the frameworks, curricula and educational standards of every German federal state as well as the educational standards of the German Geography Society (DGfG) (DGfG 2020). The selection of the curricula was based on the following criteria: (1) all federal states should be covered. Furthermore (2), both primary education and secondary education were included within each federal state. In primary education, the subject of geography is not taught independently, but within a subject group called Sachunterricht. In secondary education, (3) different educational paths were considered. Within the secondary level, different subjects exist that include geographic education as either the subject geography, as an independent subject or as a compound subject of social studies or world studies. In subjects composed of several areas, such as social studies (consisting of, for example, history, geography, politics/economics), we only analysed the geography section. At least one of these curricula was integrated per state. For the Gymnasium educational pathway, the curricula (incl. upper secondary school) were also integrated. The analysis also included current curricula and framework documents (available as of January 2021). A detailed list of documents can be found in Appendix I.

3.2 Data analysis

Based on the existing literature on subject-specific digitalization in the field of geography/geomedia and the theoretical background (see 2.2), we developed and compiled an analysis grid, which consists of a system of categories. This was created using qualitative content analysis (Mayring 2015). The categories were determined through a process called structuring/deductive category application (Mayring 2015). The basis here is a system of categories developed from theory, which is applied to the material – the curricula. The structuring and system with regard to the main categories are theoretically justified.

Classifications and terms related to digital skills, technologies and geomedia in the field of geography education (e.g. Brendel 2018, Ditter et al. 2012, Krautter 2015, Otto 2018, Siegmund & Michel 2013) (see 2.2) were used to create the main categories and subcategories (see Tab. 1). According to these classifications and terms, five main categories (1. general digitalization terms, 2. hardware, 3. software/digital tools, 4. learning approaches and concepts and 5. communication and information platforms) and several corresponding subcategories were formed (Tab. 1). The subcategories were supplemented with terms from the digital-based, subject-specific education discussion (e.g. Ditter et al. 2012, Gryl 2020, Kerski 2021, Krautter 2015, Schulze et al. 2013, Steinbach 2019). To ensure reliability and validity, the categories and subcategories were derived transparently. The analysis of the German-language curricula was conducted in German.

In a further analysis, qualitative aspects were examined. This qualitative content analysis evaluated exemplary terms that were frequently mentioned in the qualitative analysis: *mobile devices and apps*. Due to the large number of terms and the associated complexity, a choice was made. According to the research questions, qualitative analyses were conducted based on the content and working methods used in the context of subject-specific digitalization. The focus was therefore on two criteria: (1) geographical content and (2) geographical working methods and competences/skills. To ensure the reliability of the evaluation, the qualitatively analysed terms (mobile devices and apps) were independent coded by the two authors. The intercoder reliability was 93.10%.

Due to the low frequency of references to the learning approaches and concepts category (cf. research question 3), it was not considered from a content-analytical perspective. The lack of learning ap-

Tab. 1: Digitalization categories and analysis grid

Main categories	Terms (subcategories)
General digitalization terms	Digital
	Mobile
	Online
Hardware	Computers
	GPS
	Mobile phones/Smartphones
	Mobile devices
	Tablets
Software/digital tools and digital media and methods	Apps
	Augmented reality (AR)
	Browsers
	Digital maps
	Digital games
	ePortfolios
	Remote sensing/Satellite imagery
	Geocaching (App)
	Geographic information systems/Geoinformation systems/GIS (skills)
	Presentation software
	Simulations and animations
	Spreadsheets
	Word processing
	Virtual reality (VR)
	Virtual field trips
Learning approaches and concepts	Blended learning
	Digital competences
	Digital learning
	Digital literacy
	E-learning
	Mobile learning
	Online classrooms
	Virtual classrooms
Communication and information platforms	Chats
	E-mail
	Podcasts
	Social media
	Social networks
	Web 2.0
	Wiki/WikiQuest

proaches and concepts (see Fig. 1) will be discussed later with a focus on the question of how to address the integration of learning concepts in curricula.

