University of Zurich[UZH]

The Use of Geographic Information Systems for Data Visualization and Analysis in Geography Education at Swiss High Schools

GEO 511 Master's Thesis

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Abstract

Geographic Information Systems (GIS) are becoming increasingly important for both professional and personal use. Not least, during the COVID-19 pandemic, they demonstrated their potential to help solve current and future problems with data analysis and visualization. In addition, smart devices, navigation applications, and social media are bringing more and more people into regular contact with GIS in their daily lives. Because of these developments, GIS has become an important part of education. While its basic concepts can be taught at lower levels, the in-depth study of GIS software and related data visualization and analysis is recommended for higher grades from high school onwards. Since it started being introduced into education, GIS has been shown to bring real-world relevance to the classroom and to be a helpful tool for promoting constructivist teaching methods.

However, little is known about how GIS is used in Swiss high school classrooms. Therefore, the aim of this Thesis is to find out more about the use of GIS in Swiss secondary schools, the factors influencing its use, and the possibilities to support teachers. To this end, a survey was conducted among high school geography teachers throughout Switzerland. The results showed that about 50% of the teachers use GIS, and 40% let their students work with GIS software to visualize and analyze geographical information during their lessons.

Based on the results from the survey, it was also found that the mention of GIS in the curriculum, the provision of GIS software by a school, and geography being a teacher's first subject are external factors influencing the use of GIS. A teacher's age, teaching experience, and the inclusion of GIS in a teacher's studies do not play a major role. Furthermore, a teacher's knowledge of GIS and how to use it in the classroom, the importance attributed to GIS, and the perceived availability of teaching materials, are internal factors influencing its use. The perceived availability of time, and the importance attached to data visualization and analysis and to GIS as a useful tool for this, do not seem to influence the use of GIS.

It also emerged that teachers are most interested in support in the form of additional teaching material that is time-efficient, linked to other curriculum topics, covers different levels of difficulty, and comes with clear instructions and data. Therefore, a teaching unit has been developed in response to these needs.

Keywords: *GIS, GIS Use, Data Visualization, Data Analysis, High School, Secondary School, Education, Switzerland*

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Chapter 1 Introduction

Since time immemorial, information about the earth's surface, places, their nature, and the paths that connect them have been critical to many aspects of human life (Unwin et al., 2012). The technological advances of the recent decades have changed not only people's professional and everyday lives but also the way spatial information is used and processed (Zawacki-Richter & Latchem, 2018). The first Geographic Information System (GIS), which came to the market in 1960, opened up new possibilities for the acquisition, processing, visualization, and analysis of spatial data (Waters, 2017; Waters, 1998). Since then, GIS has demonstrated its ability to help understand spatial phenomena, associated processes, and their influence on space, thus contributing to the solution of current and future problems (Bearman et al., 2016). This was not least evident during the COVID-19 pandemic when it was used to plan and mitigate its consequences (Brooks et al., 2017; Geraghty & Kerski, 2020). In its early years, GIS was mainly used by experts in government and industry to facilitate decision-making, uncover spatial patterns and solve problems. More recently, it has been increasingly used by non-experts due to more user-friendly technology and the increasing amount of spatial data available (Bearman et al., 2016).

In addition, technological advances such as the Global Positioning System (GPS), smart devices, and the advent of social media services have gradually brought GIS into people's everyday lives (Unwin et al., 2012; Waters, 2017). As a result, not only have their users been exposed to GIS on a regular basis, but they have also automatically become producers of geographic information, whether they are aware of it or not (Scull et al., 2016; Unwin et al., 2012). These developments and the increasing importance of GIS led Unwin et al. (2012) to question whether some, aspects of GIS and related concepts should not be taught to everyone.

1.1 Research Gaps and Goals

Followed by the growing importance of GIS, the urge to introduce it to education has steadily increased. While universities have embraced the technology since its emergence, it has been introduced only slowly at lower levels of education (Geraghty & Kerski, 2020).

While basic spatial concepts can and have to be taught already in lower grades, the application of complex GIS software is recommended only at the upper secondary level. This comes as a basic understanding of technology, maps, statistics, and forms of representation is required for working with GIS and for synthesizing various concepts into one big picture (Falk & Hoppe, 2004; Herzig, 2007). For this reason, this Master's Thesis will focus on high school education.

Furthermore, as it is impossible to draw a global picture of the use of GIS in secondary education within the scope of this Thesis, the focus was set on capturing how GIS is used in Switzerland's high school education. Further, the emphasis has been exclusively on geography education, even though GIS is also applied in other fields, as GIS is inherently attributed to the discipline of geography.

When looking at the current usage of GIS in Switzerland, it appears that the most current study originates from 2012, suggesting that one-third of all Swiss secondary schools were using GIS at that time (Stark & Treuthardt, 2012). Moreover, while visualization and analysis are part of Switzerland's national framework curriculum, an explicit mention of GIS is missing (EDK, 1994). Therefore, it is hard to tell to what extent GIS is currently applied in Swiss high schools.

For this reason, the aim of this Master's Thesis is to find out how GIS is currently applied in Switzerland's high school geography education. Since the integration of GIS ultimately depends on the teachers, it is important to identify factors that are crucial for its use (Gómez-Fernández & Mediavilla, 2022). Studies have already uncovered that external factors, such as the availability of resources and school regulations, but also internal factors, such as teachers' knowledge and attitudes, influence the use of GIS (Bednarz & Van der Schee, 2006). However, it is unclear what external factors are present in Switzerland, what the attitude of Swiss teachers towards the topic is, and how this influences the use of GIS. Furthermore, it will be determined how teachers can be supported in introducing GIS to the classroom, and based on their demands, some form of support will be implemented.

1.2 Research Questions

Based on the research gaps and goals described above, three research questions were determined that will be answered with this Thesis:

RQ1: How is GIS currently used for data visualization and analysis in Swiss high school geography education?

RQ2: Which external and internal factors influence the use of GIS for data visualization and analysis in geography classes at Swiss high schools?

- **H2.1:** The use of GIS is influenced by the presence of GIS in the curriculum, the providence of GIS software by a school, geography being a teacher's first subject, the inclusion of GIS in a teacher's study, the teaching experience, and the age of a teacher.
- **H2.2:** The use of GIS is influenced by a teacher's perception that GIS, spatial data handling, data visualization, and analysis are important, and that GIS is helpful in teaching these topics. Furthermore, the use is influenced by a teacher's knowledge of GIS software and how to use it in the classroom, and the perceived availability of time and material.

RQ3: How can geography teachers be supported in the use of GIS for data visualization and analysis in Swiss high schools?

The following chapter presents the background of GIS, its impact on education, and state-of-the-art knowledge of its use in Switzerland's high school education. Chapter three describes the methods used to answer the research questions, the primary method being a survey. Afterward, the results of the survey are presented in chapter four. Based on the teachers' needs identified in the survey, a teaching unit was designed, which is presented in chapter five. In chapter six, answers to the research are delivered, the findings are discussed, and limitations and opportunities for future research are identified. Finally, a conclusion summarizes the work and the main findings.

Chapter 2 Background

2.1 Importance of GIS for Geography

The aim of this chapter is to outline the importance of GIS for geography and everyday life, by first addressing the historical development of GIS and then presenting potentials and limitations of GIS.

2.1.1 Historical Development of GIS

A geographical information system (GIS) is a computer system that allows the collection, storage, and processing of spatial information, allowing for spatial analysis. The Canada Geographic Information System (CGIS), developed in the mid-1960, is usually cited as the first such system (Foote et al., 2012; Kerski et al., 2013), although the concepts of spatial analysis that underlie GIS were developed and applied much earlier (Waters, 2017). For example, the map overlays of troop movements created by Berthier in the 18th century are often referenced. Equally famous is the work of Dr. John Snow from 1854, who overlayed London's water pumping stations with the incidence of cholera cases on a map, providing evidence that the disease is transmitted by water and not air. His work showcases the relevance of spatial data analysis, as the containment of the epidemic could save many lives. Both equally demonstrated knowledge of how to organize, visualize and link spatial data, considered basic GIS concepts (Waters, 2017; Waters, 1998). However, despite the promising beginnings, only about a century later, those concepts of combining spatial data by overlaying them on maps started to gain importance in the field of geography again (Waters, 2017). Following the development of the first GIS by the Canadian Land Inventory System in the 1960s, GIS have been widely used by the government, non-profit organizations, and industry, as they have proven to be an efficient and cost-effective tool for geospatial data management and decision-making. Fostered by the development of the Internet, technological progress, and the availability of spatial data, GIS have become a powerful platform for the analysis, understanding, and management of the Earth in almost all areas of society (Kerski et al., 2013).

According to Coppock and Rhind (1991), four periods in the development of GIS can be distinguished up to the early 1990s, while Waters (2017) proposes a classification for the following years. The first phase extends from the mid-1950s to about 1975 and is characterized as a pioneering period. During this time, the first GIS was developed, the current market-leading GIS software company "*ESRI*" was founded, and the first geocoded census data was produced by the US Census Bureau (Coppock & Rhind, 1991; Waters, 2017). At this time, during the emergence of spatial science, the quantitative/scientific ways of thinking geographically were dominant, often referred to as the "quantitative revolution". This development was mainly criticized by human geographers, as from their point of view, quantitative methods cannot adequately represent the world and its processes by their narrow parameters. These arguments were taken up again in the 1990s to criticize the worldview conveyed by GIS (Fragher, 2017; Schuumann, 2000).

The second period started in the mid-1970s and ended in the early 1980s and has been identified as a governmental-supported, experimental period, where conceptual and software developments were mainly government-funded and took place within academia and governmental agencies (Waters, 2017).

The third phase reaches from the early 1980s to 1990, characterized as the commercial period, followed by the fourth phase, beginning in 1990, identified as the user dominance era (Waters, 2017). During this fourth phase, critical GIS was born as human geographers began to question the effects of GIS on geographical thinking and called for a more reflective GIS that addresses the epistemological and ontological implications of spatial analysis and visualization (Schuurman, 2006). Beginning in the mid-1990s, the era of geographic information science (GIScience) emerged, shifting the focus from purely technological aspects to the handling and use of spatial data. This period was marked by the second wave of criticism, signed by the works "*Ground Truth*" by John Pickles (1995) and "*GIS and Society*" by Eric Sheppard (1995). Critics expressed their concerns about GIS being best suited for large corporations and public institutions rather than for disenfranchised people. In addition, they were skeptical about a technology they viewed as a relic of the quantitative revolution resulting in a reassertion of the narrowmindedness of the spatial paradigm (Schuurman, 2006; Waters, 2017). As a response to this criticism, a movement called public participation in GIS (PPGIS) was launched, incorporating social science methodologies and theories (Waters, 2017).

From 2005 to the present, a new era has begun characterized by technological progress that has enabled volunteered GIS, web GIS, mobile GIS, cloud computing, and Big Data analysis (Waters, 2017). Continued advances in computer technology have led to a transition to a "data-driven" geography which, from the perspective of previously applied criticism, represents a step back to initial concerns (Miller & Goodchild, 2015; Waters, 2017). Nevertheless, precisely such developments positively impacted on geographic thinking, as simpler technologies and openly available data allowed more time to be spent on analysis rather than processing and collecting data (Geraghty & Kerski, 2020). In addition, web-based GIS, in particular, promoted collaboration among people around the world and the integration of real-time information. Such collaboration was demonstrated during the COVID-19 pandemic, where GIS was used by multiple countries to jointly combat the pandemic (Geraghty & Kerski, 2020).

Since its first appearance in the 1960s, GIS has evolved from a tool used exclusively by experts to an increasingly important part of people's everyday lives. Nowadays, everyone involved with technical devices such as smartphones, smart homes, or smart cars gets in touch with GIS on a regular, if not daily, basis. Geographic information and location-based services are ubiquitous. This trend is called neogeography and is driven by technologies such as the geographic positioning system (GPS), online mapping services, and social media, making everyone who uses these services simultaneously consumers and producers of geographic information (Unwin et al., 2012; Waters, 1998). Regarding these developments, GIS seems to have a significant impact on geography and everyday life. Alternatively, as Nigel Waters wrote:

> *"There is little doubt that over the past fifty years, GIS has been a transformative science for both the academic discipline of geography and the world we inhabit." – Waters, 2017, p. 11*

For more detailed information about the history of GIS, please refer to "GIS: History" by Nigel Waters (2017) and "Formalization Matters: Critical GIS and Ontology Research" by Nadine Schuurman (2006).

2.1.2 Relevance and Limitations of GIS

In chapter 2.1.1, the proliferation of GIS, its influence on geography and everyday life, and some critical reactions were already addressed. In this subchapter, the focus is set on the relevance and limitation of GIS for geography and the world.

Geography can be defined as the knowledge and understanding of spatial phenomena, associated processes, and their influence on spatial entities from the global to the microlocal scale. GIS is able to integrate different aspects and scales related to phenomena, their processes, and consequences, thus providing insights into the connections between different elements (Bearman et al., 2016). Already in the early 2000s, most, if not all, large governmental and commercial organizations had access to some form of GIS technology. At that time, GIS was often used solely to display spatially referenced data, but not for more advanced spatial analysis (Birking et al., 1999; Waters, 2017). Since then, GIS has transformed the ways of decision-making in government, academia, industry, and society (Kerski, 2003). Nowadays, besides using GIS to generate maps, the system is also used for in-depth spatial data analyses, serving as a tool for managing spatial data, making strategic decisions, and managing resources (Bualhamam, 2012; Usmani et al., 2020).

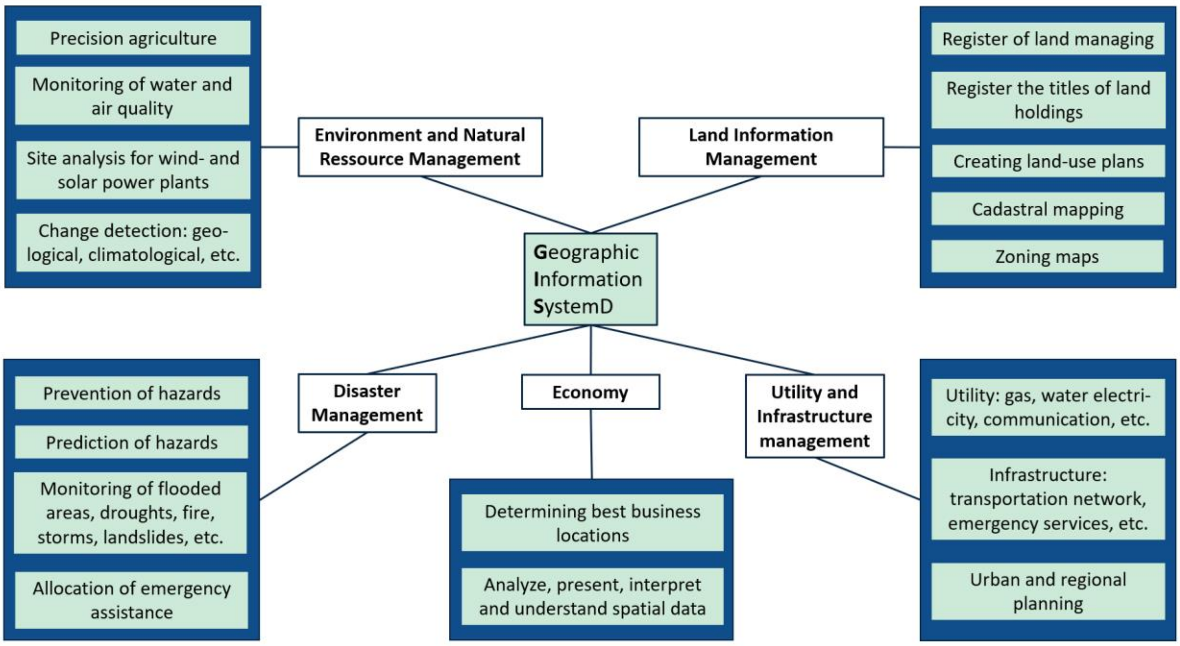


Figure 2.1: *Professional areas where GIS can be applied based on the papers of Jebur (2021) and Usmani et al. (2020).*

Due to its wide range of applications, GIS has a worldwide, vast, and fast-growing market and industry, leading to a great demand for data and software products, but also for knowledge and experience and hence for professionals (Bualhamam, 2012; Jebur, 2021; Kemp et al., 1991). *Figure 2.1* shows an overview of some main professional application areas of GIS technology. However, geographic information and GIS have gained importance not only for professional use cases but also in everyday life, especially through location-based services and smart devices that make everyone using these services simultaneously a producer of geographic information (Unwin et al., 2012). This comes as the provision of location-based services and the performance of Big Data and market analytics rely on such data, gathered, voluntary or not, partly unconscious from citizens (Scull et al., 2016). This raises significant concerns regarding privacy and ethics regarding the use of personal spatial data, as the potential for abuse is growing. Those issues get even worse as spatial data is getting available to a much more comprehensive range of people and can not only be accessed by professionals (Bearman et al., 2016; Scull et al., 2016; Usmani et al., 2020). With the easily accessible supply of spatial data, the potential to apply GIS and geocomputation techniques in many fields opens up. Unfortunately, there is often a lack of sufficient geospatial skills and spatial literacy, which can hinder critical spatial thinking, wherefore education in this domain is getting more important (Bearman et al., 2016).

GIS can also help to find solutions for issues relevant to human life. This comes as many of the major current and future problems the world is facing - be it population growth, climate change, sustainability, migration, and natural hazards - have a geographic component (Brooks et al., 2017; Jebur, 2021). However, also many minor problems, such as finding good soil for growing crops, finding reliable places for disposing of hazardous waste, or determining the range of endangered species, have geographic components. Moreover, for many concerns of everyday life, such as finding the shortest walk to a destination, geographic information plays an essential role (Jebur, 2021). In all three cases, this geographic dimension can be expressed with the help of GIS, which enables the linking of quantitative methods with "real world" applications, thus contributing to the solution of those problems (Jebur, 2021; Longley, 2000). The potential of GIS was demonstrated not most recently during the Covid-19 pandemic, where in particular web-based GIS systems were used to plan and mitigate the consequences of the pandemic. Most notable were dashboards that helped to provide situational awareness, assess vulnerabilities, and provide predictions of future impacts on hospitals (Geraghty & Kerski, 2020). Nonetheless, some geographers expressed their doubts that technological systems are, and ever will be, capable of generating significant insights into geographical problems, as they cannot adequately represent the world by its limited parameters (Fragher, 2017; Longley, 2000), as stated by Longley (2000):

> *"Yet while new sources of digital data will enable us to paint ever-more vivid portraits of the real world, we should be cautious that such portraits may be fiction, not fact, triumphs of gloss over substance" – Longley, 2000, p.41*

One of the main critique points is about the positivist nature of GIS technology, shaping "fuzzy" (social) data to aesthetically pleasing representations, thus merely quantifying rather than qualifying it, inherently leading to a limited way of how individuals think geographically (Fragher, 2017). Related to this, another limitation coming along with GIS is that the use of proprietary GIS software may lead to a shift in intellectual focus from spatial analysis to mastery of the technology, which in the long term may lead to a de-skilling within the discipline of geography (Clarke et al., 1995; Longley, 2000). Further, the focus on IT skills rather than on spatial literacy, critical spatial thinking, and map design could be worsened by the short product life cycles of the technology (Bearman et al., 2016; Longley, 2000). Due to technological advances in recent years and the focus on more user-friendly applications, complexity

could be reduced, facilitating the mastery of technical skills, thus creating more space to explore spatial concepts (Bearman et al., 2016).
Another critique is questionable ethics due to the subjectivity behind knowledge created with GIS, which can be led by political and social practices (Fragher, 2017; Kwan, 2007). For this reason, it is inherent to make people aware that such knowledge is only a representation of reality, may be informed by subjectivity, and may be used to manipulate data and people. Hence, the importance of educating people on how to use GIS and the resulting information is pointed out again (Fragher, 2017; Jebur, 2021; Longley, 2000).

As discussed above, GIS significantly impacted the role of geography and could demonstrate the relevance of the subject for the world in providing means to solve emerging problems (Longley, 2000). Spatial data has become ubiquitous in recent years and has brought everyone into contact with GIS in one way or another. Besides the positive aspects, there are concerns about privacy, ethics, and reliability of knowledge created through GIS and a de-skilling due to the technical focus. For this reason, it gets increasingly substantial to raise people's awareness of the topic and teach them about GIS and related concepts, which helps to counteract mentioned concerns.

2.2 GIS in Education

Due to the increasing relevance of GIS for the economy, science, and everyday life, GIS has gradually become an essential topic for education. Understanding the underlying concepts of GIS and the information created with it, is further critical to countering the criticism leveled at GIS for limiting spatial thinking and raising ethical concerns. This subsection first addresses the implementation of GIS in education and then discusses the opportunities and limitations of implementing GIS in education.

2.2.1 Historical Development of GIS in Education

Four stages of GIS development in education were identified by Kohloshyn (2017), which serve as a structure for the following chapter.
The first stage spans from the late 1970s to the early 1990s, marked by technological development and initial attempts at GIS education programs at the university level. Starting with universities in the United States and Canada, a total of 450 universities in the United States, Europe, and Australia offered GIS education in the 1990s. GIS was used not only in the discipline of geography but also in other sciences such as history, computer science, biology, and mathematics (Khudiakova, 2008; Kohloshyn et al. 2017). This period was further characterized by the development and growth of computer-assisted instruction, which was based on computer-assisted learning (CAL) and primarily followed behaviorist teaching principles, the predominant form of instruction at the time (Zawacki-Richter & Latchem, 2018). Behaviorist approaches assume that development is mainly guided by external influences. The teacher plays a central role in the process of knowledge construction from students and is seen as the primary source of information. On the other hand, the students are pure information receivers who learn to react to environmental stimuli through experience (Schnotz, 2011).
Fostered by technological advancements, in the early 90s, the first high schools in the United States and Canada began to integrate GIS into their curriculum (Kerski et al., 2013; Kohloshyn et al., 2017).

This example was followed by individual high schools from Denmark, France, Germany, Finland, the United Kingdom, the Netherlands, and Sweden (Kohloshyn et al., 2017). The main reason for using GIS at this time was that it was perceived as a practical tool to introduce students to the use of technology and get them interested in science (Bednarz, 2004; Kerski et al., 2013). At this time, the prevailing discourse was about how computer literacy could be integrated into the curriculum and whether technology should be introduced into the classroom at all (Zawacki-Richter & Latchem, 2018).

In the second stage, which began in the mid-1990s and ended at the beginning of the 21st century, GIS education programs became more widespread in the United States, Western European countries, and Australia. In addition, leading companies developing GIS software, such as ESRI, Intergraph, and MapInfo Corp., began to participate more actively in GIS education at all levels. Nonetheless, only a small number of high schools were actually used GIS for education (Kohloshyn et al., 2017).

During the first part of this phase, from 1987 to 1996, independent multimedia learning was predominant in schools. The first laptops were developed, the World Wide Web was created, and the first smartphones appeared on the market. However, most computers did not have access to the Internet. Implementing CAL remained a major problem related to constraints such as large classes, limited time and resources, and a lack of possibilities for teachers' professional development (Zawacki-Richter & Latchem, 2018).

During the second part of this phase, reaching from 1997 to 2005, more student-centered teaching approaches, including problem- and inquiry-based learning, came into focus, leading to a shift from behaviorist to constructivist methods of teaching (Gonzalez & Torres, 2020; Johansson, 2003; Kerski, 2003). Constructivist approaches recognize both internal and external influences as essential to student development (Schnotz, 2011). Those methods emphasize hands-on and research-based learning, spotlighting the students rather than the teacher (Johansson, 2003; Kerski, 2003). Thereby, students' roles change from passive recipients of information to active generators of knowledge, while the teacher's role shifts from the primary source of information to a supporting and motivating role in the process of students' knowledge construction (Johansson, 2003).

Besides pedagogical changes, the period was characterized by the expansion of the Internet, becoming the largest worldwide database, and the first social media platforms that came to life. Fostered by technological development and the shift to constructivist teaching, computers were increasingly seen as a tool for supporting collaborative learning. The focus was now on students rather than on the technology itself. This led to a shift in the conversation from "if" technology should be used for instruction to "how" technology can be used to enhance learning (Zawacki-Richter & Latchem, 2018).

Even tough GIS enable constructivist teaching, and studies have shown that GIS can bring positive aspects to the classroom, GIS has received little attention in the majority of school education at the beginning of the 21st century (Herzig, 2007; Ugurlu, 2011; Walshe, 2018). In 2003, less than 50% of schools in the US, Canada, and Great Britain, used GIS for their teaching, while less than 20% of schools in France, Sweden, and Finland were using the technology (Kohloshyn et al., 2017).Reasons for this may be the availability of equipment and technological know-how (Walshe, 2018).

The third and fourth stage ranging from 2005 to 2012, and 2012 to 2017, can be grouped as they were characterized by the spread of GIS in school education in Eastern Europe, Asia, Africa, and Latin America. In addition, the more active implementation of GIS occurred in countries where the integration of GIS had already begun (Kohloshyn et al., 2017). During the third stage, Kerski et al. (2013) conducted a global study evaluating the usage of GIS in secondary education. They found that all except 5 of the 33 studied countries relied on partnerships with universities and industry for introducing GIS (Kerski et al., 2013). This is also supported by the findings of Kohloshyn et al. (2017), This is also supported by Kohloshyn et al. (2017) findings, as they mention software companies such as Esri providing software, online courses, and teaching materials to schools. Nonetheless, only China, Finland, India, Norway, South Africa, Taiwan, Turkey, and the United Kingdom had integrated GIS into their national curriculum by then, and the adoption of GIS around the world remained low (Kerski et al., 2013; Tan & Chen, 2015; Walshe, 2018). From 2005 to 2017, education, in general, was mainly influenced by online learning and the emergence of the digital age. The Internet started becoming mobile, the first online courses were offered, and social media platforms experienced massive growth. Thus, the importance of digital media in all aspects of life grew, sometimes referenced as the “digital turn” (Zawacki-Richter & Latchem, 2018). Therefore, it is not surprising that a trend toward using web-based GIS for education started emerging (Kerski et al., 2013). Besides commercial Web GIS services from companies like Esri and the launch of Google maps in 2005, platforms specially designed to meet the needs of education were launched (Kerski et al., 2013; Kerski & Baker, 2019).

Since 2017 technological usage in education has grown, reaching its peak during the COVID-19 pandemic, affecting education in profound ways. Classes in many countries have had to be held online at times, so teachers have had to convert teaching materials and methods into digital form (Geraghty & Kerski, 2020). The huge impact of the pandemic on the use of technology and GIS in education was stated by Geraghty and Kersky as follows:

> *“Education will never be the same, educators have been resilient and innovative, modern GIS was well poised to be used in the face of disruption, and the attention on interactive maps and spatial thinking has never been greater.”* – (Geraghty & Kerski, 2020, p. 64)

While GIS has been introduced as a stand-alone subject in universities almost since its emergence, GIS has only entered secondary and primary education in the last 20 years and is mainly used to teach other core content outside of GIS (Geraghty & Kerski, 2020). However, as Kerski (2013) mentioned, drawing a picture of the global landscape of GIS in precollegiate education remains difficult because of differences between and within countries in schooling, technological infrastructure, and the recognition of GIS as a teaching tool.

A more detailed overview of how different countries and have integrated GIS into education can be found in the book “International Perspectives on Teaching and Learning with GIS in Secondary Schools” by Andrew J. Milson, Ali Demirci, and Joseph J. Kerski (2012). Further, in the paper “The Impact of COVID-19 on Geography, GIS and Education” by Estella Geraghty and Joseph J. Kerski (2020), more can be read about the influence of COVID-19 on the use of GIS in education.

2.2.2 Relevance and Limitations of GIS in Education

The relevance of GIS for society has steadily increased in recent years and also in education years the potential of GIS has been recognized. In this subchapter, the potential and limitations of GIS use in education will be discussed.

GIS undoubtedly has the potential to provide students with basic concepts of spatial data handling, including data visualization and analysis (Bednarz & Van der Schee, 2006). Those skills at the simultaneously result in the growth of other competencies, such as spatial or geographical thinking, that is, understanding how objects in space relate to each other and knowing how to analyze them. Critical spatial thinking is a fundamental characteristic of geography that is enhanced by its interdisciplinary nature. In order to understand the complexity and multiscale nature of spatial problems, students need to be able to handle and make sense of spatial information (Bearman et al., 2016; Fragher, 2017). GIS and related concepts can play an important role in providing students with relevant skills for spatial analysis and reasoning, thus being a valuable resource for teaching spatial thinking and geographical knowledge (Bednarz & Van der Schee, 2006; Bualhamam, 2012; Fragher, 2017; Gonzalez & Torres, 2020). Already in the early 2000s, a study by Kerski (2003) revealed that GIS could improve students' capabilities of spatial thinking, as students learning with GIS-based instruction demonstrated better abilities to synthesize, identify and describe reasons for spatial patterns than student learning with traditional instruction methods.

The complexity of GIS technology challenges those benefits for critical spatial thinking, as the handling of the technology can take a considerable amount of time, thus shifting the focus from contextual analysis to technical skill acquisition (Bearman et al., 2016; Walshe, 2018). In order to avoid this, Kerski (2003) recommends that rather than focusing on how GIS should be brought into the curriculum, one should focus on how GIS can help to meet curricular goals. According to Bearman et al. (2016), connecting GIS with other geographic topics is even crucial to enable spatial thinking. This connection enables lessons that focus on the analysis of content-oriented questions rather than on the usage of GIS (Falk & Hoppe, 2004; Walshe, 2018). However, GIS should not be used everywhere where it is possible but rather where learning content can be conveyed effectively (Herzig, 2007).
Due to the complex nature of GIS technology, teachers play an essential role in guiding students in the process of working with GIS by providing goals and instructions. Otherwise, untargeted interactions with technology will happen, which is likely to solely increase computer and data literacy without achieving content goals (Herzig, 2007; Kerski, 2003). Still, "cookbook" type teaching approaches are not desirable, as this leads to students only following instructions without thinking about the purpose and meaning of what they are doing (Kerski, 2003; Walshe, 2018).
Furthermore, as frequently observed when technology is used in the classroom, GIS can amplify the heterogeneity between students due to considerable differences in technological skills (Bearman et al., 2016). A study by Kerski (2003) opposed those fears, as GIS did not appear to enhance inequities between students.
In addition to spatial reasoning concerns, the complexity of GIS systems can pose a challenge to the implementation of GIS in the classroom, as many teachers lack the skills to do so (Bednarz & Van der Schee, 2006). However, in recent years, GIS have overcome parts of their complexity due to

technological developments and user-friendly designed interfaces (Bearman et al., 2016). In particular, the advent of web-based GIS applications presented a simpler version of the bulky desktop applications by providing only a subset of the analytical tools, which simplified the integration into the classroom (Kerski & Baker, 2019).

As the use of GIS in the classroom still requires a wide range of competencies, teacher training is crucial in the advent of GIS in high schools. According to the study by Kerski (2003), teachers need more support for the training and implementation of GIS. Additionally, many available training possibilities focused on the functioning of GIS, while the application is sparsely didactically reflected (Herzig, 2007). Further, inadequate skills of teachers in technology, data, and geospatial ideas have been identified as a reason for not using GIS (Johansson, 2003). This lack of skills can lead teachers to see GIS solely as a tool for creating digital maps without diving into complex spatial analyses, wherefore they may not see the value it can bring to the classroom (Herzig, 2007).

Also, the availability of teaching material can considerably influence the use of GIS. As the creation of relevant teaching content is very time intensive, and especially less-than-knowledgeable teachers are dependent on guidance, a lack of easily implementable and ready-to-use material can hinder the deployment of GIS (Bednarz & Van der Schee, 2006; Johansson, 2003; Kerski, 2003). The positive influence of available teaching material on the application of GIS in the classroom has been observed by the introduction of the first textbook of GIS-based lessons for precollegiate instruction in the United States by Malone, Palmer, and Voigt (2002), "Mapping Our World" (Bednarz & Van der Schee, 2006; Kerski, 2003; Kerski & Baker, 2019).

The deployment of GIS applications in the classroom emphasizes teaching arrangements that rely on discovery, independent, and problem-oriented learning (Falk & Hoppe, 2004; Herzig, 2007). Therefore, GIS applications are suited to help teachers implement constructivist and inquiry-based learning environments (Johansson, 2003). Helping students develop time-appropriate media skills and preparing them for lifelong learning is inevitably linked to learning environments emphasizing self-directed learning processes, which are inherent to constructivist teaching (Falk & Hoppe, 2004). Further, inquiry-based learning methods are desirable, as they enhance students' autonomy, which can positively influence their motivation (Woolfolk, 2014). Besides the general advantages of constructivist teaching methods, GIS can support active knowledge construction, especially in problem-based settings, through complex information processing and high-quality interaction (Falk & Hoppe, 2004). Still, inquiry-based learning also has some downsides, as lessons become more challenging to plan and control, and results are hard to foresee. If they are used, there must be a high tolerance for uncertainty and an urge to change the traditional school environment (Herzig, 2007; Kerski, 2003). Further, for instruction to be successful, teachers must have good background knowledge and problem-solving skills (Kerski, 2003).

GIS also offers the opportunity to carry out project-based teaching, which builds up media skills and develops the ability to work in a team. Thus, a contribution can be made to higher educational goals, such as dealing with technologies in the information and knowledge age (Falk & Hoppe, 2004). Unfortunately, regular school structures are not well-suited for longer projects due to frequent interruptions in the work process, resulting in time loss, wherefore project weeks should be preferred for such (Herzig, 2007; Falk & Hoppe, 2004).

In general, constructivist methods of teaching often require more time resources than traditional teaching methods. This is amplified by one of the main challenges of GIS in the classroom, being its time-intensive nature for both preparation and implementation of lessons (Falk & Hoppe, 2004; Kerski, 2003). As time resources allocated to geography are limited, teachers must constantly manage restricted resources and available time when planning and implementing lessons (Herzig, 2007; Johansson, 2003). Therefore, teachers often experience a lack of time for developing and executing GIS-based lessons (Falk & Hoppe, 2004; Kerski, 2003). Further, the complexity of GIS software often leads to unforeseen delays due to technical problems or training periods, which take more time than expected (Herzig, 2007).

One of the literature's most often named advantages is that GIS itself is relevant and can be used to address issues relevant to the real world (Bednarz, 2004; Walshe, 2018). It has been shown that students' motivation is increased by connecting teaching material with topics that are meaningful to their lives (Woolfolk, 2014). Because of the students' constant contact with technologies, many with spatial nature, the use of GIS connects directly to their lifeworld (Falk & Hoppe, 2004). Additionally, GIS allows the creation of a real-world problem-solving environment by relying on field data, satellite images, and maps, giving students insights into complex processes of the real world (Kerski, 2003). The reference to everyday life can even be improved if topics relate to the student's immediate environment. GIS offers the possibility to integrate self-collected data into projects, which enables this connection (Herzig, 2007; Johansson, 2003). It is, therefore, not surprising that teachers perceive real-world relevance as one of the essential benefits of GIS in the classroom (Kerski, 2003). Still, one must be aware that using self-collected data comes along with high time expenditures due to data collection and processing.Therefore, working with prefabricated data can sometimes be beneficial, as their use is more time efficient during preparation and in class. Nevertheless, this can be accompanied by lower student identification resulting in smaller motivation (Herzig, 2007; Johansson, 2003).
In addition to the connection to students' lifeworld, GIS is a relevant topic as it has a general educational value. This is because handling computer-based geo-information is seen as a basic competence of a modern information and communication society (Strobl, 2004). Further, GIS can enhance students' creativity and technological know-how by allowing them to practice the manipulation of graphics, charts, and maps, beyond the capabilities of normally used spreadsheet and presentation tools (Johansson, 2003; Kerski, 2003). Moreover, GIS offers the opportunity to teach methodological skills that are essential in real life and at work (Herzig, 2007; Johansson, 2003). In general, studies have found that using GIS could increase students' motivation and interest in geography (Kerski, 2003). Besides the above-mentioned real-world relevance, this can be explained by students' interest in acquiring new and previously unused technologies.

In addition to the already mentioned constraints for a GIS implementation, other factors such as hardware, software, and data availability were mentioned in the literature. In recent years, the accessibility to those resources has drastically increased in developed countries (Kerski, 2003; Walshe, 2018). Already in the early 2000s, technological accessibility had increased to a level where the usage of GIS was more dependent on teachers' adaptability rather than the accessibility to technology (Kerski, 2003). In addition, web-based GIS allow access to anyone with an Internet connection, eliminating

hardware requirements that had to be met to install the desktop versions. Furthermore, access to data has increased due to the advent of open data, which enabled easy and often cost-free access to data (Kerski & Baker, 2019). Still, this may not be the case in all countries of the world.
Further, as mentioned above, the availability of curriculum materials can also play an important role in teachers' practice, but the value teachers attribute to the content is decisive for its use, especially if GIS is not anchored in the curriculum (Kerski, 2003; Powell, 1999; Bednarz & Van der Schee, 2006). Previous studies have shown that in addition to external factors, internal factors also influence the use of technology in the classroom. This refers, among other things, to the value a teacher attributes to a technology for supporting instruction and learning (Bednarz & Van der Schee, 2006; Gómez-Fernández & Mediavilla, 2022; Hughes, 2005; Scherer et al., 2015). Further it includes, the personal characteristics of teachers, including prior knowledge, interests, and beliefs about an issue, attitudes towards a technology as well as technical skills and pedagogical style, are of importance (Bednarz & Van der Schee, 2006; Gómez-Fernández & Mediavilla, 2022; Murphy & Alexander, 2004; Shin, 2017).

2.3 GIS in Switzerland's High School Education

In the following subchapter, the use of GIS at Switzerland's high schools for education will be discussed. Further, teaching material, software, and data, which are available for use in German-speaking GIS lessons in Switzerland, are presented. Thereby, the focus is set solely on high-school education.

In Switzerland, already at the end of 2003, licensing agreements were concluded with Esri to ensure nationwide GIS use at high schools. At this time, the first cantons and high schools started including GIS in their curricula (Herzig, 2007). In 2006, the first book comprising teaching material "*Geografische Informationssysteme (GIS) - Grundlagen und Übungsaufgaben für die Sekundarstufe II*" (Geographic Information Systems - Basics and Exercises for Secondary Level II) was published by Treier, Treuhardt Bieri, and Wüthricht (Herzig, 2007; Stark & Treuthardt, 2012; Treier et al., 2006). Still, only one-third (44) of all secondary schools in Switzerland were using GIS in 2012, and the use of GIS was mainly attributable to dedicated teachers who advocated for its use (Stark & Treuthardt, 2012).
To the best of my knowledge, no recent study makes statements about the use of GIS in Swiss high school education. Therefore, Swiss high school curricula were examined to gain insights into the extent to which GIS is anchored in the curriculum and consequently to which teachers are obliged to use GIS for their lessons. In Switzerland, a national framework curriculum roughly defines what must be taught and learned in high schools. Since this curriculum provides rather general guidelines for orientation, these need to be further specified. This specification is regulated by every canton individually, and either happens on a cantonal or high school level (EDK, 2022a). Based on the cantonal websites listed on the website of the "*Conference of Cantonal Directors of Education*" (EDK), it has been determined how this specification is carried out in each canton (EDK, 2022b). These websites revealed that a cantonal curriculum is issued in half of the 26 cantons. In contrast, in the other half, the responsibility for developing a curriculum lies with the individual schools. *Figure 2.2* shows a map that indicates whether the responsibility for issuing the curriculum lies with the canton or with the individual high schools.

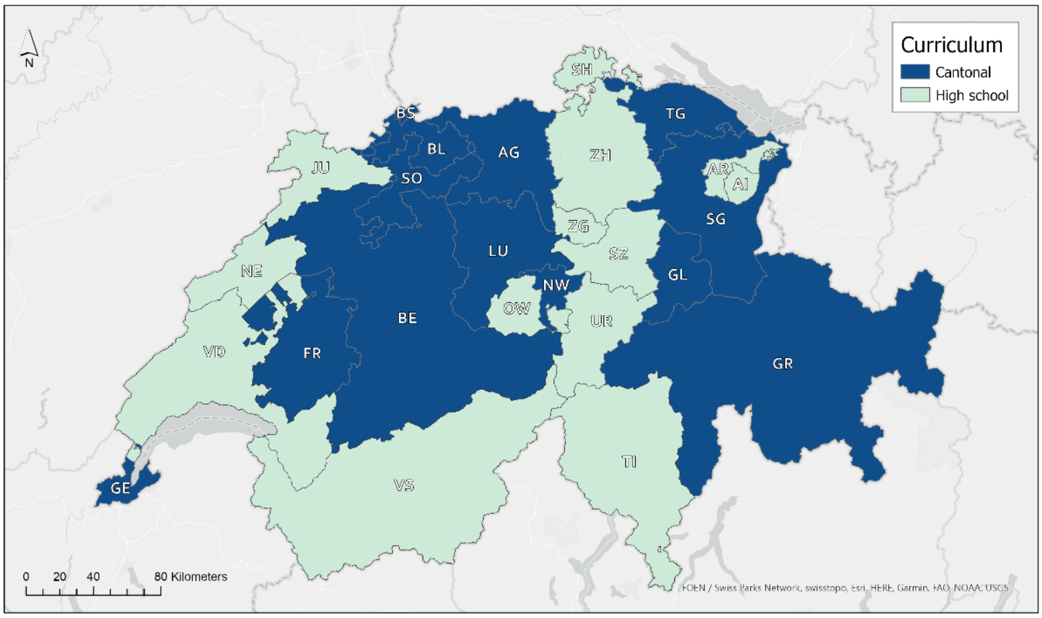


Figure 2.2: *Map showing if the responsibility for issuing the curriculum lies with the canton or the high schools. The map has been created with ArcGIS Desktop based on information extracted from the website of EDK and a boundary layer provided by Esri (EDK, 2022b; Esri, 2022a).*

In September 2021, 166 high schools existed in Switzerland (SBFI, 2021), out of which 69 had to define their own curriculum.

The national framework curriculum mentions that students have to learn geographic visualization methods and should learn how to analyze the interaction of geographic phenomena. As it is not specified how those goals are reached, and an explicit mention of GIS is missing, it is impossible to predict to what extent GIS is taught at Swiss high schools without studying all curricula (EDK, 1994). As this would go over the scope of this Master Thesis, only the curricula of the 13 cantons responsible for issuing the high school curriculum were studied. Thus, the cantons studied were Aargau, Bern, Basel-Landschaft, Basel-Stadt, Fribourg, Geneva, Glarus, Graubünden, Luzern, Nidwalden, Solothurn, Sankt Gallen, and Thurgau. In the cantons of Bern and Fribourg, two curricula were analyzed since there existed, one for the German-speaking part of the canton and one for the French-speaking part. This is why a total of 15 documents were analyzed, which could be found on the respective cantonal websites (EDK, 2022b). Attention was paid to whether GIS is explicitly mentioned in the curricula as a learning content of the basic subject of geography. Further, it was also noted if the analysis and visualization of geographic information are mentioned in the curriculum.