4 Results

We present the results in a quantitative overview analysis based on the categories (Tab. 1) followed by a content analysis of the subcategories and individual terms.

4.1 Overview of digitalization terms in geographic education

In a first step, the 57 curricula were analysed with regard to the 5 main categories (see Fig. 1).

The largest number of mentions is related to the general terms category (n = 537), followed by the software/digital tools and digital media and methods category (n = 275). Hardware is identified 111 times. The communication and information platforms (n = 21) and learning approaches and concepts (n = 4) categories are mentioned by far the least.

Further analysis explored the subcategory of terms that exist in the curricula. In total, 948 terms related to digitalization were found in 57 curricula. Of these, the term 'digital' occurs most frequently (n = 480), followed by 'remote sensing/satellite images' (n = 94) and 'GIS/geographical information systems/geoinformation systems' (n = 85). These

geography-specific work methods are emphasized in many curricula. Table 2 provides a complete overview of the frequencies of use of each term (≥ 3 mentions).

In a further step, an analysis was performed according to the different types of schools. A differentiation was made between primary, lower secondary and upper secondary schools. In principle, it was found that in most cases, content and working methods are present in the curricula of all school types. Nevertheless, there are also some exceptions. For example, some geomedia or geographical methods are not present in primary school curricula. These include, for example, digital maps or GIS. In other cases, a significant increase is observed between the primary and upper secondary school levels. This is the case with remote sensing.

4.2 Content analysis of geographical content and working methods

The content analysis evaluates exemplary terms that were frequently mentioned in the quantitative analysis: *mobile devices and apps.*

4.2.1 Analysis of the hardware category – *Mobile devices*

From the hardware category, the term 'mobile devices' (incl. mobile phones, smartphones, tablets) was analysed in terms of content because these tools
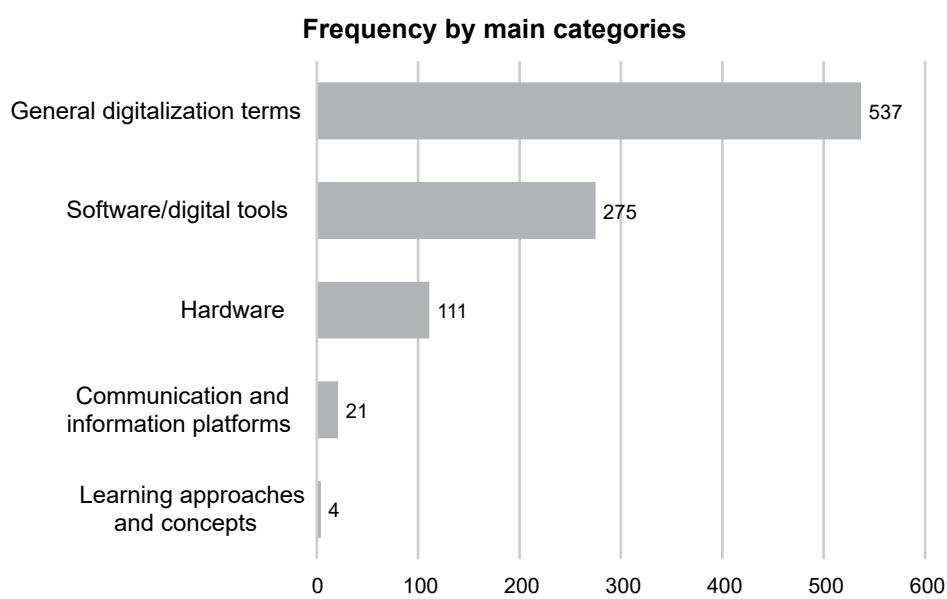

Fig. 1: Frequency by main categories

Tab. 2: Terms within the context of digitalization in nationwide curricula and frameworks