From the analysis emerged that the cantons Aargau, the German speaking part of Bern, Basel-Landschaft, Basel-Stadt, Glarus and Solothurn have included GIS in their curriculum. The analysis of geographic information was mentioned in all documents except for the one from Nidwalden. Further, the visualization of data was mentioned in 13 curricula, except for those of Geneva and Nidwalden.

In *Table 2.1*, the results of the analysis are summarized by listing cantons that included one of the topics in their curricula. In *Appendix A*, a more detailed overview of the analysis can be found.

Table 2.1: *Cantons that included GIS, data analysis, and data visualization in their curricula*

GIS	Data-Analysis	Data-Visualization
Aargau, Bern (German), Basel-Landschaft, Basel-Stadt, Glarus, Solothurn	Aargau, Bern (German), Bern (French), Basel-Landschaft, Basel-Stadt, Fribourg (German), Fribourg (French), Geneva, Glarus, Graubünden, Luzern, Solothurn, Sankt Gallen, Thurgau	Aargau, Bern (German), Bern (French), Basel-Landschaft, Basel-Stadt, Fribourg (German), Fribourg (French), Glarus, Graubünden, Luzern, Solothurn, Sankt Gallen, Thurgau
Number of documents: 6	Number of documents: 14	Number of documents: 13

Based on this analysis, only in 6 cantons can it be firmly assumed that GIS is part of the basic geographic education of high schools. No reliable statements can be made for the other high schools, especially those that create their own curricula. Furthermore, it can be assumed that there are teachers who use GIS, although it is not explicitly mentioned in the curriculum. This may be mainly the case because it is a suitable means to teach students how to analyze and visualize data, which are concepts inherent to almost all cantonal curricula. In order to gain a deeper insight into to what extent and how GIS is actually used in Switzerland's high schools, a survey was conducted. The results of this survey can be found in Chapter 4.

2.3.1 Teaching Material

It is a general problem that teachers have little time for planning and implementing innovative teaching concepts (Räber et al., 2021). For this reason, it is assumed that the availability of teaching material is an essential factor influencing the introduction of GIS to the classroom. Therefore, in this chapter, the best-known sources for teaching materials in the German-speaking region are presented. The sources presented are either officially published teaching aids like books and journals or teaching material that is available online and can be found on Google.

This section briefly presents officially published teaching aids that are prominent in Switzerland. The first teaching aid, "*Geografische Informationssysteme (GIS) - Grundlagen und Übungsaufgaben für die Sekundarstufe II*" (Geographic Information Systems - Basics and Exercises for Secondary Level II) by Treier et al. was launched in 2006 (Herzig, 2007). It was aimed to facilitate the introduction to GIS and contained theoretical introductions for teachers and exercise lessons that can be worked on with ArcView 9. As it has not been revised since 2009, the contents are now outdated due to the further development of the Esri software (Treier et al., 2006).
Another source for German teaching material is the paid booklet "*Praxis Geographie*" (Practice geography), which provides lessons from the 5th grade onwards, and has repeatedly included teaching units with GIS (Westermann, 2022). As early as 2003, the first teaching unit that included GIS was published in one of the journals (Herzig, 2007; Hoppe, 2003).
Further, teaching material on current topics in geography is provided in the didactic journal "*Geographie Heute*" (Geography Today). The booklets contain, among other things, worksheets with current

data and map material (Friedrich Verlag GmbH, 2022). Already in 2001, the first teaching unit on GIS was published (Herzig, 2007; Mund & Schäfer, 2001).

In the following results of the two search queries, "GIS Unterrichtsmaterial" (GIS teaching material) and "GIS Schule" (GIS School) are discussed. Therefore, the results presented do not include all possible teaching aid sources but rather those that can be found within a small amount of time. Esri offers the "*Esri Schulprogramm*" (Esri School Program) for German-speaking countries, which provides teachers with tutorials about their technologies and various teaching materials that can be used free of charge (Esri Suisse, 2022). Esri has been committed to the spread of GIS use in schools for a considerable time. This was expressed not least in the licensing agreements made with Swiss schools in 2003 (Herzig, 2007).
The "*PH Bern*" provides various teaching materials for classes from the 7th grade onwards. Besides an introductory GIS course, they provide topic-specific worksheets with the corresponding solutions for ArcGIS Online. They further refer to the ArcGIS Online tutorials provided by Esri and the page where school accounts can be created for using the Esri products (PH Bern, 2022).
On top of that, the website "*Die deutschen Bidlungsserver*" (The German education servers) has its own search engine called "*EliXier*", explicitly designed for educational media, providing a list of links to existing GIS educational materials. However, some of the material is only available for a fee, and some links are outdated (Die deutschen Bildungsserver, 2022).
A section about GIS can also be found on the website "*Zum unterrichten*" (To teach). Among other things, tutorials for working with QGIS or another desktop GIS are offered. There are also many links to teaching material and data that can be used for projects (Zum Unterrichten, 2022).
Moreover, a series of articles by "*Klett*" about GIS in the classroom could be found. In these articles, didactic aspects of the use of GIS were highlighted on the one hand. On the other hand, the use of GIS for teaching urban development models was shown (Schober, 2015).
Another website of **Esri** was found by using the first search query, which offers a lesson gallery that provides short and longer self-learning units on the use of their products. These are not explicitly designed for the school context but offer the possibility for students to work independently on a topic. In addition to purely technical units, lessons are offered about topics that are part of the geography curriculum (Esri, 2022b).
Another site that provides teaching material and ideas on various topics is "*SchulGIS*". Besides teaching material on curriculum-relevant topics, short introductory articles about GIS, related applications, and geodata are available. Further, links to other websites providing teaching material are listed (Sailer, 2022a).
Furthermore, "*OpenSchoolMaps*" can be found, which is a website that offers various teaching materials and partly the corresponding solutions, which can be downloaded in German, English, and French. They refer to OpenStreetMap, uMap, Apache Superset, and QGIS3. The teaching material's primary focus is learning how to use the different applications (OpenSchoolMaps.ch, 2022).
A website providing introductory material for QGIS that guides through the program with embedded exercises could also be found. Besides a general introduction to GIS, technical skills in QGIS are taught As the teaching unit is no longer maintained and operates on a outdated QGIS version, adjust ion

would be needed in order to use it would need to be adjusted for use (Creative Commons, 2022; Web-Archiv, n.d.).
The "*Digital Learning Hub Sek II*", provides a teaching unit consisting of two parts. Basic knowledge and GIS skills are taught in the first part, while in the second part, those are practiced with ArcGIS Online, within the context of geology. The complete unit can only be accessed with a Moodle account of a Swiss high school (Schubiger et al., 2022).

Especially in the digital age, teaching materials that are made available online are becoming increasingly important. Overall, it can be said that there is a wide variety of teaching materials, most of which are available free of charge, some related to curricular content. However, most lack didactic processing, and solutions are not always available. In addition, some of the materials need to be updated, so teachers would have to revise them before using them.

2.3.2 GIS Software

As already mentioned, a GIS enables the collection, management, modeling, analysis, visualization, and interpretation of spatial data. There are different types of GIS; among other things, a distinction is made between desktop and web GIS. While desktop GIS must be installed locally and offer a wide range of analysis functions, web GIS can be accessed on the Internet without installation. Therefore, hardware requirements can be neglected when using web-based GIS, and students can use the tool on their own devices (Kerski & Baker, 2019). Compared to desktop GIS, web GIS offer limited possibilities for data processing. While the limited capabilities of web GIS are often listed as a disadvantage, it can also be an advantage in the field of education (Kerski & Baker, 2019; Kerski et al., 2013). According to Kerski and Baker (2019), features provided by web GIS, such as buffer, overlay, and filter, are the functions used most by educators in any case. The abundance of features in desktop GIS can become a burden in this environment, sometimes preventing the use of GIS in the classroom altogether (Kerski & Baker, 2019). In the following, some examples of desktop and web GIS are presented, which are available in Switzerland and can be applied for free by high schools.

The two most prominent desktop GIS, available for free at Swiss high schools, are presented hereafter. The first desktop version is "*QGIS"*, an open-source GIS that is freely available and can be downloaded from the Internet. It contains tools to view, edit, and analyze spatial data (Creative Commons, 2022).
The second desktop version is "*ArcGIS Desktop"*, which is a chargeable GIS application developed by Esri. In Switzerland, schools have free access to this application due to license agreements. It provides the basis to create, analyze and manage geographic data (Esri, 2022c).

In the following, some web GIS applications frequently used in Switzerland are presented. "*ArcGIS Online"* is a chargeable web GIS provided by Esri, but it is free for schools. Besides essential tools of online maps like zoom, pan, and a search function, it allows one to visualize data according to one's needs. It also provides more advanced analysis functions such as creating buffers, identifying hot spots, and filtering data. Nevertheless, it offers fewer functionalities than the desktop version "*ArcGIS Desktop*" provided by Esri (Esri, 2022d).

"Map.geo.admin.ch" is a free web GIS that allows the display of various predefined data layers from swisstopo on a map. Information ranging from historical maps, temperature, and precipitation data to population and economic data is available. The web GIS allows measuring distances and areas, setting points and lines, and adding text. Created maps can be exported. It further enables the import of own data and to make comparisons with the help of a slider (swisstopo, 2022).
Besides the web GIS applications mentioned above, most Swiss cantons and some municipalities provide their own GIS browser. For example, the canton of Zurich has a GIS browser that provides various data that can be displayed on a map. Besides the basic functions of web maps, the browser also provides tools for measuring or drawing, and the created maps can be downloaded (Kanton Zürich, 2022).

Switzerland's high schools have free access to several Desktop and web GIS versions. On the one hand, desktop versions allow for in-depth analysis of geographic data, which might be exceptionally well suited for more extended project works. On the other hand, web GIS offer a less complex approach to integrating GIS into the classroom, which suits the purpose of everyday teaching.

2.3.3 Data Sources

Due to the advent of open data, there is a vast amount of freely available data on the Internet. Some data sources providing local and global data that Swiss high schools can freely use are presented in the following.

The "*Living Atlas*" is a database provided by Esri, which can be accessed by subscription only. Due to the license agreements with Switzerland's schools, the database is also available for educational purposes. They provide information from around the globe and Switzerland-specific data, such as economic or environmental information (Esri, 2022e).
Further, "*Swisstopo*" makes its administrative data available for free use. The data can be obtained from their website or from map.geo.admin.ch, and exclusively Switzerland-wide information is provided including, historical and weather data or traffic networks (Landestopographie, 2022).
Moreover, data can be retrieved from "OpenStreetMap", a community-driven online mapping service that provides global data about roads, buildings, public transport stations, and much more. This data can be downloaded for free and integrated into GIS applications (OpenStreetMap contributors, 2022).
Besides the mentioned data sources, many cantons offer regional data on their websites. For example, the canton of Zurich provides free and chargeable geodata on geolion.zh.ch (Kanton Zürich, 2022).

In general, a wide range of spatial data is available online for free use in Switzerland. The offer ranges from a global to a local scale, which allows the processing of different geographical questions. However, integrating the available data into a GIS can be challenging and requires technical knowledge.

Chapter 3 Methods

In order to learn more about the use of GIS in Switzerland's high schools, a survey was conducted. According to Janes (1999), surveys are a good way, sometimes even the only way, to gather information on the current state of a group of people. Further, they can provide a snapshot of how things are at a certain point in time (Janes, 1999; Kelley et al., 2003). Still, one has to keep in mind that a survey is time-consuming for both the creator and the participants. Therefore, surveys should only be used if the information gathered is valuable, has not been acquired by a similar survey, or is available in another way (Janes, 1999). As, to the best of my knowledge, no current information on the use of GIS in Switzerland's high schools exists, a survey seemed the only way to get a quantitative and qualitative overview of its use. The conducted survey falls under descriptive research, as it aimed to gather information about the current use of GIS at Swiss high schools and how teachers can be supported in using GIS by determining the challenges and advantages of GIS in the classroom. The use of GIS was then set into context by describing associated external and internal factors, as it has shown that both can influence on the use of GIS in the classroom (Bednarz & Van der Schee, 2006; Hughes, 2005; Murphy & Alexander, 2004). The availability of software, the presence of GIS in the curriculum, if geography is the first teaching subject, the age of a teacher, and the teaching experience, served as external variables. Internal variables were depicted by teachers' agreement with statements about GIS, data visualization, and analysis, including their perception of their own knowledge on those topics. The information about where teachers need to be supported in order to use GIS was used to concept a teaching unit according to their needs, which is presented in Chapter 5.

When designing the survey, the general principles of survey design were followed. Thereby, the survey was primarily oriented by the guidelines listed by Janes (1999) and a similar study conducted by Johansson (2003) in Finland. According to Janes (Janes, 1999), good survey questions are related to the problem at hand, clear, unambiguous, short, precise, not leading, and answerable. In order to meet these requirements, double-barreled and negative formulations of questions were avoided (Janes, 1999; Johns, 2010). Further, definitions of special terms are desirable to avoid confusion (Janes, 1999). For this reason, a definition of what is meant by the use of GIS for teaching was given at the beginning, which was defined as follows: "A system that enables the collection, processing, organization, analysis and visualization of spatial data is used (e.g., ArcGIS, QGIS or map.geo.admin.ch). In this study, the mere viewing of online maps is not considered as GIS use."

In literature, it is discussed if participants should be given an option not to answer a question in case they do not know or want to answer. The problem with this is that missing values are generated when such an option is selected. Further, it could be misused by participants who want to finish the survey as quickly as possible. Nevertheless, to avoid biased results if people are forced to choose an answer or abandon the survey, it was decided to include an "I do not know / No answer" option for most of the questions (Couper, 2008; Schuman & Presser, 1996).

In the following, the survey is discussed in more detail by taking a closer look at the hypotheses, the target group, the structure of the survey, and the methods I used to analyze the results.

3.1 Target Group

The survey's target group is all geography teachers who teach at a Swiss high school. Since this was the only requirement, no focus was placed on the gender or age distribution of the target group. In order to have geography teachers from the whole of Switzerland represented in, the survey was conducted in German, French, Italian, and English. Due to a lack of skills, the survey could not be translated into the fourth national language, Romansh. Since most Romansh speakers grow up bilingual or at least learn another national language at school, these teachers should still be able to answer the survey. However, the survey was translated into English to be on the safe side and include teachers from international schools.
The published list from the SBFI (2021) containing recognized high schools was used to reach Switzerland's high school geography teachers. Additionally, the high schools listed on the website "gymnasium.ch" were used to complete the list (Internetgalerie AG, 2022). Then, whenever possible, the teachers' e-mail addresses were extracted from the respective high school's website. If no e-mail addresses were provided, that of the school's secretariat was used. Hence, 417 e-mail addresses of geography teachers and 78 e-mail addresses of the secretary's offices were obtained. Thus, geography teachers from all over Switzerland could be invited to participate in the survey.

3.2 Survey Structure

In this part, the structure of the survey is discussed. Overall, the survey consisted of four blocks of questions to enlighten different aspects of GIS use in the classroom. The order of the groups of questions was defined based on recommendations from the literature. It is recommended to start with interesting questions that allow easy entry into the survey. This helps the participants to get into the topic and may encourage them to complete the survey. Afterward, more challenging and personal questions can be asked. Demographic questions should be posed at the end of the survey because they are often perceived as less interesting and are quick and eager to answer (Janes, 1999). For this reason, the survey started with general statements about perceptions of GIS in high school, followed by more specific questions about whether and how GIS is used in one's classroom. Those were followed by some open-ended questions to gather a deeper insight into teachers' thoughts, while the demographic questions were left for the end. A detailed overview of the individual question blocks can be found below. In order to have a look at the entire questionnaire, please refer to *Appendix B.*

3.2.1 Question Group 1: Attitudes Toward GIS, Data Visualization and Analysis

This group of questions aimed to find out more about teachers' attitudes toward GIS, visualization, and analysis, thus identifying internal factors that might influence the use of GIS in the classroom and contributing to answering research question two (RQ2).

For this reason, respondents had to indicate how strongly they agreed with 10 statements on a Likert scale from one to seven. According to Weijters et al. (2010), seven-point scales are suitable for participants with high cognitive ability and experience with questionnaires. As the survey was only sent to high-school teachers having at least a master's degree, a seven-point scale was used, thus allowing the possibility of a neutral answer. There is some debate in the literature as to whether a neutral option is advantageous. On the one hand, a neutral midpoint is recommended so that participants are not forced to agree or disagree with a statement if they do not have a clear opinion. If this would not be given, reduced data quality and annoyed participants could be the result. On the other hand, it can be helpful if participants have to choose a side, especially when controversial topics are discussed. Otherwise, it has been shown that they tend to choose the neutral middle when they would otherwise respond in a socially less acceptable way (Johns, 2010). As it is assumed that teachers can have a neutral agreement on one of the statements and no controversial topic is discussed, a neutral midpoint was offered. Further, to be able to directly summarize the answers by using means, percentages, and comparable measures for indicating the average agreement on a statement, a neutral midpoint has to be given (Carifio & Perla, 2008; Chyung et al., 2017). Moreover, an option for undecisive participants and a fully labeled scale is recommended, wherefore this was implemented in the survey as well (Chyung et al., 2017; Weijters et al., 2010).

3.2.2 Question Group 2: The Use of GIS in the Classroom

Question group two consisted of questions to determine if and how teachers use GIS in the classroom, but also about some external factors that might influence the use of GIS, thus providing answers to research question one (RQ1) and research question two (RQ2). Whenever possible, and a logical preset of answers could be defined, single- and multiple-choice questions were used, as they are easier to evaluate than open questions (Janes, 1999; Kelley et al., 2003). Open questions were used if it was impossible to define a pre-set of answers as they were too numerous or unknown. In this block of questions, conditions were used to ask more in-depth questions to participants who gave specific answers. For example, teachers who used GIS were asked more in-depth questions about how they applied it, while teachers who did not were asked why they did not.

3.2.3 Question Group 3: Open Questions

This question group consisted of four open questions allowing the participants to share their thoughts more comprehensively. The answers to these questions were mainly intended to find out more about the perceived advantages and disadvantages of GIS in the classroom and where teachers need for support, thus providing answers to research question three (RQ3).

3.2.4 Question Group 4: Demographic Information

The last question group consisted of demographic questions about teachers' age and experience, education, and the cantons in which they teach. Those questions were intended to help place the teachers' responses into a larger context and to determine dependencies between demographic information and the use of GIS in Swiss high schools, consequently providing answers to research question two (RQ2).

The years of experience a teacher has were grouped according to the phase model of Hubermann (1991) presented by Messner and Reusser (2000), which can be found in *Figure 3.1*. This model was chosen because it helps to assess how teachers with different work experiences behave. Thus, the results can be better classified and analyzed. The different stages are described in more detail below.

According to Hubermann's phase model (1991), the first three years can be identified as the career entry, where teachers are in a state of survival and discovery. Between the fourth and sixth year of experience, there is stabilization, followed by the seventh to eighteenth year, where teachers start to experiment or re-evaluate their teaching. In the following years, serenity, or conservatism, follows, which finally results in disengagement between the thirty-first and fortieth year of experience (Messner & Reusser, 2000).

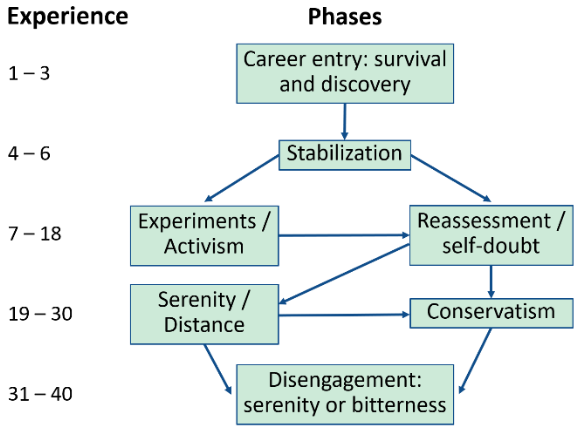


Figure 3.1: *Phase model according to Huberman presented by Messner and Reusser translated to English (Hubermann, 1991; Messner & Reusser, 2000).*

3.3 Coding Scheme for Open Questions

A qualitative approach was used to analyze the open-ended questions. The questions were developed to determine for what topics GIS is suited, where teachers see benefits and challenges of GIS in the classroom, and how they can be supported in using GIS.

Of the qualitative methods, structuring content analysis was the best suitable method. A content-structuring analysis aims to identify and conceptualize content-related aspects of the material and then describe the material systematically with regard to the defined aspects. In order to conduct a content-structuring analysis, the first step is to familiarize oneself with the material. In the next step, superordinate categories are derived from the research question. In the third step, subcategories of the previously defined superordinate categories are defined. Subsequently, the category system is tested and, if necessary, adjusted. Once the category system is elaborated, all material is coded. In the final step, the results are presented, interpreted, and the research question is answered (Schreier, 2014). In order to create the category scheme, codes can either be derived from theories or obtained from the data itself. A mixture of both is often used, which was also done in this case (Züll, 2015). For this work, the above-described steps were followed. The coding scheme was mainly derived from the data and partially was also based on the literature.

Chapter 4 Results

In this chapter, the results from the survey are presented. In total, 172 persons answered the survey, of whom 146 completed it. Only the results of the 146 complete answers were considered for the analysis. First, the quantitative results are shown and second, the qualitative results will be introduced. For the analysis of the results, R was used for plotting and statistical testing, Excel was used for data preparation and coding of the open questions and ArcGIS Desktop was used for creating maps.

4.1 Quantitative Results

In this section, quantitative results obtained by the survey are presented. First, the demographic information of the target group is introduced, followed by teachers' attitudes toward GIS, data visualization and analysis. Afterward, information about the number of teachers using GIS and how it is applied in the classroom will follow. Finally, factors influencing the use of GIS are shown.

4.1.1 Demographics

All but one of the survey participants were teaching geography at the time the survey was administered. This participant noted that they were only actively teaching their other subject at the time of the survey. In total, 55 teachers (37.7%) indicated that besides geography, they were teaching another subject. The distribution of the subjects taught can be viewed in *Figure 4.1*.

Overall, 123 participants (84.3%) mentioned that they teach geography in their first subject, 19 participants (13%) teach geography in their second subject, and four participants (2.7%) did not provide an answer.

GIS and GIScience were part of the studies from 97 participants (66.4%), while 47 people (32.2%) stated that they had not come into contact with GIS during their studies, and four did not answer the question.

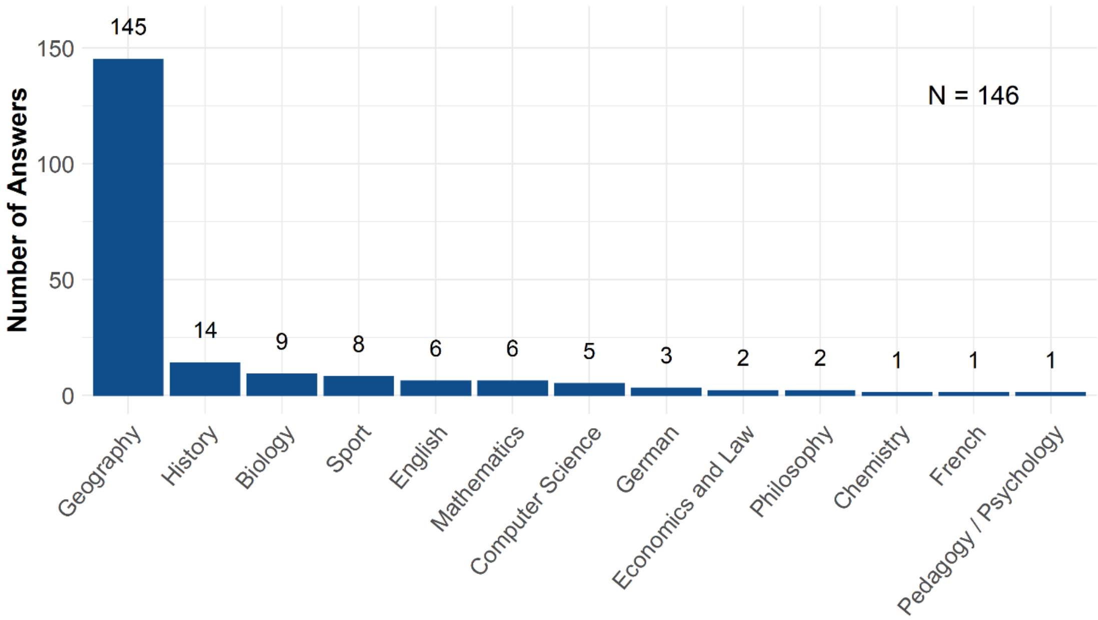


Figure 4.1: *Answers to the question: What subjects do you teach? (N= number of respondents).*

Sixteen teachers (11%) reported having less than three years of teaching experience. A total of 23 participants (15.8%) had between four and six years of teaching experience. Sixty teachers (41.1%) indicated having seven up to eighteen years of experience, while 38 participants (26%) had between nineteen and thirty-one years of experience. Only nine teachers (6.2%) reported more than 31 years of experience. The distribution of teaching experience is shown in *Figure 4.2*.
One respondent was younger than 25 years, while 24 teachers (16.4%) were between 25 and 34 years old. Most, namely 61 teachers (41.8%), were between 35 and 33 years old, while 27 participants (18.5%) were between 45 and 54 years old. A total of 33 teachers (22.6%) were between 55 and 64 years old. In *Figure 4.3*, the age distribution of teachers can be found.

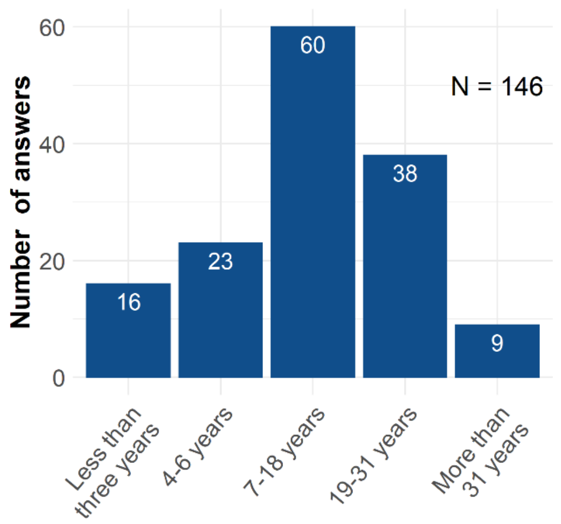


Figure 4.2: *Answers to the question: How long have you been teaching? (N = number of respondents).*

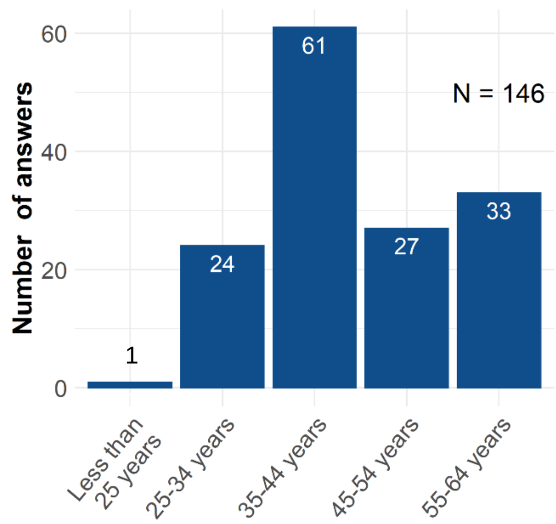


Figure 4.3: *Answers to the question: How old are you? (N = number of respondents).*

4.1.2 Attitudes Toward GIS, Data Visualization and Analysis

At the beginning of the survey, the participants were asked about their attitudes toward statements related to GIS and data visualization and analysis. Those results can be viewed in *Figure 4.4* and are presented in the following section. In *Table 4.1*, the classification of average agreement values to the original categories can be found.

Table 4.1: *Classification of the average agreement on the ten statements posed during the survey.*

Average Agreement	Category	Average Agreement	Category
1-1.4	Strongly disagree	4.5-5.4	Rather agree
1.5-2.4	Disagree	5.5-6.4	Agree
2.5-3.4	Rather disagree	6.5-7	Strongly agree
3.5-4.4	Neutral		

On average, teachers reached a value of 3 for statement 1, that there is enough time to use GIS in the classroom, indicating that they rather disagree on having sufficient time for its use.
Statement 2 reached an average agreement of 3.7 about knowing the latest GIS technologies. This shows that teachers saw the statement as neutral, with a tendency to rather disagree.
Overall, an average agreement of 3.9 was reached for statement 3, that there is enough teaching material available to integrate GIS into the classroom. This shows that teachers saw the statement as neutral, with a slight tendency to rather disagree.
On average, teachers viewed statement 4, which states that a teacher knows how to use GIS in the classroom, neutrally with a tendency to rather agree, as a score of 4.4 was achieved.

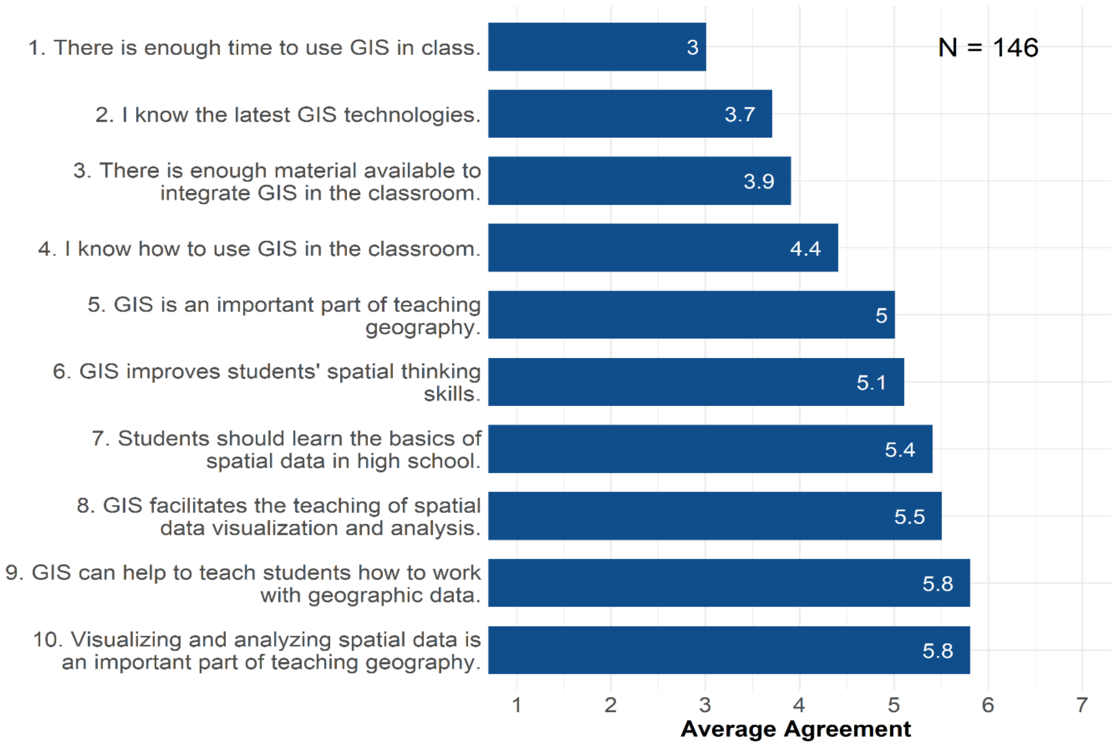


Figure 4.4: *Average agreement on a scale of 1-7 (1= I strongly disagree, 7 = I strongly agree) on ten statements (N = number of respondents).*

Statement 5 reached an average value of 5, indicating that teachers rather agree that GIS is an important part of teaching.

Overall, statement 6, about GIS improving students' spatial thinking skills, reached a value of 5.1 depicting, that teachers rather agreed on the statement with a slight tendency to agree.
With a value of 5.4, statement 7 was rather agreed on with a tendency to agree, stating that students should learn the basics of spatial data in high school.
On average, teachers reached a value of 5.5 for statement 8, that GIS facilitates the teaching of spatial data visualization and analysis, indicating that they agree with a tendency to rather agree on the statement.

Statement 9 reached an average agreement of 5.8, being that GIS can help to teach students how to work with geographic data. This shows that teachers agreed on the statement with a slight tendency to rather agree,

With a value of 5.8, teachers agreed with a slight tendency to rather agree with statement 10, stating that visualizing and analyzing spatial data is an essential part of teaching geography.

4.1.3 The Use of GIS in the Classroom

In total, 39 teachers (26.7%) indicated that GIS is part of the curriculum in the canton or high school in which they teach, which was not the case for 77 respondents (52.7%). Thirty teachers (20.6%) were unsure if GIS is a part of their curriculum.

Overall, 71 participants indicated that the school in which they teach provides GIS software, while 56 answered that their school does not provide GIS software. Nineteen teachers did not know whether software is provided.

When looking at the results to the question, if GIS is used in the classroom, 74 teachers (50.7%) answered yes, while 72 teachers (49.3%) indicated that they do not use GIS.

The percentage of GIS users per canton is depicted on the map shown in *Figure 4.5*. As two teachers were employed in two different cantons, the results of 148 answers are presented in the following.

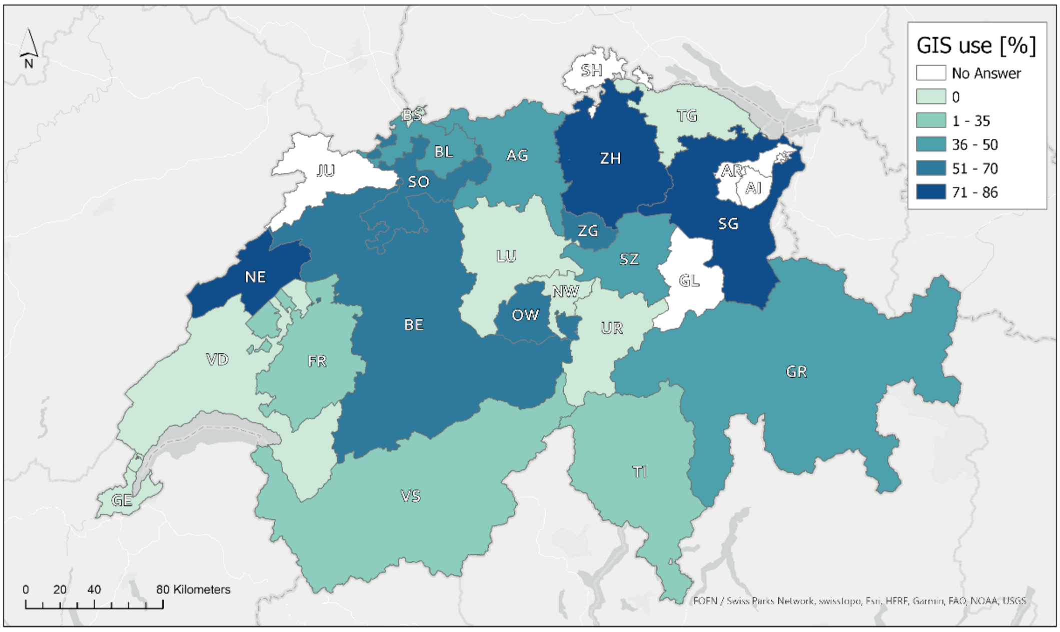


Figure 4.5: *Map showing the percentage of participants that use GIS within a canton. The map has been created with ArcGIS Desktop based on results from the survey and a boundary layer provided by Esri (Esri, 2022a)*

No answers were received from the cantons Appenzell Ausserhoden, Appenzell Innerhoden, Glarus, Jura, and Schaffhausen. In seven cantons, namely Basel Stadt, Genève, Luzern, Nidwalden, Thurgau, Uri, and Vaud, in total, 26 answers were received, but none of those respondents reported deploying GIS. In Freiburg, 17.7%, in Ticino, 16.7%, and in Valais, 33.3% of teachers use GIS. In the canton of Aargau, 38.5%, Graubünden, 42.9%, Basel Land, 50%, and Schwyz, 50% of the teachers are employing GIS. Even a higher use of GIS could be observed in the four cantons Zug at 60%, Obwalden at 66.7%, Solothurn at 66.7%, and Bern at 68.2%. The highest percentage of teachers using GIS could be found in the cantons of Zurich at 74.4%, Neuchatel at 80%, and Sankt Gallen at 85.7%.

On average, 33.3% of teachers are employing GIS in cantons with a cantonal curriculum but no mention of GIS. 53.3% of teachers use GIS in cantons with GIS as part of the cantonal curriculum, and 58.3% of the participants are deploying GIS in cantons with no cantonal curriculum. The exact number of teachers per canton can be found in Appendix C.

In the following, answers to questions that were asked explicitly to the 74 participants who use GIS in their teaching are introduced.

Overall, 58 teachers (75%) use ArcGIS Online for their teaching, nine teachers (12.2%) deploy QGIS, and eight teachers (10.8%) use ArcGIS desktop. A total of 23 teachers (32.1%) indicated that they use other GIS software such as map.geo.admin.ch, cantonal GIS, Google Earth, and more. In *Figure 4.6*, the distribution of GIS software used by teachers is shown.

Most respondents that use GIS, namely 60 (81.1%), use it during the 9th or 10th school year. Forty-five teachers (60.8%) use it between the 11th and 12th school year, while 12 teachers (16.2%) use GIS between the 7th and 8th school year. *Figure 4.7* lists the number of teachers using GIS during a specific grade.

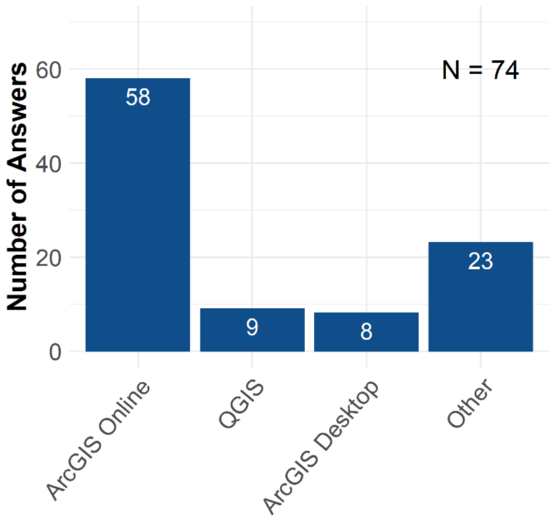


Figure 4.6: *Answers to the question: What GIS software do you use for teaching GIS? (N = number of respondents).*

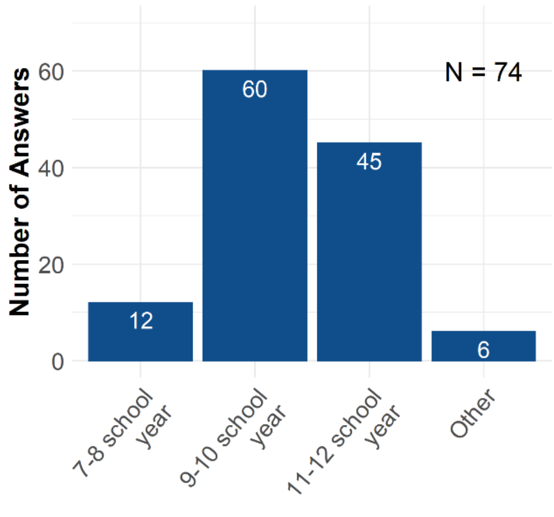


Figure 4.7: *Answers to the question: At what grades do you use GIS in your classroom? (N = number of respondents).*

To the question in what context GIS is used for teaching, more than 64 respondents (86.5%) answered that they use GIS in the basic subject of geography. Twenty-six teachers (35.1%) use it in the supplementary subject, and 17 participants (23%) use it during project weeks. Twelve teachers (16.2%) indicated that they are using GIS in another context, including excursions, matriculation projects, and natural science internships. These results are also presented in *Figure 4.8*.

To the question of whether GIS is used as a method, meaning as a means to teach other geographic content, 50 participants (67.6%) answered yes. Seventeen of the respondents (23%) indicated that they are not using it to teach other content, and seven (9.5%) did not provide an answer.

Overall, 42 teachers (56.8%) indicated that they use GIS as the main learning content during their lessons, while 27 respondents (36.5%) do not. From five teachers (6.8%), no answer was provided.
Further, 32 participants (43.2%) use GIS to prepare teaching material, while 34 respondents (46%) do not. Eight teachers (10.8%) did not answer the question.
In the lessons of 54 teachers (73%) that apply GIS in the classroom, students are using GIS software by themselves, while this is not the case for the students of 14 teachers (18.9%). Six respondents (8.1%) did not provide an answer.
In total, 56 teachers (75.7%) use self-created teaching materials for their lessons with GIS. Overall, 35 respondents (47.3%) use materials from colleagues, and 20 teachers (27.1%) use already existing materials. Twenty-nine teachers (27.1%) use other sources. Out of those, 18 teachers mentioned that they use the materials provided by ESRI. The results are also shown in *Figure 4.9*.

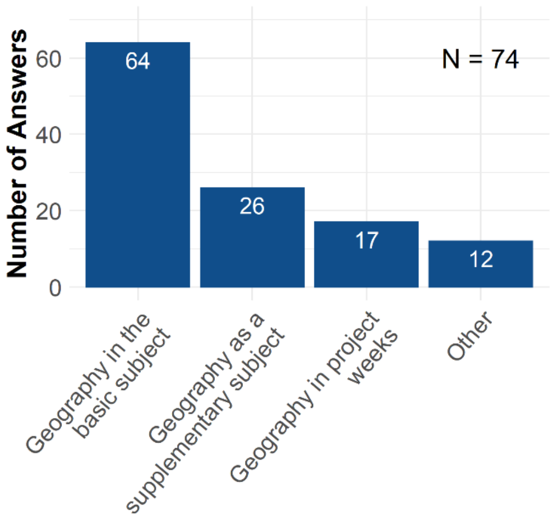


Figure 4.8: *Answers to the question: In what context do you use GIS in the classroom? (N = number of respondents).*

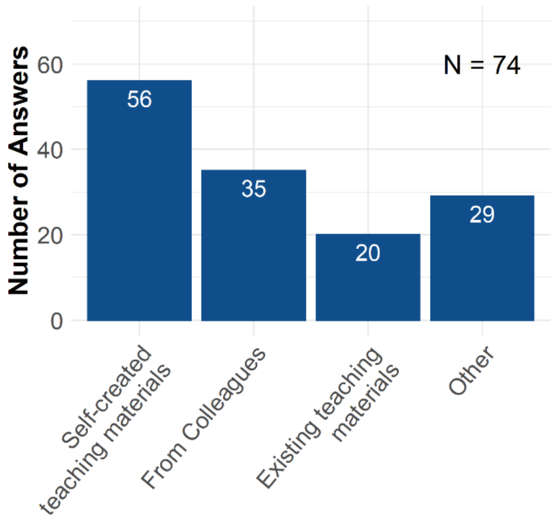


Figure 4.9: *Answers to the question: What material do you use for teaching with GIS? (N = number of respondents).*

In the following, answers to questions that were specifically asked to the 72 participants that do not use GIS in their teaching are presented.
Out of those, 18 teachers (25%) have used GIS in the past but are not using it anymore, while 54 respondents (75%) have never used it at all.
All teachers that do not use GIS were asked about the reasons why they do not, which are shown in *Figure 4.10*. The most prominent reason for not applying GIS was that there is too little time available, which was picked by 54 respondents (75%). The second most selected reason is a lack of competencies, which was chosen by a total of 50 respondents (69.4%). Thirty teachers (41.7%) selected that teaching with GIS is too much effort as a cause for not using GIS. Overall, 28 participants (38.8%) selected that there is too little available teaching material. By 19 teachers (26.4%), the missing providence of technology was chosen as a reason, and 16 participants (22.2%) picked the dependence on technology as a factor. A total of 13 teachers (18.1%) selected that they do not perceive the topic as relevant as other topics, and 12 participants (16.6%) selected a lack of training opportunities as a

reason. Ten teachers (13.8%) picked the costs as a reason, and six teachers (8.3%) had a bad experience with GIS in the past. Eight teachers selected the possibility to provide other reasons, where they listed a lack of geography lessons, a lack of time due to recent career entry, and the complexity of GIS.