	Primary school	Lower secondary school	Upper secondary school	TOTAL
General digitalization terms	**200**	**225**	**112**	**537**
Digital	186	191	103	480
Mobile	3	3	1	7
Online	11	31	8	50
Hardware	**46**	**47**	**18**	**111**
Computer	27	14	9	50
GPS	6	23	6	35
Mobile devices (Mobile phone/Smartphone/ Tablet)	13	10	3	26
Software/digital tools and digital media and methods	**23**	**162**	**90**	**275**
App	3	2	1	6
Augmented reality (AR)	1			1
Browser	3	1	1	5
Digital games	1			1
Digital maps		12	5	17
ePortfolio				
Geographic information systems/ Geoinformation systems/GIS (skills)		55	30	85
Presentation software				
Remote sensing/Satellite imagery	6	50	38	94
Simulation and animation		17	9	26
Spreadsheets	2	6		8
Virtual reality (VR)				
Word processing	3	4		7
Geocaching	1	4	2	7
Virtual field trip/Virtual Spaces	3	11	4	18
Learning approaches and concepts	**2**		**2**	**4**
Blended learning				
Digital competences	2		2	4
Digital learning				
Digital literacy				
E-learning				
Mobile learning				
Online classroom				
Virtual classroom				
Communication and information platforms	**8**	**12**	**1**	**21**
Chats	2	1		3
E-mail	4	3		7
Podcasts				
Social media	1			1
Social networks	1	6	1	8
Web 2.0				
Wiki/WikiQuest		2		2
TOTAL	**279**	**446**	**223**	**948**

are particularly important in students' lives. In addition to private use, they are increasingly being used in research, e.g. citizen science, and in education, e.g. mobile learning. From a subject-related and practical school perspective, for example, they are suitable for spatial orientation and navigation. This section analyses the extent to which geography lessons should include mobile phones and mobile devices, according to the framework requirements.

The term 'mobile devices' appears a total of 26 times in the framework curricula, including mentions of mobil phones, smartphones and tablets. These terms occur in the curricula and framework plans of every type of school, i.e. primary, lower secondary and upper secondary schools, and are mainly mentioned in the context of methodological and media skills classifications. In addition, the subject-specific curricula require that students know how to operate a mobile phone as well as use mobile devices to obtain and process information, e.g. prepare a presentation.

The following geographical topics are found in connection with mobile devices (incl. mobile phones, smartphones, tablets) and describe the broader context through examples. It should be noted that these are individual cases that cannot be generalized to all curricula:

• Globalization: In the context of globalization and worldwide interconnectedness, the focus is on production chains, and mobile phones are used. This is addressed in the eighth grade curriculum for the Realschule in Bavaria: "The students present economic interdependencies based on the production of two different consumer goods (e.g. smartphones, jeans)" (Bayerisches Staatsministerium für Bildung und Kultus, Wissenschaft und Kunst 2016: 638). Similarly, the mobile phone plays a role in the tenth grade curriculum of the Gymnasium in Bavaria, where "global value chain (jeans, mobile phone)" are relevant topics (Bayerisches Staatsministerium für Bildung und Kultus, Wissenschaft und Kunst 2017: 56). Within the same topic of globalization, the "production process and marketing of a smartphone" are similarly mentioned as a teaching proposal for the tenth grade in Rhineland-Palatinate (Ministerium für Bildung, Wissenschaft, Weiterbildung und Kultur 2015: 55).

• Mining of raw materials: In the seventh grade curriculum for the Realschule in Bavaria, the topic "Africa south of the Sahara" deals with the "mining of raw materials for, e.g. mobile phone

production" (Bayerisches Staatsministerium für Bildung und Kultus, Wissenschaft und Kunst 2016: 628).

• Mobility education: In this context, the smartphone is not actively used by the students, but the improper use of mobile phones is addressed as a more interdisciplinary topic: "Distractions caused by mobile devices on the road" (Ministerium für Bildung des Landes Sachsen-Anhalt 2019: 10). In a slightly different context, but also within mobility education, the smartphone is included in the curriculum for Berlin and Brandenburg. Here, one of the eight themes for primary education is the topic of bicycles. Here, the "smartphone is tested for speed determination and path tracking" (Senatsverwaltung für Bildung, Jugend und Familie 2016: 34, Ministeriums für Bildung, Jugend und Sport Land Brandenburg 2016: 34).