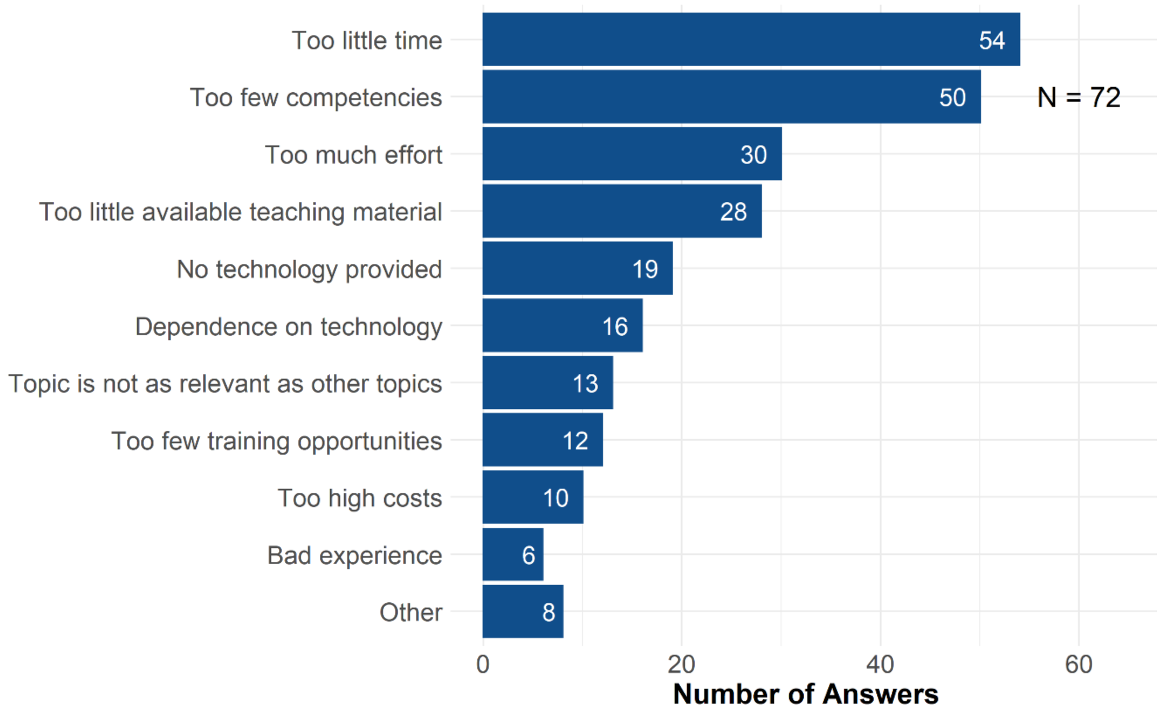


Figure 4.10: *Answers to the question: For what reasons do you not use GIS in the classroom (N = number of respondents).*

The following results were obtained by the whole study group, meaning all 146 participants.
Overall, 119 teachers (81.5%) responded that students analyze geographic data during their classes. For 16 participants (11%), this is not the case, and 11 teachers (7.5%) did not provide an answer. Out of those 119, in the classroom of 50 participants (42%), students use GIS software to analyze geographic data.

In the classroom of 106 teachers (72.6%), students visualize geographic data, which is not the case in classes of 31 teachers (21.2%). No answer to this question was provided by 9 participants (6.1%). Of those 106 teachers, 52 respondents (49.1%) let students use GIS to visualize geographic data.

Overall, in the classroom of 65 participants (44.5%), students use GIS for either data visualization, data analysis, or both.

4.1.4 Factors Influencing the Use of GIS

In order to find out what external and internal factors influence the use of GIS in high schools, Fisher's exact test was used to test for independence. This test is suited because nominal and ordinal variables were derived from the survey and because it is an independent sample. Further, Fisher's exact test can also work with small samples with lower than five values per category, which is beneficial as large sample sizes were not given for every category (Hae-Young, 2017). As for some questions, the possibility "I don't know/No answer" was given, the participants who selected this option were excluded statistical testing of that specific question.
Moreover, answers were additionally grouped into larger categories whenever few responses were achieved. This was the case for the age groups, which were the initial five groups that were summed into three groups: under 25-34 years old, 35-44 years old, and over 45 years old.
The teaching experience was also divided into three groups: 0-6 years of teaching experience, 7-18 years of teaching experience, and over 18 years of teaching experience.
Further, the agreement on the ten statements was also grouped into three groups: 1-3 for disagreement, 4 for neutral, and 5-7 for agreement.

First of all, the results of the statistical tests between the use of GIS and the external factors are presented. In *Table 4.2*, the p-values are listed, whereas those being significant are highlighted. Since Fisher's exact test does not provide information on the direction of dependency, the percentage of teachers using GIS or not was calculated based on the factors. Percentage values higher than 60% or smaller than 40% were highlighted. Those results can be found in *Table 4.3*, *Table 4.4*, *Table 4.5*, *Table 4.6*, *Table 4.7*, and *Table 4.8*.
With a p-value of 0.0106, a statistically significant correlation could be found between the use of GIS and the mention of GIS in the curriculum of the school or canton in which a teacher teaches. From the results in *Table 4.3*, it can be anticipated that the mention of GIS positively influences the deployment of GIS, as more than 70% of participants having it in the curriculum apply it. If it is not mentioned, only 45.5% of teachers employ it.
A statistically significant dependence could be found between the providence of software by the respondents' high schools and the application of GIS, achieving a p-value of $5x10^{-6}$. Regarding table *Table 4.4*, 75.6% of teachers where software is provided use GIS in the classroom, while only 33.9% of the teachers where software is not provided use it in the classroom.
A statistically significant dependence could be found between whether geography is taught in the first subject and if GIS is used in class, resulting in a p-value of 0.0269. *Table 4.5* shows that only 26.3% of teachers who are not instructing geography in their first subject use GIS in the classroom. For teachers having geography as their first subject, GIS is used by 54.5%.
No statistically significant relationship could be found between whether GIS was part of a teacher's studies, as the test resulted in a p-value of 1. This is also reflected in table *Table 4.6*, as all values are close to 50%.

Table 4.2: *Results from the Fisher's exact tests between the use of GIS and external factors. Statistically significant p - values are highlighted.*

Question	Curriculum[1]	Software[2]	Subject[3]	Studies[4]	Experience[5]	Age[6]
Do you use GIS for your teaching?	0.0106	0.000005	0.0269	1	0.4753	0.3906

[1]Is the teaching of GIS skills in the curriculum of the canton/school in which you teach?
[2]Does your school provide GIS software?
[3]Do you use GIS in your lessons?
[4]Do you teach Geography as your first subject?
[5]Were Geographic Information Systems (GIS) and related Science (GIScience) part of your degree program?
[6]How many years have you been teaching?
[7]How old are you?

With a p-value of 0.4753, no statistically significant dependence was found between a respondent's teaching experience and the deployment of GIS. The percentage values of respondents listed in *Table 4.7* reflect this as well. Only teachers with an experience level from 0-6 years, with 59% of teachers using GIS, achieved a higher value, while 48.3% of respondents with teaching experience between 7-18 years and 46.7% of teachers with an experience over 18 years use GIS in the classroom.
There could be found no statistically significant relation between the age of teachers and the application of GIS in the classroom, as a p-value of 0.3906 resulted. *Table 4.8* shows that 44% of teachers under 35 years, 57.4% of teachers between 35-44 years, and 46.6% of teachers over 44 years apply GIS for their teaching.

Table 4.3: *The percentage of teachers who do not use GIS in the classroom compared to teachers who do, based on whether GIS is part of the curriculum.*

GIS Use \ Curriculum	No	Yes
No	54.5%	28.2%
Yes	45.5%	71.8%

Table 4.4: *The percentage of teachers who do not use GIS in the classroom compared to teachers who do, based on whether their school provides GIS software.*

GIS Use \ Software	No	Yes
No	66.1%	25.4%
Yes	33.9%	74.6%

Table 4.5: *The percentage of teachers who do not use GIS in the classroom compared to teachers who do, based on whether they teach geography as their first subject.*

GIS Use \ Subject	No	Yes
No	73.7%	45.5%
Yes	26.3%	54.5%

Table 4.6: *The percentage of teachers who do not use GIS in the classroom compared to teachers who do, based on whether GIS was part of their studies.*

GIS Use \ Studies	No	Yes
No	46.8%	49.5%
Yes	53.2%	50.5%

Table 4.7*: The percentage of teachers who do not use GIS in the classroom compared to teachers who do, based on their teaching experience.*

GIS Use \ Experience	0-6	7-18	18+
No	41%	51.7%	53.3%
Yes	59%	48.3%	46.7%

Table 4.8*: The percentage of teachers who do not use GIS in the classroom compared to teachers who do, based on their age.*

GIS Use \ Experience	<35	35-45	45+
No	56%	42.6%	53.4%
Yes	44%	57.4%	46.6%

The results of the Fisher's exact test between the use of GIS and the internal factors, comprising ten statements about GIS, data visualization and analysis, are presented in the following. In *Table 4.9*, the p-values are listed, whereas those being significant are highlighted. The statements were also tested against the above-discussed external factors. Further, in order to be able to assume a direction of the relation, in *Table 4.10*, the average agreement with statements was calculated based on whether GIS is used, and those that have achieved a significant Fisher's test are highlighted. The average agreement on the statements based on whether GIS is used is further visualized in *Figure 4.11*. The classification of the average agreement values can be found in table *Table 4.1*.

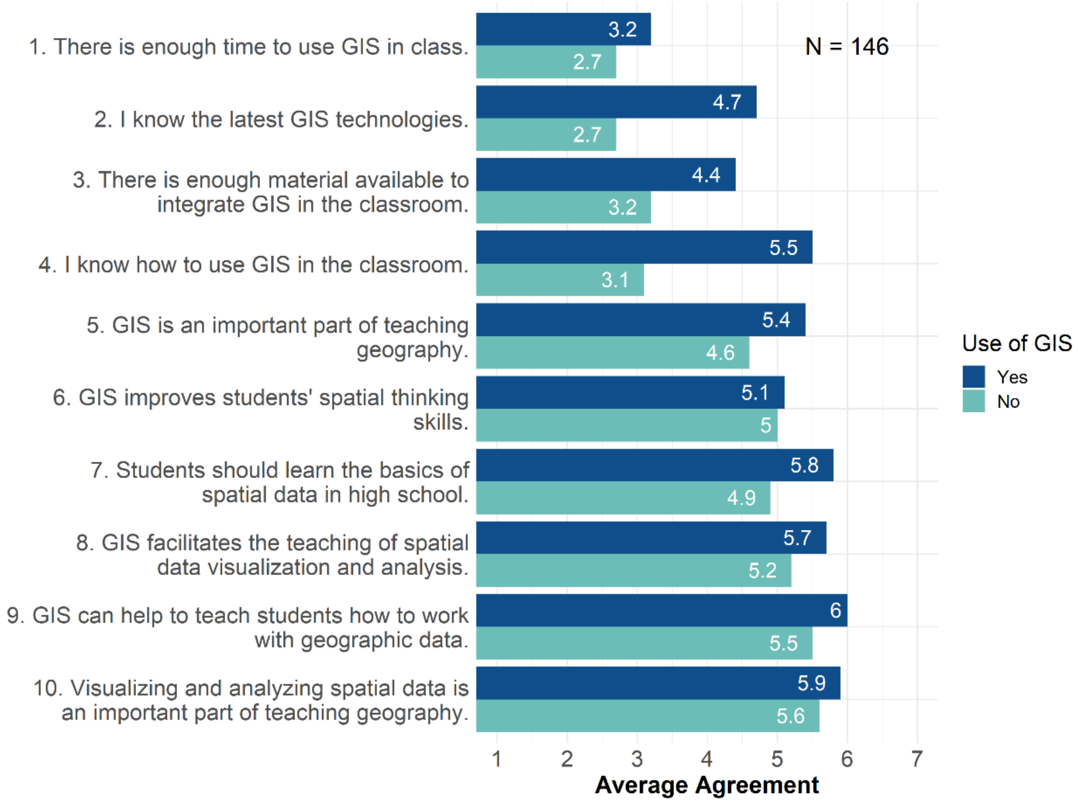


Figure 4.11: *Average agreement on a scale of 1-7 (1= I strongly disagree, 7 = I strongly agree) on ten statements split by whether GIS is used in the classroom (N= number of respondents).*

No statistically significant correlation could be found between **statement 1**, that there is enough time to use GIS in the classroom, and the use of GIS. Nevertheless, teachers using GIS achieved a higher average agreement, with a value of 3.2, than those not using GIS, with an agreement of 2.7. A statistically significant relation was found with a p-value of 0.0179 to whether GIS was part of a participant's studies and statement 1. Teachers having GIS in their studies achieved an average agreement of 2.7, while those for whom GIS was not a component achieved a value of 3.4.

A statistically significant dependence with a p-value of 0.0005 was found between the use of GIS and the agreement with **statement 2**, which was about whether teachers know the latest GIS technologies. While teachers who use GIS reached an average agreement of 4.7, teachers not using GIS achieved a score of 2.7. This statement further correlates with a p-value of 0.0005 with the availability of software, with participants who are provided with software achieving an agreement of 4.7. In contrast, those not provided with software achieved a value of 2.9. Moreover, with a p-value of 0.03298, a relation was found to whether geography is a teacher's first subject. Teachers for whom this was the case achieved an agreement of 3.9, while those for whom it was not achieved a score of 2.6. Further, a significant p-value of 0.0182 was found for a teacher's experience, with participants with 0-6 years of experience obtaining an average agreement of 4.1, those with 7-18 years 3.7, and those with over 18 years 3.2.

Statement 3, which deals with a teacher's perception that enough instructional materials are available, with a p-value of 0.001, is significantly related to the use of GIS. Teachers who use it achieved a higher agreement with a value of 4.4 than teachers not using GIS, obtaining a value of 3.2. Furthermore, a significant p-value of 0.005 was obtained regarding whether a teacher's school provides GIS software. An average agreement of 4.3 was achieved if this is, and a value of 3.2 if this is not the case.

A statistically significant dependency was found with a p-value of 0.0005 for **statement 4**, that a teacher knows how to use GIS in the classroom, to whether GIS is used. While teachers using it achieved a value of 5.5, equivalent to agree, for those who are not, a value of 3.1 resulted. Moreover, the providence of software achieved a significant p-value of 0.0005 for statement 4. An average agreement of 4.3 was achieved if it was, and a value of 3.2 if it was not.

With a p-value of 0.0009, a significant correlation was determined between the use of GIS and **statement 5**, addressing GIS being an essential part of teaching geography. While teachers using GIS obtained an agreement of 5.4, for those who do not, a value of 4.6 resulted. Further, a p-value of 0.0233 was achieved for the experience of a teacher, thus implying a correlation. Thereby, teachers with 0-6 years achieved an average agreement of 4.9, those with 7-18 years 5.2, and those over 18 years 4.9.

No statistically significant correlation was found between the use of GIS and **statement 6** that GIS improves students' spatial thinking. Teachers who use GIS achieved an average agreement of 5.1, while those who do not achieved a value of 5. With a p-value of 0.02049, a statistically significant relationship was found with whether GIS was part of a participant's curriculum. While teachers for whom this was the case achieved an agreement of 4.9, those for whom it was not obtained one of 5.2.

A statistically significant relationship was found with a p-value of 0.0025 between the use of GIS and the agreement with **statement 7**, that students should learn the basics of spatial data in high school. Here, teachers using GIS reached an average agreement of 5.8, while those not using it reached an agreement of 4.9. Further, with a p-value of 0.04198, a statistically significant correlation was found with whether software is provided. Teachers, where this is the case, achieved an average agreement of 5.7, while those where it is not achieved a value of 5.1.

No statistically significant relationship was found between **statement 8,** that GIS facilitates teaching spatial data visualization and analysis, and the use of GIS or any of the other external factors. On average, teachers who use GIS scored an agreement of 5.7, while those who do not use it achieved a value of 5.2.

A statistically significant relationship was found with a p-value of 0.0385 to **statement 9**, that GIS can help to teach students how to work with spatial data. Thereby, for teachers using GIS, an average agreement of 6 resulted, while for those who are not, an agreement was 5.5 obtained. Moreover, a correlation with a p-value of 0.0115 was found with the availability of GIS software. Teachers who are provided with software scored an average agreement of 6, while those who are not scored 5.6. Furthermore, a statistically significant relationship was found with a p-value of 0.0085 with whether geography was a teacher's first subject. For teachers where this is the case, an average agreement of 5.8 resulted, while for those having another subject as their first, a value of 5.7 resulted.

***Table 4.9**: Results from the Fisher's exact tests between the agreement with ten statements (internal factors) and the use of GIS and external factors. Statistically significant p - values are highlighted.*

	Statement / Question	GIS use[1]	Curriculum[2]	Software[3]	Subject[4]	Studies[5]	Experience[6]	Age[7]
1	There is enough time to use GIS in class.	0.4208	0.2299	0.6512	0.3358	0.0179	0.191	0.8324
2	I know the latest GIS technologies.	0.0005	0.1324	0.0005	0.03298	0.7801	0.0182	0.0905
3	There is enough material available to integrate GIS in the classroom.	0.001	0.5162	0.005	0.4633	0.5462	0.8095	0.6603
4	I know how to use GIS in the classroom.	0.0005	0.1059	0.0005	0.2919	0.5722	0.1334	0.5366
5	GIS is an important part of teaching geography.	0.0009	0.5242	1	0.1779	0.912	0.0233	0.695
6	GIS improves students' spatial thinking skills.	1	0.02049	0.2859	0.8191	0.954	0.6062	0.6873
7	Students should learn the basics of spatial data in high school.	0.0025	0.1424	0.04198	0.2389	0.4213	0.2925	0.7434
8	GIS facilitates the teaching of spatial data visualization and analysis.	0.0835	1	0.5987	0.3308	0.9425	0.3313	0.7416
9	GIS can help to teach students how to work with geographic data.	0.0485	0.0975	0.0115	0.1399	0.0085	0.6713	0.6957
10	Visualizing and analyzing spatial data is an important part of teaching geography.	0.7556	0.3453	0.7361	0.0875	0.3933	0.4307	0.103

[1] Do you use GIS in your lessons?
[2] Is the teaching of GIS skills in the curriculum of the canton/school in which you teach?
[3] Does your school provide GIS software?
[4] Do you teach Geography as your first subject?
[5] Were Geographic Information Systems (GIS) and related Science (GIScience) part of your degree program?
[6] How many years have you been teaching?
[7] How old are you?

There was no correlation found between **statement 10**, that visualization and analysis of spatial data is an important part of teaching geography, and the use of GIS or any of the external factors. Teachers who use GIS scored an average agreement of 5.9, and those who do not achieved a value of 5.6.

Table 4.10: *Average Agreement with the ten statements based on whether GIS is used or not and external factors. Highlighted are fields that achieved a statistically significant Fisher's test.*

Statement \ Question	GIS use[a]		Curriculum[b]		Software[c]		Subject[d]		Studies[e]		Experience[f]			Age[g]		
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	0-6	7-18	18+	<35	35-44	45<
1	3.2	2.7	3.2	3	3	3	3.1	3.2	2.7	3.4	3.2	2.6	3.3	3.2	2.8	3
2	4.7	2.7	4.2	3.7	4.7	2.9	3.9	2.6	3.8	3.5	4.1	3.7	3.2	3.8	4	3.3
3	4.4	3.2	4.5	3.6	4.3	3.2	3.9	3.4	3.7	4.2	3.7	3.9	3.9	3.5	3.8	4.1
4	5.5	3.1	5.1	4.3	5.3	3.5	4.4	3.8	4.4	4.3	4.7	4.4	4	4.7	4.4	4.1
5	5.4	4.6	5.3	4.9	5.1	5.1	5.1	4.7	5.1	4.9	4.9	5.2	4.9	5.1	5	4.9
6	5.1	5	4.8	5.2	5	5.3	5.1	4.9	5	5	4.9	5.2	5.1	5	5.1	5.1
7	5.8	4.9	5.8	5.1	5.7	5.1	5.4	5.5	5.4	5.5	5	5.5	5.5	5.3	5.4	5.3
8	5.7	5.2	5.5	5.4	5.6	5.4	5.5	5.3	5.4	5.6	5.1	5.5	5.7	5.1	5.6	5.5
9	6	5.5	5.9	5.8	6	5.6	5.8	5.6	5.8	5.7	5.6	5.9	5.7	5.7	5.8	5.7
10	5.9	5.6	5.9	5.7	5.9	5.8	5.8	5.5	5.8	5.8	5.6	5.8	5.8	5.6	5.8	5.8

Row header:

1. There is enough time to use GIS in class.
2. I know the latest GIS technologies.
3. There is enough material available to integrate GIS in the classroom.
4. I know how to use GIS in the classroom.
5. GIS is an important part of teaching geography.
6. GIS improves students' spatial thinking skills.
7. Students should learn the basics of spatial data in high school.
8. GIS facilitates the teaching of spatial data visualization and analysis.
9. GIS can help to teach students how to work with geographic data.
10. Visualizing and analyzing spatial data is an important part of teaching geography.