• Perception of space and the subjectivity of medially mediated spaces: Within this topic, which is intended for the tenth grade, the concepts of space are addressed as well as the difference between real space and virtual or real mediated space. In the corresponding curricula for the Gymasium in Saarland, it is stated that "medially mediated or even virtual spaces are often equated with real spaces. This is where the subject area comes in with its central objective: It wants to create an awareness of the differences between real space and medially constructed space as a key qualification" (Ministerium für Bildung und Kultur 2014: 10).

In addition to these concrete topics related to globalization, mobility education and spatial concepts, the curricula mention subject-specific or interdisciplinary working methods that are related to mobile devices:

• Development of media literacy: Some curricula describe cross-curricular competencies related to mobile devices. These do not refer specifically to geography, but are instead relevant to all subjects. In the curriculum for Schleswig-Holstein, media is one of ten thematic areas. Among the possible topics within the area of media, "tablets and mobile phones including apps" are mentioned here (Ministerium für Bildung, Wissenschaft und Kultur und Berufsbildung 2019: 30). In a similar way, the curricula for the Gymnasium in Saxony-Anhalt also include "competencies in the use of digital tools and devices" (Ministerium für Bildung des Landes Sachsen-Anhalt 2016: 10).

Media use in school and leisure time: The curriculum for primary education in Mecklenburg-Western Pomerania addresses the use of media. Here, in the overarching area of the use of media in the first and second grades, the topic is "media at school and in leisure time" (Ministerium für Bildung, Wissenschaft und Kultur Mecklenburg-Vorpommern 2020: 34).

4.2.2 Analysis of the software/digital tools category – *Apps*

From the software/digital tools category, we analyse the term 'apps' (n = 6). This term is used in primary and secondary school curricula, which predominantly enlist apps for visualization, spatial orientation and promoting media skills, i.e. as a tool for data preparation. Apps are utilized in three main content areas:

- Climate and climate change: An app addresses the topic of climate and climate change in Saarland in the curriculum for social sciences. Here, it is cited in the context of weather forecasting "for determining the weather/climate elements" (Ministerium für Bildung und Kultur 2014: 54).
- Media and politics: An app is discussed again in the same curricula in Saarland in the curriculum for social sciences. Here, it is mentioned as a basic concept in the context of the topic of media and politics for the tenth grade, without further specifying the context (Ministerium für Bildung und Kultur 2014: 79).
- Use of public and private transport: In the context of apps, curricula for primary schools in Saxony-Anhalt suggest reading timetables and "using route planners or programs/apps from transport providers to orient oneself in the transport network of a place of residence" (Ministerium für Bildung des Landes Sachsen-Anhalt 2019: 11).

In addition, the curricula address the following working method:

- Explanatory videos on geographical content: In the curriculum in Mecklenburg-Western Pomerania for Gymnasiale Oberstufe, apps are mentioned in the context of explanatory videos: "Using apps, students can create their own videos to explain geographic content using drawings they have made themselves" (Ministerium für Bildung, Wissenschaft und Kultur Mecklenburg-Vorpommern 2019: 5).

5   Discussion

This contribution analyses the topic of digitalization in school curricula and framework documents. Specifically, it focuses on which subject-specific content, working methods and learning approaches are explicitly included in these documents. Primarily, the results show a focus on a more general, non-subject-specific level represented by terms such as 'digital' or 'computer'. At the subject-specific level, 'geographic information systems (GIS)', 'remote sensing' and 'satellite images' are other areas of focus that are also frequently mentioned in the curricula and frameworks. Although digitalization is occurring, it remains at a very general level, with the exception of GIS and remote sensing. The geographical potential mentioned in the specialist literature, e.g. in Brendel (2018), Ditter et al. (2012), Krautter (2015), Siegmund & Michel (2013) and Steinbach (2019), is not utilized at the curriculum level.