Column header:

[a]Do you use GIS in your lessons?
[b]Is the teaching of GIS skills in the curriculum of the canton/school in which you teach?
[c]Does your school provide GIS software?
[d]Do you teach Geography in your first subject?
[e]Were Geographic Information Systems (GIS) and related Science (GIScience) part of your degree program?

4.2 Qualitative Results

In this section, the results derived from the open questions are presented. For every question, a category scheme has been created relying on the data and literature. The procedure was described in more detail in chapter 3.3. Besides the identified superordinate categories, a category called "Other" has been added for every question in order to be able to track answers that did not fall within any of the defined categories or for respondents that did not provide an answer.

4.2.1 Topics Taught with GIS

The answers to the question "For which topics can GIS be used in the classroom?" will be discussed in this subsection. It was posed only to the teachers who indicated that they currently use GIS in their teaching, or who have used GIS in the past, including 92 teachers. Four superordinate categories have been determined, whereupon the subcategories of physical and human geography have been derived from the literature (Gebhardt et al., 2006), and the subcategories from interdisciplinary topics and application competence were identified from the data. An overview of the categories and their respective number of mentions can be found in *Table 4.11* and *Table 4.12*.

Table 4.11: *Categories for the question "For which topics can GIS be used in the classroom?" and the number of mentions (#). (Number of respondents = 92) – Part 1.*

Interdisciplinary Topics	#	Physical Geography	#	Human Geography	#
Spatial planning	17	Geomorphology	31	Urban geography	24
Cartography	16	Landscape and urban ecology	11	Population geography	15
For many purposes	15	Hydrogeography	10	Economic geography	14
Natural Hazards	8	Biogeography	8	Social geography	11
Change detection	7	Climatic geography	8	Geographical development research	4
Resources and Raw materials	7	Soil geography	3	Political geography	3
Total[1]	51	Total[1]	46	Total[1]	45

[1] The number of participants that mentioned at least at least one of the subcategories.

Table 4.12: *Categories for the question "For which topics can GIS be used in the classroom?" and the number of mentions (#). (Number of respondents = 92) – Part 2.*

Application Competence	#	Other	#
Data visualization	14	No answer	4
Data analysis	13		
Research projects	6		
Total[1]	28	Total[1]	4

[1] The number of participants that mentioned at least at least one of the subcategories.

Subcategories of **interdisciplinary topics** were named by 51 respondents (55.4%). This category includes all topics that could not be assigned to either physical or human geography. Of these, 17 teachers (18.5%) saw GIS as a valuable tool for teaching spatial planning. Another 16 participants (17.4%)

mentioned cartography, which comprises topics such as orientation in space, mapping tasks, and map interpretation. A total of 15 respondents (16.3%) mentioned that GIS could be used for many purposes without giving further specifications. Natural hazards were addressed by eight participants (8.7%), with GIS being used to analyze hazard maps that depict natural disasters. Seven respondents (7.6%) mentioned that GIS could help to detect changes such as land use and environmental changes. For example, satellite imagery was cited as a means of showing glacial retreat. Another seven teachers (7.6%) mentioned that GIS could be used to discuss resources and raw materials, including issues such as resource distribution and related problems such as deforestation of rainforests.

A total of 46 respondents (50%) cited topics from **physical geography.** The most commonly mentioned topic was geomorphology, mentioned by 31 teachers (33.7%), including desertification, earthquake distribution, plate tectonics, volcanism, and geology. From 11 teachers (12%), landscape and urban ecology topics were mentioned, comprising site or habitat analysis. Ten participants (10.9%) addressed topics of hydrogeography, such as glaciology, hydrology, and sea level rise. Biogeography was mentioned by eight respondents (8.7%), including ecology, vegetation, biodiversity, land cover, and habitats. Climate geography, comprising topics such as climatology, meteorology, and climate change, was mentioned by eight teachers (8.6%). Soil geography was mentioned by three teachers (3.2%) in the context of soil science.

Topics from **human geography** were mentioned by a total of 45 teachers (48.9%). Urban geography was mentioned the most frequently by 24 teachers (26.1%) and included topics such as gentrification and segregation, settlement development, urban development, noise, and regional spatial analysis. Topics from population geography, such as the representation of population geographic data, migration movements, poverty, demography, and population development, were addressed by 15 respondents (16.3%). Fourteen participants (15.2%) mentioned that GIS could be used for topics of economic geography topics such as comparing economic figures at the country level, resource distribution, and economic aspects of environmental exploitation. Eleven teachers (12%) mentioned topics from social geography, addressing globalization, global interdependence, and disparities. A total of four respondents (4.3%) mentioned geographic development research, such as population development and development theories, as topics. Three people (3.2%) mentioned political geography, including topics such as energy policy, geopolitics, and migration.

Application competencies that can be taught by using GIS were mentioned by 28 teachers (30.4%). With 14 mentions (18.9%), data visualization was the most frequently named competency by the teachers surveyed. Teachers considered GIS useful for visualizing both self-collected and pre-processed spatial data such as income, poverty, population density, or noise. It was also mentioned that GIS could be used to create thematic maps. Thirteen teachers (17.6%) indicated that GIS is useful for teaching students' data analysis skills, including the calculation, analysis, and interpretation of spatial structures, such as those used for habitat and site analyses. Six teachers (8.1%) considered GIS useful for research projects. They mentioned that by using GIS, students could independently carry out a complete research process from collection, management, analysis, and presentation.

Four teachers (5.4%) did not answer the question. Therefore, they fell into the category of **other**.

4.2.2 Benefits of GIS in the Classroom

This subsection presents the results of the question "What benefits can GIS bring to the classroom?" are presented. It was posed to all of the 146 participants. Five main categories could be identified: data, application competence, didactic and methodical aspects, topicality, and motivation. The categories were mainly based on the answers but also influenced by benefits determined from the literature, presented in subchapter 2.2.2. An overview of the categories and their respective number of mentions can be found in *Table 4.13* and *Table 4.14*.

Table 4.13*: Categories for the question "What benefits can GIS bring to the classroom?" and the number of mentions (#). (Number of respondents = 146) – Part 1.*

Data Literacy	#	Skill Acquisition	#	Didactic Aspects	#
Data visualization	48	Dealing with technology	23	Inquiry-based learning	25
Data analysis	31	Spatial thinking	21	Digital teaching	11
Data handling	18	Linking/deepening	15	Individualization	11
Data collection	12	Handling maps	9	Interdisciplinarity	8
		Solving problems	9	Project work	8
		Critical thinking	4	Different method (variety)	6
Total[1]	67	Total[1]	56	Total[1]	44

[1] The number of participants that mentioned at least at least one of the subcategories.

Table 4.14*: Categories for the question "What benefits can GIS bring to the classroom?" and the number of mentions (#). (Number of respondents = 146) – Part 2.*

Relevance	#	Motivation	#	Other	#
Preparation for university / scientific work	15	Variety	9	No answer	30
Practical relevance	13	Use of technology	8	Other responses	1
Relevant to everyday life	13	Interest	7		
Future-oriented	10	Topicality	3		
Total[1]	39	Total[1]	22	Total[1]	31

[1] The number of participants that mentioned at least at least one of the subcategories.

The most frequently mentioned advantage addressed by 67 participants (45.9%) was that students learn how to deal with spatial **data**. Out of these, 48 teachers (32.9%) named data visualization as an advantage, as GIS allows students to take a look behind the visualization of spatial data as they learn more about classes, symbols, and other cartographic principles. According to the teachers, this helps them choose good spatial data representations. Further, some teachers stated that GIS allows them to create visualizations for their classes, which fit their needs. Thirty-one teachers (21.1%) indicated that GIS software is well suited to teach students how to conduct spatial data analysis, which enables the assessment and interpretation of spatial information. As spatial data, sometimes even self-collected data, is analyzed, teachers stated that students often are more interested in the topic.
A total of 18 people (12.3%) mentioned data handling and data management as a benefit of GIS. According to some responses, GIS promotes data literacy and teaches students how to deal with spatial

data. Some teachers noted that GIS allows students to go through an entire holistic process, from collecting or searching for data, through data processing and visualization, to data analysis and interpretation. They mentioned that this encourages critical thinking about the collection, presentation, and interpretation of spatial data among students. According to 12 teachers (8.2%), another advantage of GIS is that students learn to collect and search for relevant data independently.

A total of 56 teachers (38.4%) named **skill acquisition** as a benefit that GIS brings to geography lessons. Among those, 23 teachers (15.8%) mentioned that students learn how to use technology. Therefore, students can gain methodological skills and enhance their technical affinity. By 21 teachers (14.4%), it was stated that using GIS could improve students' spatial thinking ability by better understanding geographical data and its spatial distribution. This is, as reported by the respondents, because GIS can help students to gain new insights into space and recognize the relevance of spatial data by using GIS to represent it. Fifteen participants (10.3%) mentioned that GIS could help students to link and deepen previously learned content. One teacher pointed out that many overarching concepts need to be brought together when using GIS to achieve meaningful results. In addition, it was mentioned that working with GIS can help students to establish better spatial connections and links between various factual contents. This allows for a deeper examination of topics. Teachers felt that GIS could improve the use and understanding of maps. It was also noted that by creating their own maps, learners have to think more carefully about processes, leading to a greater depth of content. Further, according to the teachers, the creation of maps can expose students' misconceptions, which helps them interpret maps correctly in the future. Nine teachers (6.1%) indicated that the use of GIS also helps students develop problem-solving skills. According to some respondents, this is the case because GIS is well suited to work on problem-oriented tasks where problem-solving processes are depicted, problem spaces are captured, and problem-solving strategies are developed. Therefore, students need to work in a solution-oriented way. Four teachers mentioned that GIS promotes learners' critical thinking because, through the collection and representation of spatial data, possibilities for manipulation can be brought to light.

A total of 44 teachers (30.1%) of the participants mentioned **didactic aspects** as advantages associated with GIS. Of these, 25 teachers (17.1%) indicated that GIS enables inquiry-based learning, which enhances students' self-efficacy and independence. According to some teachers, the use of GIS promotes constructivist teaching methods because students are cognitively activated through the independent use of GIS and are thus used as actors who construct knowledge. This allows for a depth of content that could not be achieved through other methods, making students more able to reproduce and transfer what they have learned to other things. In addition, according to some people, students feel taken seriously, which leads to increased motivation. It was mentioned by 11 participants (7.5%) that GIS strengthens digital teaching. Another advantage of GIS, according to 11 teachers (7.5%), is that it promotes the individualization of lessons because students can find answers to their own questions and carry out individual projects, which supports self-directed learning. Eight respondents (5.5%) mentioned interdisciplinarity as an advantage of GIS. In particular, the combination of computer science and geography was listed, but also biology, economics, and mathematics were mentioned as being suitable for collaboration. Another eight participants (5.5%) mentioned that GIS could be used for project work and matriculation projects.

The **relevance** of GIS for everyday life and geography was mentioned as an advantage by 39 respondents (26.7%). Thereby, fifteen teachers (10.3%) see GIS as a suitable tool to prepare students for their studies by allowing them to work on small research projects and thus gain insight into scientific work. In addition, the teachers see GIS as a suitable tool to arouse students' interest in geography. Thirteen respondents (8.9%) mentioned the practical relevance of GIS as a benefit, as the students can work with a tool that is used in the professional world, giving insights into the work of geographers. By 13 participants (8.9%), it was mentioned that GIS could be used to work on problems relevant to everyday life. In addition, GIS can establish a connection to the students' lifeworld, as it allows them to work with self-collected data. In general, it was mentioned that GIS could create real-world relevance, as students can work with real data used for decision-making. Ten respondents (6.9%) saw an advantage of GIS software as being very future-oriented. They saw the potential of GIS to help the subject of geography get rid of its "dusty" image by dealing with current topics using modern technology. In addition, several teachers mentioned that students could be made aware of the presence and relevance of geography in and for our society.

The positive impact of GIS on student **motivation** was mentioned as an advantage by 22 teachers (15.1%). According to nine teachers (6.2%), GIS allows for a change from everyday teaching because it offers a different approach to geographic topics than commonly used teaching methods, thus increasing student motivation. Moreover, the students feel taken seriously because they are allowed to work with software also used by experts, which increases their self-efficacy. Another aspect that can motivate students, as stated by eight respondents (5.5%), is the fact that modern technologies are used and that students can work with interesting software themselves. Seven teachers (4.8%) mentioned that GIS could arouse students' interest, leading to greater motivation. They mentioned that students are interested in the technology and the topics worked on with GIS. Three teachers (2.1%) addressed the topicality of GIS and the topics treated as a factor in improving students' motivation.

The answers of 31 people (21.2%) fell into the category **other**. Out of those 30 participants (20.6%) did not provide an answer and one person addressed the relationship between the students and the teacher.

4.2.3 Challenges of GIS in the Classroom

The answers to the question "What challenges can GIS bring to the classroom?" are presented in this subsection. It was posed to all the 146 teachers. Five main categories could be identified: time exposure, technology, complexity, competencies of teachers and heterogeneity. The categories were mainly based on the answers, but also influenced by challenges determined from the literature, presented in subchapter 2.2.2. An overview of the categories and their respective number of mentions can be found in *Table 4.15* and *Table 4.16.*

Table 4.15: *Categories for the question "What challenges can GIS bring to the classroom?" and the number of mentions (#). (Number of respondents = 146) – Part 1.*

Time Exposure	#	Technology	#	Complexity	#
Time	50	Problems	25	Complexity	18
Time in class	36	Screen time	9	Complexity for students	16
Too much time spent on method/technology	32	Availability	8	Complex for teachers	9
Time for Preparation	12	Control	6	Work through instructions	7
		Cost	6		
		Fast change	5		
Total[1]	96	Total[1]	50	Total[1]	47

[1] The number of participants that mentioned at least at least one of the subcategories.

Table 4.16: *Categories for the question "What challenges can GIS bring to the classroom?" and the number of mentions (#). (Number of respondents = 146) – Part 2.*

Teacher Competence	#	Heterogeneity	#	Other	#
Competencies of teachers	13	Student competence	7	Find Material	6
Supervision of students	8	Work Pace	6	Expense and income	5
Education	5	Interest	5	No answer	14
				Other Responses	2
Total[1]	24	Total[1]	17	Total[1]	21

[1] The number of participants that mentioned at least at least one of the subcategories.

The most frequently mentioned disadvantage of using GIS, which was mentioned by 95 teachers (65.1%), was the **time exposure** connected to its use. Of 50 people (34.3%), the time needed for using GIS was mentioned without specifying more precisely what and in which areas they consider it to be problematic. The time needed for using GIS in the classroom itself was mentioned as a disadvantage by 36 teachers (24.7%). On the one hand, teachers here mentioned that it takes much time to introduce and learn new technologies and that there can be much unproductive time until all the devices and software are up and running. On the other hand, it was mentioned that time resources in geography are very scarce, so there is not enough time to teach complex GIS concepts. Also, according to the respondents, there can be a great loss of time when technical problems occur. Thirty-two teachers (21.9%) indicated as a drawback that too much time is spent introducing students to the technology, which shortchanges other important geography topics. Therefore, according to one teacher, too much time is spent on methodology, leaving too little time for content. Further, some teachers believe that content can be taught well in other ways that take less time. One teacher emphasized that more time is spent on technical issues of visualizing spatial data than on the fundamental goal of analyzing spatial data and understanding spatial processes and relationships. The time-consuming preparation of teaching units with GIS was mentioned as a disadvantage by 12 teachers (8.2%). On the one hand, it was pointed out that teachers must first learn the tool themselves. On the other hand, much time has to be invested to stay up to date, as technology is constantly changing. One teacher mentioned that they lack time to create relevant teaching materials, and another that it takes much time to create student accounts for the use of GIS software.

Technology aspects, thus addressing challenges related to technology, were mentioned by 50 teachers (34.2 %). Twenty-five (17.1%) mentioned technical problems. According to several teachers, technical problems can be the downfall during class, and a prepared lesson cannot be held at its worst. Moreover, much time is lost when technical problems occur. In addition, participants stated that good knowledge is required from teachers in order to be able to deal with technical difficulties. One teacher also mentioned that the program needs to work equally on every device, especially if every student has to bring their own device. A total of nine teachers (6.2%) mentioned that students have to spend more time in front of the screen when using GIS as a drawback. Another eight teachers (5.5%) addressed the availability of hardware and software, which is not given in all schools. Six people (4.1%) pointed out that a teacher loses control over what students do on the laptop once they are on the screen. It was mentioned by several teachers', that computers introduce distraction for students in the classroom. Another six respondents (4.1%) addressed the financial costs of GIS software as a disadvantage. Five participants (3.4%) mentioned the rapid development of technology as a challenge. As a result of the constant change, lessons need to be constantly adapted, and the teachers need to keep up to date.

A total of 47 teachers (32.2%) cited the **complexity** of GIS as a challenge. Eighteen teachers (12.3%) did not indicate whether complexity was a problem for the teacher or the students. They mentioned that the complexity of the software requires much effort, which could lead to excessive demands and, consequently, frustration. Seventeen teachers (11.6%) stated that students could perceive GIS applications as complex and abstract. According to them, this could lead to students being overwhelmed and having problems operating the software. The complexity of the software can also lead to problems for the teacher, as indicated by nine respondents (6.2%). This manifests in the complexity of creating course materials and program administration. It was also pointed out that teachers need to master the technology themselves before they can use it in the classroom. Due to the complexity of GIS applications, seven teachers (4.8%) mentioned that it can happen that the students solely work through instructions and, therefore, do not engage with the processed topic as a drawback.

Another challenge mentioned by 24 teachers (16.4%) is a **teacher's competence** required for using GIS in the classroom. Thirteen teachers (8.9%) indicated that they need to have a good understanding of the software in order to help students with problems without wasting time in class. Eight respondents (5.5%) noted that it could be challenging to supervise students using GIS as a high amount of teacher supervision is required when using the technology. According to the respondents, this is because students depend on instruction and guidance from the teacher. Furthermore, learners usually need to be supervised on an individual basis. Moreover, five persons (3.4%) pointed out that teacher training is often insufficient to prepare them to use GIS in the classroom. In addition, according to one teacher, the cost of retraining teachers is high, wherefore the willingness is low.

Heterogeneity among students was mentioned by 17 respondents (11.6%) as a challenge of using GIS in the classroom. Of these, seven teachers (4.8%) mentioned the different competencies of the students. According to the participants, there is a great difference in the level of technology skills among students, which is why not all are equally successful in familiarizing themselves with GIS. This could lead to students with low technical skills being overwhelmed. Furthermore, according to 5 participants, the work pace of students can be very heterogeneous because they cope with the program at different speeds. One teacher stated that the observed individual differences in work progress are accentuated when using GIS. For this reason, teachers have to deal with strong individuality. Five participants (3.4%) pointed out students' different interests as a challenge of GIS. According to one teacher, GIS applications are often complex and abstract for students, wherefore not all students use them with enthusiasm, and a wide gap in student motivation can be observed.

The answers of 21 responses (14.3%) fell into the category other. Of these, 14 teachers (9.6%) did not provide an answer. Six respondents (4.1%) indicated that it is difficult to find projects and data that can be used in the classroom. Five teachers (3.4%) pointed out that the benefits generated by using GIS do not justify the expenses of its use. According to one of these teachers, the content can often be taught thoroughly without GIS, and another teacher indicated that the learning content is often developed inefficiently with GIS. Two respondents (2.4%) gave answers that could not be evaluated.

4.2.4 Circumstances Under which GIS Would Be Used

In this section, the answers to the questions "Under what circumstances would you use GIS for your teaching (again)?" are presented. This question was answered by 72 teachers and was only posed to those who do not use GIS currently. Five main categories were identified: teacher competence, material, curriculum, setting and technical aspects. The subcategories were determined based on the answers. An overview of the categories and their respective number of mentions can be found in *Table 4.17* and *Table 4.18.*

Table 4.17: *Categories for the question "Under what circumstances would you use GIS for your teaching (again)?" and the number of mentions (#). (Number of respondents = 72) – Part 1.*

Teacher Competence	#	Material	#	Curriculum	#
Further training	13	Available teaching material	22	More time in class	16
Time for independent training	11	Available data	3	Part of the curriculum	2
More competence	7				
Education	2				
Total[1]	26	Total[1]	23	Total[1]	18

[1] The number of participants that mentioned at least at least one of the subcategories.

Table 4.18: *Categories for the question "Under what circumstances would you use GIS for your teaching (again)?" and the number of mentions (#). (Number of respondents = 72) – Part 2.*

Setting	#	Technical Aspects	#	Other	#
Teaching other topics	11	Available hardware	5	No Answer	5
Project weeks	8	Functionalities of the software	5		
		Available software	4		
		Technology is working	2		
Total[1]	17	Total[1]	14	Total[1]	5

[1] The number of participants that mentioned at least at least one of the subcategories.