In addition to general terms, concepts from the software category are mentioned frequently, as opposed to those in the learning approaches and concepts and communication and information platform categories, which are mentioned less frequently.

In the main category of software, 'simulations and animations', work with 'digital maps' and 'virtual field trips' (Wiktorin 2018) and 'virtual spaces' receive mentions. Thus, the frameworks explicitly require the use of subject-specific software and tools and digital geomedia. Yet, they hardly mention relatively modern techniques and digital learning worlds: specifically, tools such as VR and AR (Carrera et al. 2018, Jekkerbluehill & Ohl 2018), as well as online or virtual classrooms, are either completely absent or hardly present in the documents. Digital or virtual teaching and learning spaces are likely to become increasingly important in future educational contexts; the COVID-19 pandemic has increased the development potential of these contexts significantly.

The results also reveal a deficit in the learning approaches and concepts of digital teaching, such as blended learning, mobile learning and e-learning (Brendel 2018, Krautter 2015, Feulner & Ohl 2014), which either do not or seldom appear in the curricula. The lack of digital learning concepts in curricula is initially not surprising because the traditional curricula determine learning contents, learning objectives and subject-specific skills. Despite the clear need for the use of digital tools and software, concepts of digital-based teaching are either absent or hardly mentioned. The lack of digital media and tools in teaching frameworks reveals a clear discrep-

ancy between the need to use these tools and the integration of digital-based concepts in the classroom. Curricula could include more learning approaches and educational methods with regard to learning objectives and especially digital skills. For example, the promotion of skills using digital learning concepts could be directly related to data collection and data storage (Ridsdale et al. 2015) and data protection and privacy knowledge and skills (Steinhauer 2018), utilizing mobile devices and a mobile learning approach (de Witt & Gloerfeld 2018). This could address the perspective that digitalization is an infrastructure that, on the one hand, includes technology and, on the other, also encompasses the ability to use the technology and the learning processes necessary to do so (Stalder 2021).

A deficit in terms of communication and information platforms becomes clear from the frequencies of use of the concepts because the terms 'podcasts', 'social media' and 'Web 2.0' (Ditter et al. 2012: 228) were largely absent. These media should be developed further in the field of geography education in consideration of the fact that they offer opportunities and benefits but also present challenges, especially regarding geographical content. This applies equally to curricula, frameworks and geography education research. An example of this is climate change, as the issues involved require societal action, which requires a high level of communication and interaction between science and society. This exchange is facilitated by the corresponding platforms (e.g. Twitter, YouTube, Instagram) (Walter & Brüggemann 2019) and can be manifold: scientists can communicate scientific knowledge, while various societal actors can spread misinformation or 'fake news'. In this vein, geography education must adequately prepare students to deal with geographically relevant content on social media platforms, which highlights the need for the further implementation of this skill in frameworks and curricula.

The analysis of the different types of schools showed that some geomedia or geographic work methods are not present in primary school curricula. This seems to be understandable in the case of GIS, since these are very complex working methods that can only be applied in a meaningful way in higher grades. Implementation approaches can also be found, in particular, at the secondary level (Höhnle et al. 2014, Kerski 2003, 2021). It is noticeable that digital map work in primary schools is not mentioned in any of the curricula. The reasons behind this cannot be specified at this point, but a discussion should be initiated in the future.