The most frequently mentioned aspect that needs to change for teachers not using GIS to apply it in the classroom is **teacher competence**. This aspect was named by 26 teachers (36.1%) of the respondents. Out of those, 13 teachers (18.5%) are interested in further training opportunities, which, according to the teachers, should be oriented towards the curriculum and should be time efficient. More time for independent familiarization with GIS and preparation of teaching units with GIS was asked for by 11 participants (15.3%). Seven teachers (9.7%) mentioned that they do not use GIS in the classroom because of a lack of own competencies. Two participants (2.8%) saw the reason for the lack of competencies in teacher education, where GIS was not or only a small part.

Twenty-three teachers (31.9%) mentioned that they would consider using GIS if more **material** was available. Of those, 22 teachers (30.5%) were asking for more teaching material that is didactically prepared, student-friendly, easy to implement, and relates to topics from the curriculum. Some teachers also demanded instructional material that guides them on how to use GIS in the classroom. Three teachers (4.2%) asked for more accessible, relevant, and high-quality data.

Curriculum-related aspects were mentioned by 18 teachers (25%). Thereby, 16 teachers (22.2%) stated that they would use GIS if there were more geography lessons, while two teachers (2.8%) mentioned that they would only use it if GIS was anchored in the curriculum.

It was mentioned by 17 teachers (22.2%) that they would use GIS in a special or different **setting**. Of those, 11 participants (15.3%) said they would use GIS to teach other geographic topics. By eight participants (11.1%), it was mentioned that they would use GIS within the context of project weeks. One of those teachers explained that GIS requires a lot of training time, which is why it is hard to implement in the context of 45-minute lessons, wherefore project weeks are better suited.

Technical aspects were mentioned by a total of 14 teachers (19.4%). Five participants (6.9%) noted that for them to use GIS, the required hardware needs to be available. Another five teachers (6.9%) stated that they would use GIS if the software provided additional functionalities. The functionalities mentioned by them were simple ways of integrating data and various representation possibilities that are easily applicable. Four teachers (5.5%) addressed the availability of software, and another two participants (2.8%) mentioned that they would only use GIS if the technology were reliable and would always work seamlessly.

No answer was provided by five participants (6.9%), wherefore their answer fell into the category **other**.

4.2.5 Possibilities to Support Teachers

The results of the question "How do you think teachers could be supported in using GIS in the classroom" are presented in this subsection. This question was posed to all the 146 teachers. Five categories could be identified: material, teacher competence, curriculum, technical aspects and support. The code words were determined based on the answers. An overview of the categories and their respective number of mentions can be found in *Table 4.19* and *Table 4.20*.

Table 4.19: *Categories for the question "How do you think teachers could be supported in using GIS in the classroom?" and the number of mentions (#). (Number of respondents = 146) – Part 1.*

Material	#	Teacher Competence	#	Curriculum	#
Available teaching material	74	Further training	49	More time in class	24
Available instructional material	26	Time for independent training	12	Part of the curriculum	4
Available data	16	Education	7		
Curriculum related material	12				
Total[1]	83	Total[1]	62	Total[1]	27

[1] The number of participants that mentioned at least at least one of the subcategories.

Table 4.20: *Categories for the question "How do you think teachers could be supported in using GIS in the classroom?" and the number of mentions (#). (Number of respondents = 146) – Part 2.*

Technical Aspects	#	Support	#	Other	#
Available software	12	Support by specialists	8	Support is sufficient	4
Functionalities of the software	12	Cooperation	5	No Answer	10
Technology is working	2	Additional support person	3		
Available hardware	1				
Total[1]	21	Total[1]	12	Total[1]	14

[1] The number of participants that mentioned at least at least one of the subcategories.

In total, 83 teachers (56.8%) mentioned that they could be supported with additional **material**. Of those, 74 teachers (50.7%) demanded concrete, practical, and easy-to-implement teaching material. The material should address different difficulty levels and include instructions, data, and solutions. Further, the teaching material should be individually adaptable and usable for a long time. One of the main requirements was that teaching units take as little time as possible during class and be linked to other geographic topics. According to 26 teachers (17.8%), teaching material should be equipped with detailed instructions on how the teacher can use GIS in the classroom, as this can lower the inhibition threshold. They demanded documents that convey the basics of GIS and point out how GIS can be connected with content relevant to the curriculum. Some teachers requested explanatory videos and manuals explaining the use of GIS step-by-step. Sixteen respondents (11%) asked for more diverse data sets which are freely available and easy to find, as, according to some teachers searching and finding relevant data is often the most time-consuming. Twelve teachers (8.2%) requested that the material relates to topics from the curriculum. Out of those, some requested additional material on the curriculum-relevant topic covered.

Enabling the acquisition of **teacher competence** was cited by 62 participants (42.5%) as means of supporting teachers. Of these, 49 teachers (33.6%) stated that they would like further training to acquire the necessary knowledge to use GIS in the classroom. According to the answers received, training courses should be inexpensive or financed by schools and provide teachers with ready-to-use teaching material. Some teachers were interested in long-term professional development courses to gain in-depth knowledge of GIS to be confident to use it in the classroom. Twelve teachers (8.2%) wished for more time for independent training to familiarize themselves with GIS and prepare teaching sequences, which according to the responses, is very time-consuming. Seven respondents (4.8%) mentioned that GIS should be part of the basic training of geography teachers, where they should already have to design lessons with GIS already there.

Twenty-seven teachers (18.5%) indicated that they would like a change in the **curriculum** to support the use of GIS in the classroom. Of those, 24 participants (16.4%) mentioned needing more time for geography instruction. More geography lessons were generally requested. On the other hand, it was noted that 45 minutes is usually too short for using GIS and that after a week's break, the time needed to start again is high. For this reason, some teachers demanded project weeks where they could introduce GIS. Four teachers (2.7%) asked for GIS to be embedded in the curriculum to justify its use.

In order to support teachers, 21 participants (14.4%) mentioned **technical aspects** that need to change to facilitate the use of GIS. Of those, 12 teachers (8.2%) mentioned software availability that must be improved. Another 12 respondents (8.2%) addressed the usability of GIS software, which needs to be easy to use and reliable such that no time gets lost during class due to technical complexity and related problems. Further, some teachers mentioned that technology should be adapted to the needs of high schools. Support through the seamless working of technology was requested by two teachers (1.4%), and one respondent mentioned that support could be provided through the availability of hardware.

A total of 12 teachers (8.2%) were asking for additional **support**. Thereby, support from specialists was requested by eight respondents (5.5%). Such support was requested in the form of courses conducted directly by experts and the introduction of GIS at the school by professionals. Moreover, teachers were interested in a hotline or contact person that could be consulted in case of technical problems. Five participants (3.4%) wished for better cooperation between teachers and platforms to exchange information and material. Three teachers (2.1%) mentioned the need for an additional supervisor who could assist them during lessons in which GIS is used. Otherwise, they requested lessons in half classes since the use of GIS often requires a high level of student supervision.

The responses of 15 people (10.3%) fell into the category **other**. Out of those, ten teachers (6.9%) did not provide an answer, while four teachers (2.7%) mentioned the available support already is sufficient.

Chapter 5 Conception of a Teaching Unit

The literature review showed that there is already a lot of material available to support the use of GIS in the classroom. However, the survey revealed that 56.7% of the teachers were interested in additional material tailored to their needs. Therefore, it was decided to design a teaching unit based on the needs of the teachers identified in the survey. This unit is presented in the following chapter. Only those aspects of the survey that were of interest for the design of the unit are presented below. A detailed discussion of the results can be found in *Chapter 6.*

5.1 Design Based on Survey Results

The created teaching unit consists of two independent modules and is in German. Thereby, the first module serves as a short introduction to the basic concepts of GIS. The second module is a hands-on practical exercise where students work with ArcGIS online. As the first module does not include any practical exercise with GIS software, the focus of this section will be on the second teaching module.

From the survey emerged that the main problem teachers see in using GIS in the classroom is the time available. Among other things, this was the most frequently cited disadvantage of GIS, as its use is perceived as time-consuming in the preparation and delivery of instruction. Because of the limited time available, especially in the classroom, there is a great interest in teaching materials that link GIS to other geographic topics relevant to the curriculum. For this reason, the second module tackles the curriculum-relevant topic of "urban geography", which teachers frequently mentioned to be suited for teaching with GIS. This topic is taught in Swiss high schools between the 9^{th} and 11^{th} grade (Amt für Berufsbildung und Mittelschule, 2020; Gymnasien des Kantons St.Gallen, 2010; Kanton Solothurn, 2019). The second module was based on the chapter "Stadt" (City) from the textbook "Geografie: Wissen und verstehen – Ein Handbuch für die Sekundarstufe II" (Geography: Knowing and Understanding - A Handbook for Secondary Level II) by Egli et al. (2016), which is used in many Swiss high schools as teaching aid. Nevertheless, teachers were also interested in material that conveys the basics of GIS, wherefore the first module was created, serving as a short introduction to what GIS are.

The survey showed that the complexity of GIS and its technical difficulties are a major drawback in preparing and using it in the classroom. Due to the complexity, good knowledge of the technology is required from teachers. Otherwise, they could struggle with problems that occur during instruction. In order to minimize problems, the second module was based on the web-based GIS "ArcGIS Online". This GIS application is provided by ESRI and is free of charge for Swiss high schools. It was chosen because several advantages of web-based GIS for education due to lower complexity and no requirements for installation were mentioned by Kerski and Baker (2019). Further, it was the most frequently mentioned GIS used by teachers, wherefore some teachers are already familiar with its use, and good suitability for classroom use can be assumed. In addition, it has more functions for data analysis than, for example, map.geo.admin.ch, and data provided by Esri can be quickly integrated. Consequently, another demand of teachers, that teaching material should come along with data, can be tackled.

Teachers were also interested in instructions about the use of GIS and explicit teaching units in the classroom. Therefore, an additional commentary for teachers was created, offering them explanations of the functions used. In addition, frequently occurring problems and possible solutions were listed.
The complexity of GIS can also pose a problem to students, as according to teachers' answers, students can get overwhelmed and consequently frustrated by the technology. Further, it was mentioned in the literature that untargeted interactions with software could hinder in achieving content goals (Herzig, 2007; Kerski, 2003). Therefore, a step-by-step instruction that guides students through the exercise and the program was created to prevent this from happening. An example of a step from the second module can be found in *Figure 5.1*. For each step, screenshots of the required functions were added to facilitate students in finding the correct functions. It was deliberately decided not to show screenshots of the entire interface for every step. On the one hand, the handout would have become confusing and lengthy. On the other hand, an overview of the entire interface was provided at handout's beginning, shown in *Figure 5.2*. Thereby, key features of the ArcGIS Online "Map Viewer Classic" interface were explained.
Step-by-step instructions were listed as a disadvantage of GIS, as they can hinder students from engaging with the content in depth. However, such a guide is necessary to carry out the lesson in the shortest possible time. According to Walshe (2018), content-related questions can help students actively think about the topic. For this reason, the second module was accompanied by thematic questions, where students had to analyze the obtained results.

6. **Layer entfernen:** Klicken Sie auf «Weitere Optionen» (17) > «Entfernen» um den Layer «*Public Transport Switzerland and Lichtenstein – Tracks*» zu entfernen.

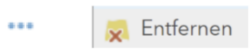
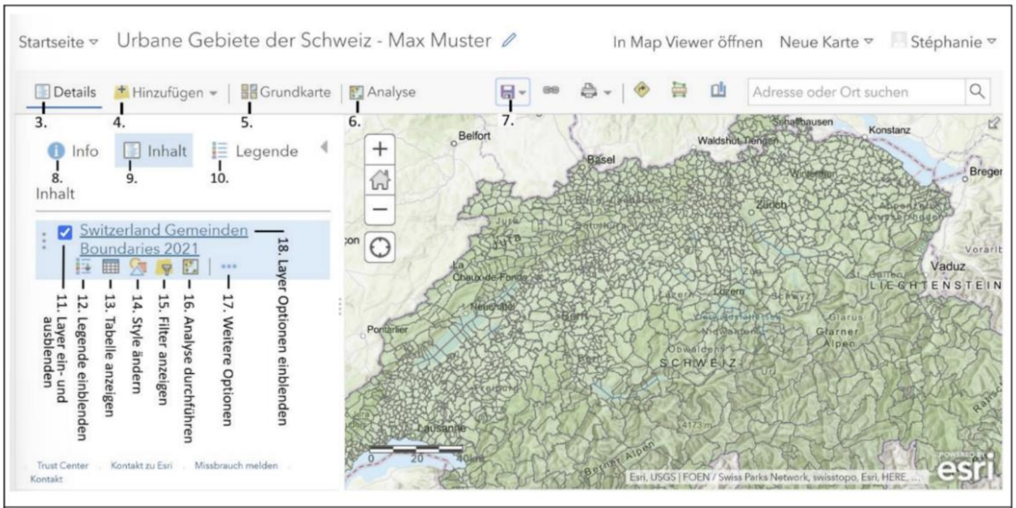


Figure 5.1: *Example of a step where students have to remove a layer from the map.*

Concerns were also expressed about student heterogeneity in technical skills and interests due to the use of technology. According to some teachers, differences in work pace are exacerbated when technology is used. For this reason, additional tasks were created that could be given to the faster students to keep them occupied.

It was also expressed that teaching material should be individually adaptable and equipped with appropriate solutions. To ensure individual adaptability, on the one hand, the first and second modules can be used independently from one another. Teachers can further set a region-specific focus within the scope of the second module by slightly adapting the tasks. In addition, it is up to the teacher to decide whether the students should work individually or in pairs. Latter is recommended when a teacher has to supervise a large class, as students can support one another, which requires less supervision from the teacher. In the teacher's commentary, different possibilities for implementation are specified, and solutions to the tasks are provided.



3. **Details:** Side Panel ein- und ausblenden.
4. **Hinzufügen:** Layer zur Karte hinzufügen.
5. **Grundkarte:** Grundkarte ändern.
6. **Analyse:** Analysefunktionen, um Layer zu analysieren.
7. **Karte speichern:** Aktuelle Karte speichern.
8. **Info**: Übersicht über Karteninformationen.
9. **Inhalt**: Übersicht über Layer der Karte.
10. **Legende**: Legende der eingeblendeten Layer.
11. **Layer ein- und ausblenden:** Layer der Karte ein- und ausblenden.
12. **Legende einblenden:** Legende des Layers einblenden.
13. **Tabelle anzeigen:** Datentabelle des Layers anzeigen.
14. **Style ändern:** Darstellung (z.B. Farben, Klassen...) des Layers ändern.
15. **Filter anzeigen:** Filter basierend auf Daten des Layers anwenden.
16. **Analyse durchführen:** Analysefunktionen auf den Layer anwenden.
17. **Weitere Optionen:** Zusätzliche Optionen, um z.B. den Layer umzubenennen oder zu entfernen.
18. **Layer Optionen:** Layer Optionen werden eingeblendet, wenn auf den Layer Namen geklickt wird.

Figure 5.2: *Overview of the Interface of "Map Viewer Classic" from ArcGIS Online provided to the students at the beginning of the student's handout.*

Teachers were further interested in teaching material that could be applied over long time periods. For this reason, the first module covers overarching concepts of GIS, which stay the same for a long time. The second module tackles another curriculum-relevant topic. Moreover, besides product-specific knowledge, which is short-lived, students gain long-lasting competencies such as analyzing the visualized results.

In order to ensure verifiability, which is an essential component of good teaching, learning objectives were listed at the beginning of the student handout. Learning objectives are considered crucial in managing student learning activities and expectations and in reviewing learning processes (Städeli & Caduff, 2019). The first two learning objectives are cognitive in nature and thus cover content knowledge that is readily testable in an exam. The second two are instrumental learning objectives, which refer to the acquisition of competencies related to geographical ways of working. Although these are more difficult, if even possible, to test in exams, they are also important educational goals of geography teaching (EDK, 1994).

The results are intended to be secured in the plenum in the form of a class discussion since this form of teaching has the advantage that subject matter can be worked on in a short time, and it can be ensured that all students take away the correct results from the lessons (Meyer, 2018).

5.1.1 Content of the Teaching Unit

The content of the two modules is briefly described below. The concrete teaching material can be found in *Appendix E.*

Module 1: Introduction to GIS

The first module takes about 20 minutes and consists of a handout for the students and a dossier for teachers containing the solutions. It is intended to give the students a basic understanding of what a GIS is, what it can be used for, and what kind of data is used to work with it. During the sequence, students read a text about what a GIS is and come up with their own definition of it. Afterward, they read another text about what geodata is and in which formats it is stored. In the exercise that follows, they have to consider which data format is best suited for representing different objects. Even though this sequence enables a better understanding of GIS, it is not necessary that students review the script before module two is conducted.

Module 2: Urban Geography with ArcGIS Online

The second module takes about 90 minutes and consists of a handout that the students work through independently and a dossier for teachers with additional commentaries. Students have to identify urban areas in Switzerland by using ArcGIS Online. For this reason, they have to assign one of the three categories, “urban”, “suburban,” or “rural,” to all Swiss municipalities. Data provided by Esri in the Living Atlas is used. To assign each municipality a category, students have to calculate an index based on the number of inhabitants, population density, and railroad stations per municipality. Thereby, students are guided step-by-step through the exercise, performing various functions such as loading the data, applying filters, and summarizing point data within polygons. Once the index is calculated, they have to visualize the achieved results on a map. In the end, they have to analyze the map by describing the distribution of urban, suburban, and rural areas in Switzerland, uncovering spatial patterns, and identifying their causes. In addition, students need to consider whether the data used is sufficient in order to categorize the municipalities. To do so, they compare their own results with a data layer displaying the categorization of municipalities from the Swiss Federal Statistical Office, which is available in the Living Atlas.

5.2 Practical Realization

I had the opportunity to conduct both teaching modules with a half class comprising nine students from the 10th grade. It was a bring-your-own-device class, wherefore each student had their own laptop or tablet, and the school provided an internet connection. The implementation took place on separate days, and there was about a month between them. Therefore, they will be discussed individually. Since the teaching modules were only tested in one class, it is not possible to make general and statistically significant statements. In addition, the implementation can vary greatly based on the existing competencies of the students and the teacher, and the setting. Nevertheless, first implications about the feasibility of the teaching unit, problems, and possibilities for improvement can be derived.

5.2.1 Module 1: Introduction to GIS

When the first module was held, the students were unfamiliar with what a GIS is. The teaching module served as an introduction to a project which was not related to this Master's Thesis. Among other things, as part of this project, the students had to create maps using ArcGIS Online. Therefore, a general introduction to what a GIS is was reasonable.

The first module could be done as planned within 20 minutes, and no problems were encountered during the implementation. For the implementation, a PowerPoint was created to structure the lesson and for discuss the results. At the end of the lesson, students could give feedback in the form a short survey. From their feedback emerged that almost all of them were able to take away from the lesson what a GIS is. Further, on average, they rather agreed with the statement that they understand what a GIS is. The results are also shown in *Figure 5.3*. Some students mentioned that they found it interesting to learn something about GIS.

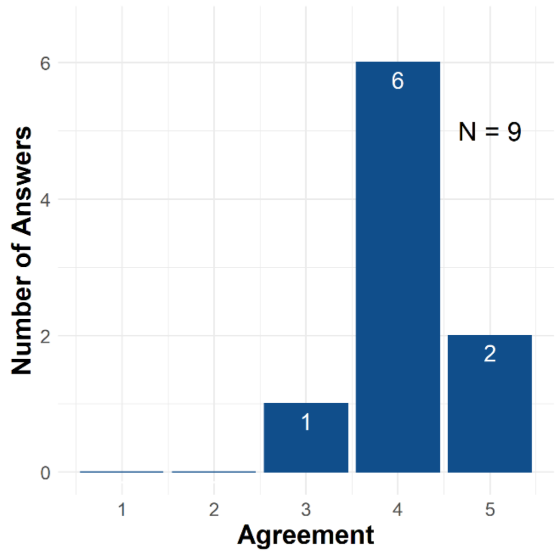


Figure 5.3*: Agreement on a scale from 1-5 (1= I do not agree, 5= I agree) with the statement: "I understand what a GIS is" (N = number of respondents).*

5.2.2 Module 2: Urban Geography with ArcGIS Online

The second module was held with the same class after they had completed their project. For this reason, the students already had an account for working with ArcGIS Online and gained some experience with the software.

The lesson started with a brief introduction to urban geography, where factors defining a city were presented. Those are also listed in the introductory text of the student handout. Afterward, students were given 75 minutes to complete the exercise, working individually or with a partner.
During the exercise, some problems arose. One was due to an updated data set, wherefore the description in the handout was not in line with the updated version of the data set. Therefore, some questions arose during the work, but the teaching unit could still be held as intended. Furthermore,

students working with a tablet encountered the problem of not being able to copy the programming code for calculating the index from the handout to ArcGIS Online. As a result, these learners had to type the code, which took more time and increased the risk of error messages.

At the end of the lesson, students were asked for feedback in a short but slightly more detailed survey than for the first module. In order to find out how well the students felt they had mastered the learning objectives, the survey asked them to indicate how strongly they agreed on achieving them. The average agreement is shown in *Figure 5.4*. Overall, students rather agreed on achieving the teaching objectives. Thereby, they felt the least confident in being capable of visualizing spatial data with ArcGIS Online.

Students were also asked whether they found the difficulty of the task too easy, just right, or too hard. The result was that eight students found the difficulty level to be just right, while one found the exercise too easy. Students were also asked how far they got within the 75 minutes. The exercise comprising 17 steps and context-related questions at the end, was finished by one student. Another student made it to step 17, while five people made it to step 15, and one person got to step 14. This shows the heterogeneity between students, wherefore the need for additional tasks for faster students is emphasized.