The content-analytical discussion of the terms in the documents does not fully exploit the potential of apps, mobile phones and mobile devices. In fact, the guidelines seldom mention the possibility of using apps for data collection; collecting weather data is one positive, albeit insufficient, exception here. Yet, there are many more possibilities for using apps in geography classes (e.g. Kotztin 2018, Steinbach 2019, Peter et al. 2020). In addition, students use apps and mobile phones in their everyday lives. The suitability of mobile phones for educational work is justified by their multiple functions, e.g. data collection, processing, communication and information retrieval. Mobile phones or mobile devices are required to use apps, yet data protection issues regarding the use of software and apps need to be addressed and may differ depending on the country and state. Despite the challenges associated with them, mobile devices have great potential and address a broad range of skills related to several areas, e.g. spatial orientation, communication and subject knowledge. Last but not least, they can promote media and methods skills with regard to responsible and goal-oriented handling. Mobile phones and apps play an important role in students' lives as well as in science, e.g. in citizen science projects (Dickinson & Bonney 2012). This is where framework curricula can come into play and, on the one hand, tie in with students' lifeworlds and, on the other, integrate ways of collecting scientific data into educational concepts. This procedure is compatible with current discourses, such as data literacy (Ludwig & Thiemann 2020, Ridsdale et al. 2015), or subject didactic concepts, such as mobile learning (Feulner & Ohl 2014). Embedding the cooperation of science and technology in learning concepts can promote students' understanding of science through technology-supported processes. The curricula already mention numerous topics and subject-specific ways of working in regard to virtual field trips (Wiktorin 2018). However, if hybrid or virtual learning environments remain important in the future, then there is still potential to broaden the topics or integrate them into every federal state's curricula.

Another aspect becomes apparent with regard to interdisciplinary working methods, skills and content. In individual cases, the documents list such details alongside subject-specific components. One example is the traffic or mobility education topic. The structure of geography as a subject must certainly be taken into account, since it combines various science, technology, engineering, and mathematics (STEM) subjects and the social sciences. Nevertheless, insights can be derived for the subject of geography. Starting from

subject-specific content and problems, e.g. navigation, the school subject of geography could offer more scopes of interdisciplinary areas than before, e.g. when it comes to orientation, the visualization of spatial data or the determination of climate/environmental data with technology-supported methods. Thus, geography offers many concrete application references in the sense of authentic and real-world problems and situations, which are also relevant to the professional world and the professions of tomorrow (Davenport & Patil 2012).

A major limitation of this study is related to the search process. During the analysis, specific search terms, e.g. digitalization, were used to analyse the documents. This means that only these exact terms were found. If, for example, synonyms exist for a term, they will not be found with this search mechanism. Another limitation is that the study only analyses a snapshot of each curriculum. As curricula are subject to regular modifications and development, the results are expected to change in the near future. This is especially true considering the rapid developments associated with the COVID-19 pandemic. However, this also presents an opportunity: This article uncovers a potential that can be considered in future developments, which is seen in terms of the adaptation and expansion of curricula specific to the federal states and which is also proposed in the ICILS (Eickelman et al. 2019a). The greater integration of subject-didactic concepts, such as mobile learning, or tools that further sharpen the subject-specific potential in its entire breadth could develop a more subject-specific design in the future. It would also be conceivable to integrate a subject-didactic design of data literacy (Ludwig & Thiemann 2020, Ridsdale et al. 2015), which, with the increasingly digitalized professional world and the associated skills expected in the working environment, could also be shaped by geographical facets, for example in dealing with environmental data or climate models. Although data handling and management are established in the discipline, the knowledge and teaching of these topics must also be understood as an educational task from a subject-didactic perspective. Accordingly, the frameworks and curricula should implement appropriate content and skills.

6 Conclusion and outlook

This paper aimed to analyse the implementation of subject-specific digitalization, especially in terms of content, digital tools and learning approaches in geography frameworks and curricula. Digitalization remains at a very general, not subject-specific, level, with the exception of GIS and remote sensing. Future modifications should sharpen the breadth of the entire subject-specific potential. A prerequisite for this, however, is equipping schools (and students) with functional WLAN as well as appropriate technology and software; this should be implemented across the board – if it is not already available. Second, modern digital learning worlds, such as VR and AR, are either completely absent from or seldom present in the curricula. This is also true for learning approaches to digital teaching, such as mobile learning, and the use of communication and information platforms/social media. These should also be implemented in the future due to the opportunities associated with them, as well as the challenges.

Finally, it should be noted that the COVID-19 crisis has already changed and will continue to change geographical learning – subsequent studies must clarify the extent to which this occurs. This raises many questions for the future and presents a new need for action to modify future curricula.

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Appendix I: Analyzed curricula of all federal states

Baden-Württemberg:

Ministerium für Kultus, Jugend und Sport Baden-Württemberg (2016): Bildungsplan Grundschule - Sachunterricht. Stuttgart. https://www.bildungsplaene-bw.de/bildungsplan,Lde/BP2016BW_ALLG_GS

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Ministerium für Kultus, Jugend und Sport Baden-Württemberg (2016): Bildungsplan Gymnasium - Geographie. Stuttgart. https://www.bildungsplaene-bw.de/,Lde/LS/BP2016BW/ALLG/GYM/GEO

Bavaria (Bayern):

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Bayerisches Staatsministerium für Bildung und Kultus, Wissenschaft und Kunst (2016): LehrplanPLUS - Realschule. München. https://www.lehrplanplus.bayern.de/bildungs-und-erziehungsauftrag/realschule

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Berlin:

Senatsverwaltung für Bildung, Jugend und Familie (2016): Rahmenlehrplan für die Jahrgangsstufen 1 bis 10 - Teil C - Sachunterricht - Jahrgangsstufen 1 – 4. Berlin. https://bildungsserver.berlin-brandenburg.de/unterricht/rahmenlehrplaene/jahrgangsstufen-1-10

Senatsverwaltung für Bildung, Jugend und Familie (2016): Rahmenlehrplan für die Jahrgangsstufen 1 bis 10 - Teil C - Geografie - Jahrgangsstufen 7 – 10. Berlin. https://bildungsserver.berlin-brandenburg.de/unterricht/rahmenlehrplaene/jahrgangsstufen-1-10

Senatsverwaltung für Bildung, Jugend und Familie (2006): Rahmenlehrplan für die gymnasiale Oberstufe - Gymnasien. Berlin. https://bildungsserver.berlin-brandenburg.de/gymnasiale-oberstufe

Brandenburg:

Ministeriums für Bildung, Jugend und Sport Land Brandenburg (2016): Rahmenlehrplan für die Jahrgangsstufen 1 bis 10 - Teil C - Sachunterricht - Jahrgangsstufen 1 – 4. Potsdam. https://bildungsserver.berlin-brandenburg.de/unterricht/rahmenlehrplaene/jahrgangsstufen-1-10

Ministeriums für Bildung, Jugend und Sport Land Brandenburg (2016): Rahmenlehrplan für die Jahrgangsstufen 1 bis 10 - Teil C - Geografie - Jahrgangsstufen 7 – 10. Potsdam. https://bildungsserver.berlin-brandenburg.de/unterricht/rahmenlehrplaene/jahrgangsstufen-1-10

Ministeriums für Bildung, Jugend und Sport Land Brandenburg (2006): Rahmenlehrplan für die gymnasiale Oberstufe - Gymnasien. Potsdam. https://bildungsserver.berlin-brandenburg.de/gymnasiale-oberstufe

Bremen:

Senator für Bildung und Wissenschaft (2007): Sachunterricht - Bildungsplan für die Primarstufe. Bremen. https://www.lis.bremen.de/schulqualitaet/curriculumentwicklung/bildungsplaene/primarstufe-15222

Senator für Bildung und Wissenschaft (2006): Welt-Umweltkunde, Geschichte, Geografie, Politik - Bildungsplan für das Gymnasium - Jahrgangsstufe 5 - 10. Bremen. https://www.lis.bremen.de/schulqualitaet/curriculumentwicklung/bildungsplaene/sekundarbereich_i-15226

Senatorin für Bildung und Wissenschaft (2008): Geografie - Bildungsplan für die Gymnasiale Oberstufe - Qualifikationsphase -. Bremen. https://www.lis.bremen.de/schulqualitaet/curriculumentwicklung/bildungsplaene/sekundarbereich_ii___allgemeinbildend-16698

Hamburg:

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Sekundarstufe I – Gymnasium – Erdkunde. Wiesbaden. https://kultusministerium.hessen.de/Unterricht/Kerncurricula-und-Lehrplaene/Kerncurricula/Sekundarstufe-I-Kerncurricula

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