They were further asked what they liked about the lesson. Here it was mentioned four times that the free working time, the independent discovery of ArcGIS Online and the creation of maps were appreciated. Two students mentioned that they liked getting to know ArcGIS Online better, and one student praised the design of the script. Overall, during the whole lesson, a high level of student motivation could be observed, which was also noted by the class teacher at the end.

When asked what could be improved in the lesson, two students mentioned that the mistakes addressed above need to be corrected.

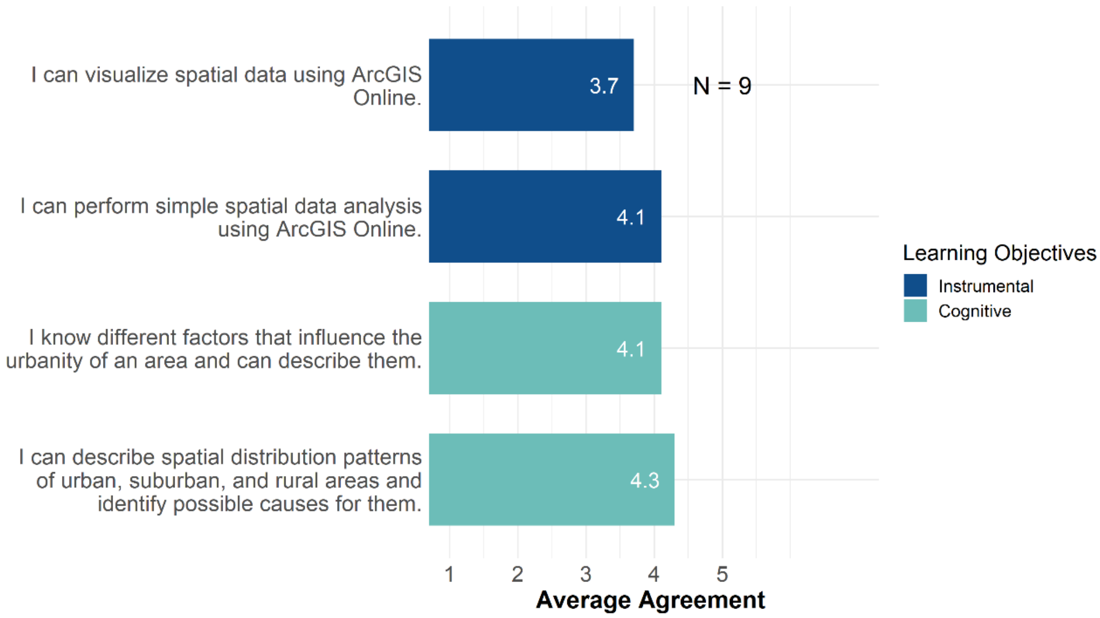


Figure 5.4: *Average agreement on a scale from 1-5 (1= I do not agree, 5= I agree) on achieving the learning objectives from the second module (N = number of respondents).*

Chapter 6 Discussion

In this chapter, the results of the Thesis are discussed and compared to findings from the literature. The discussion is structured in line with the research questions posed. Accordingly, it starts with the first research question about the current use of GIS for data visualization and analysis in Swiss high schools' geography education. Afterward, the second research question is discussed, which aims to find out what factors influence the deployment of GIS. Finally, the results of the last research question address how teachers can be supported in their use of GIS. Further, the limitations of this work and the potential for future research are outlined.

6.1 The Use of GIS in Swiss High School Education

This section provides answers to the first research question: "How is GIS currently used for data visualization and analysis in Swiss high school geography education?".

The survey indicates that 50.7% of the teachers participating in the study are currently using GIS for their teaching, while 12.3% have used GIS in the past but no longer use it. Comparing it to the third of high schools using GIS in 2012 (Stark & Treuthardt, 2012), increased deployment of GIS for education can be observed. Nevertheless, it is important to keep in mind that the other number refers to high schools and not teachers. Also, it can be assumed that teachers who use GIS are more likely to participate in the survey than those who are not interested in the topic (Kerski, 2003). For this reason, it is plausible that effectively less than 50% of Swiss high school teachers employ GIS in the classroom. However, since this might also be the case for Stark and Treuhardt's (2012) number, it can be assumed that the use of GIS has increased in the last ten years. Nevertheless, it is evident that there is still potential for improvement, as it can be assumed that only half of the students come into contact with GIS, which is lower than expected considering the technological developments since 2012.

When looking at the spatial distribution of GIS usage in high school geography education within Switzerland's cantons, it was found that the application was most widespread in the cantons of Sankt Gallen, Neuchatel, and Zurich, with more than 70% of participants using it. In the cantons of Basel-Stadt, Geneva, Lucerne, Nidwalden, Thurgau, Uri, and Vaud, GIS was not employed by any of the respondents. A detailed interpretation of the possible causes can be found in chapter 6.2, where factors influencing the use of GIS are discussed.

In the following section, results are presented only addressing the participants who indicated that they apply GIS in the classroom. The results show that most teachers, over 80%, use GIS in 9th and 10th grade, while about 60% use it in the 11th and 12th school year. This may be explained by the fact that geography is most often taught in the 9th, 10th, and 11th school year and in lower grades. Still, in the lower grades, only 18.9% of teachers use it. These results are consistent with Falk and Hoppe's (2004) paper, stating that higher grades are beneficial for more advanced use of GIS.
Almost all teachers who deploy GIS in-class use it in the basic subject, meaning that all of their students come into contact with GIS. Some also use it in the supplementary subject, during project weeks, and

for matriculation projects. Since in literature, it is stated that GIS is well suited for project-based and inquiry-based learning, this is not surprising (Falk & Hoppe, 2004; Johansson, 2003).

GIS has proven its relevance not only for various domains of industry, society, the environment, and everyday life (Bualhamam, 2012; Jebur, 2021; Unwin et al., 2012; Usmani et al., 2020). The survey results showed that GIS is also relevant for education, as it enables teaching a broad range of topics from physical and human geography. In addition, GIS is particularly well suited for interdisciplinary subjects that combine aspects from both fields. In most cases, GIS is used by teachers for topics with a strong spatial component, such as geomorphology, urban geography, and spatial planning. Herzig (2007) emphasizes that GIS should not be used arbitrarily wherever possible but where GIS can genuinely contribute to the teaching of a topic. Furthermore, the literature suggests that it is critical to use GIS to teach other curriculum-related content in order to promote spatial thinking (Bearman et al., 2016; Kerski, 2003). From the survey emerged, that GIS is used as a method for teaching other topics by 67.6% and as the main learning content by 56.7% of the participants who use GIS. This shows that GIS is frequently employed for teaching other geographic topics, thus fostering spatial thinking.

The majority of the respondents, namely 75% of those using GIS for their teaching, rely on ArcGIS Online, which is a web GIS. The desktop GIS versions QGIS and ArcGIS Desktop were both used by less than 15% of the participants. 31.1% of teachers indicated that they use other GIS, including map.geo.admin.ch and cantonal GIS. Hence it is shown that most teachers using GIS for teaching rely on comparatively less complex web GIS solutions. This is in line with previous findings indicating that web GIS software is often better suited for education due to its reduced functionality (Kerski & Baker, 2019).

In the classroom of 73% of teachers who use GIS, students have the opportunity to work with GIS software themselves. Consequently, the students' technological know-how is improved. Teachers where students do not work with GIS by themselves might use it for the preparation of teaching material, which is done by 43.2% of the teachers.

Regarding the material teachers apply during their classes, 75.7% use self-created teaching material, 47.3% use material from colleagues, and 27.1% rely on existing materials. Since a wealth of material is freely available on the internet, this result seems surprising. Reasons for this might be outdated teaching material or material that does not meet teachers' needs. Moreover, it showed that about half of the participants rely on teaching materials from colleagues, which underlines the importance of collaboration between teachers. A similar conclusion was reached in the study by Kerski (2003), which showed that other teachers using GIS strongly influence the overall deployment.

Since GIS often takes more time than traditional teaching methods (Falk & Hoppe, 2004; Kerski, 2003), it is important to remember that skills such as data visualization and analysis are also taught in addition to contextual aspects. These are geographic methods that must be instructed according to the framework curriculum (EDK, 1994). The survey showed that over 70% of all teachers surveyed have students visualize and analyze geographic data. Out of those, 40% indicated that their students use GIS to learn about data visualization and analysis. This number being lower than the percentage of teachers who use GIS, may be explained by the fact that not all teachers who use GIS let their students work with GIS software themselves.

6.2 Factors Influencing the Use of GIS

In this section, the results of the research question "Which external and internal factors influence the use of GIS for data visualization and analysis in geography classes at Swiss high schools?" are discussed.

Fisher's exact tests, testing for independence, were carried out to find out which factors influence the use of GIS. Along with these results, other quantitative and qualitative outcomes are referenced. While the first section tackles the external factors, thus addressing hypothesis 2.1 (H2.1), the second deals with the internal factors, tackling hypothesis 2.2 (H2.2).

6.2.1 External Factors

A statistically significant dependence could be found between the use of GIS and the presence of GIS in the **curriculum**. Although the Fisher's exact test does not indicate the direction of dependency, in this case, it can be assumed that the mention of GIS in the curriculum will increase the deployment of GIS in the classroom because teachers are obliged to follow the curriculum. This assumption is confirmed by the fact that 70% of teachers for whom GIS is mentioned in the curriculum use it in class, while only 45.5% of teachers for whom GIS is not part of the curriculum use it.
These findings are also reflected in the average use of GIS within the cantons. While in cantons where GIS is not mentioned in the cantonal curriculum, only 30.3% of the participants apply it, in cantons with GIS being part of the curriculum, 53.3% of the respondents do. The highest values were achieved in cantons with curricula developed on a high school level, where on average, 58% of the teachers use GIS. Deviations, such as in the canton Basel-Stadt, where GIS is part of the curriculum, but none of the respondents use GIS, could be due to a small number of participants from this canton, who should not be considered representative of all teachers in this canton. In addition, 20.6% of all the participants stated that they do not know whether GIS is part of the curriculum, which could also serve as an explanation.
The influence of the curriculum is also evident, as over 70% of teachers instruct data visualization and analysis. These are competencies that are listed in the national framework curriculum and are included in almost all cantonal curricula analyzed.
Based on these results, it can be assumed that anchoring GIS in the curriculum can increase the use of GIS. Those findings align with the literature stating that the integration of technology into the classroom is strongly linked to its integration into the curriculum (Bednarz & Van der Schee, 2006). Unfortunately, GIS seems to be present in only a small part of the curricula in Switzerland. This is assumed, as it appears in only six of the fifteen cantonal curricula analyzed, and only 26.7% of the teachers indicated that GIS is part of their cantonal or secondary school curriculum. At the moment, a revision of the national framework curriculum is in work, with the goal of adjusting it to present and future needs (Der Bundesrat, 2022). It is difficult to predict whether GIS will be a part of it until it is published. However, should it be the case, increased use of GIS in the classroom can be expected.

A strong statistically significant relationship was found between the use of GIS and the providence of GIS **software** by a school. It could be observed that teachers are more likely to use GIS in the classroom when they know that their school is providing GIS software. In general, it has been shown that a lack of technology can lead to fewer implementations (Gómez-Fernández & Mediavilla, 2022). As there are various GIS applications available for free on the Internet, such as map.geo.admin.ch, and Swiss high schools can use the GIS software of ESRI for free, in theory, all teachers could have access to GIS software. This suggests that it is not so much the general availability of GIS applications but rather the awareness of GIS applications that can be raised if schools provide GIS software. This aligns with Kerski's statement from 2003 that technological accessibility has increased to a level where the use of GIS depends more on teachers' adaptability.

With 84.3%, most teachers taking part in the survey were teaching geography as their first **subject**. A statistically significant relationship between the use of GIS and if geography was the first teaching subject of a participant could be found. Teachers having geography as their first subject were more likely to use GIS in the classroom. This could be due to the fact that respondents who teach geography as their first subject have a greater knowledge of the subject due to longer study experience. It can also be assumed that the main focus of these teachers is on the subject of geography, wherefore they may be more willing to engage with GIS.

No statistically significant relationship between the use of GIS in the classroom and if GIS was part of a teacher's **studies** could be found. This seems surprising as it can be assumed that most teachers who had GIS in their studies are more knowledgeable about how to use it. However, those teachers are also more aware of how time-consuming it can be to employ GIS, which may discourage them from using it. This assumption is supported by the statistically significant correlation between GIS being a part of a teachers' studies and the agreement with statement 1, that there is enough time in the classroom to use GIS. Thereby, teachers who had GIS as part of their training scored a lower average agreement than participants not having GIS as part of their studies.

No statistically significant correlation was found between a teacher's **teaching experience** and the use of GIS. However, when looking at the number of teachers from different levels of experience using GIS in the classroom, it is noticeable that 59% of teachers with 0-6 years of work experience use GIS, while only 48.3% of teachers with 7-18 years and 46.7% of teachers with more than 18 years of experience use GIS. This seems to contradict Hubermann's phase model (1991) since it would be expected that mainly teachers with 7-18 years of professional experience, who are in the experimental phase, would use GIS. Further, those with less experience have to deal with their career entrance and would be expected to have less time for preparing GIS lessons (Messner & Reusser, 2000). This reasoning is strengthened when considering the time-consuming preparation of lessons in general, which is even increased by the use of GIS (Falk & Hoppe, 2004; Kerski, 2003). However, when compared to the statistically significant relationship with statement 2, namely that a teacher knows the latest GIS technology, teachers with 0-6 years of experience appeared to have the highest level of agreement. Thus, a better knowledge of GIS technology might explain the increased application during this age. Similar findings resulted from another study, proving a significant influence of teaching experience on technological literacy (Inan & Lowther, 2010).

Teachers between the ages of 35 and 45 were found to be the most likely to use GIS at 57.4%, but the difference from the other **age** groups was not statistically significant, so age does not affect GIS use.

This is consistent with other studies that have found that age does not directly affect technology integration in general (Gómez-Fernández & Mediavilla, 2022; Inan & Lowther, 2010).

It can be concluded that the inclusion of GIS in the curriculum, the availability of GIS software, and whether geography is a teacher's first subject have a significant influence on the use of GIS. However, the fact that GIS was a part of a teacher's studies, as well as the teaching experience and age of the respondent, does not have a statistically significant influence. Therefore, only part of H2.2 can be accepted, suggesting an influence of all external factors listed above.

6.2.2 Internal Factors

This section discusses the relationship between GIS use and teacher agreement with ten statements about GIS, data visualization and analysis.

Overall, participants rather disagreed with **statement 1**, that there is enough time available for using GIS in the classroom. Time seems to be an issue in general, as it was the most frequently mentioned challenge of GIS and the most often cited reason why GIS is not used. This aligns with the limitations of GIS listed by the literature, stating that using GIS is time-consuming to prepare and implement lessons (Falk & Hoppe, 2004; Kerski, 2003). Nevertheless, no statistically significant relationship could be found between the perceived availability of time and the application of GIS. Similar findings resulted from Bednarz and Van der Schee's (2006) study, where time was not found to be a significant impediment to the introduction of GIS. One possible explanation for this finding was that teachers always have to decide how to spend the available time. Therefore, it is reasonable to explain that these teachers have recognized the value of GIS, which is why they find the effort to use GIS worthwhile (Bednarz & Van der Schee, 2006). This is supported by other studies, which have shown that the perceived usefulness of technology is positively influencing the use of such technology (Gómez-Fernández & Mediavilla, 2022; Scherer et al., 2015).
It is reasonable to assume that this also pertains to the teachers in this study, as a statistically significant relation to **statement 5**, stating that GIS is an integral part of teaching geography, could be found. Thereby, teachers who use GIS in the classroom agreed more strongly with this statement on average. Therefore, a positive influence of the perceived importance of GIS on its use can be assumed.
Furthermore, teachers using GIS agreed more strongly with **statement 7**, that students should learn the basics of geospatial data in school, and **statement 9**, which states that GIS can help teach students how to use geographic data. Both were found to be statistically significantly associated with GIS use. Therefore, it can be assumed that teachers who consider geospatial data important are more likely to use GIS. This might be explained by the fact, as stated by Bednarz and Van der Schee (2006), that GIS is a valuable tool for teaching spatial data concepts.

Statement 2, that teachers know the latest GIS technologies, and **statement 4**, that a teacher knows how to use GIS in the classroom, proved to have a significant correlation with the use of GIS. In both cases, teachers using GIS rather agreed on the statements, while teachers not applying it rather disagreed. Both statements refer to teachers' competencies, suggesting that technological skills and didactic knowledge positively influence GIS use. This is backed up by the fact that 69.4% of teachers who did not use GIS cited a lack of skills as a reason for not using it.

These results are consistent with the literature, which states that a lack of knowledge is one of the main barriers to the implementation of GIS in the classroom (Bednarz & Van der Schee, 2006). In addition, a study in Swiss elementary schools has shown that the integration of technology into the classroom depends on the skills that teachers are confident in (Gonzalez & Torres, 2020; Petko et al., 2018). This demonstrates the importance of teacher training, which was furthermore cited by 42.5% of all teachers as a desired means of support.
Based on the results described above, it seems surprising that no correlation could be found between the use of GIS and whether GIS was part of a teacher's studies. Therefore, it can be assumed that GIS being part of a respondent's studies does not necessarily imply a good knowledge of GIS. This could be explained by the fact that teachers may have come into contact with GIS during their studies but only have deepened this knowledge if they choose modules related to GIS. Furthermore, it is also possible that teachers have taken advantage of training opportunities after graduation.

There is a statistically significant relationship between the agreement with **statement 3** that there is sufficient material to introduce GIS to the classroom and the use of GIS. While teachers using GIS saw the statement on average neutral, those who did not use it rather disagreed. A possible explanation could be that teachers using GIS are better informed about current offers, wherefore the availability is perceived more positively. This presumption is supported as 38.8% of teachers not using GIS indicated a lack of instructional materials as a reason for not applying it in the classroom. Nevertheless, the demand for additional teaching material was overall high, as 56.9% of all teachers named it as a possibility to support them in using GIS in the classroom. This demand could be due to the high time expenses needed to create their own teaching content and the dependence of less knowledgeable people on instructional materials for guidance, which have already been referred to in the literature (Bednarz & Van der Schee, 2006; Ridha et al., 2020). It has already been shown in the past that the availability of teaching material influences the use of GIS in education. This has been demonstrated by the appearance of the first GIS lessons on the market, which led to an increased application of GIS (Kerski, 2003; Kerski & Baker, 2019). Providing materials and raising teachers' awareness of already existing offers, thus, appears essential.

Altogether, one of the highest average levels of agreement was obtained for **statement 10**, that visualization and analysis of spatial data are an important part of teaching geography. No statistically significant relationship to the use of GIS could be found. These findings align with the expectations arising from the fact that both competencies are listed in the national framework curriculum (EDK, 1994) and that over 70% of the teachers reported teaching them.
Moreover, no statistically significant relationship could be found between the use of GIS and **statement 8**, that GIS facilitates teaching spatial data visualization and analysis, which was rather agreed with. This could be explained by the fact that data visualization and analysis are main capabilities of GIS that everyone agrees on, which is supported by Bednarz and Van der Schee (2006). In their study, they stated that GIS certainly has the potential to teach students basic concepts of data visualization and analysis (Bednarz & Van der Schee, 2006).

No statistically significant correlation could be found to **statement 6**, that GIS improves students' spatial thinking, which, on average, was rather agreed with. Therefore, spatial thinking seems to be a skill attributed to GIS in general and not only by teachers actively using GIS for teaching. It is also mentioned in the literature that GIS can support spatial thinking processes, as it enables the integration of different aspects related to phenomena, which therefore might be generally accepted (Bearman et al., 2016; Milson et al., 2012).

Based on H2.2, it was assumed that the use of GIS is influenced by a teacher's perception that GIS, spatial data handling, data visualization, and analysis are important, and that GIS is helpful in teaching these topics. Further, it was hypothesized that the use is influenced by a teacher's knowledge of GIS software and how to use it in the classroom, and the perceived availability of time and material. This hypothesis could only be partially accepted. A significant relationship could be found between teachers' knowledge of software, how to use GIS, the availability of teaching material, and the perception of GIS and spatial data handling as being an essential topic for teaching geography. However, no statistically significant correlation could be found to the availability of time, the perception that GIS improves students' spatial thinking skills, and neither to a teacher's perception that data visualization and analysis are important, and that GIS is helpful in teaching these topics.

6.3 Possibilities to Support Teachers

In this section, the results of the research question "How can teachers be supported in the use of GIS for data visualization and analysis in Swiss high schools?" are discussed. To this end, mainly answers to the open questions are examined. The first section addresses teachers' demands for support, while the second section reflects the teaching unit created in this Thesis based on the teachers' needs identified.

6.3.1 Demands of Teachers

The background research revealed that there is a wealth of teaching materials, instructions, and data freely available on the Internet. However, it was found that more than half of the teachers are interested in additional **material** and have specific requirements for it, which are presented below.
Teaching materials should be usable in a time-efficient manner, as time is the most frequently cited challenge in using GIS. Therefore, it should be linked to other curricular topics so that, in addition to methodological and technical skills, content-related goals are achieved. In this context, a link to other geographical topics has been suggested by the literature, as this promotes critical spatial thinking (Bearman et al., 2016; Kerski, 2003). Teachers were also interested in teaching aid that is applicable over long time periods, addressing the challenge of fast technological development cycles. Since it is inevitable to adapt GIS exercises to the latest software versions, it is important to ensure that higher-level concepts that are transferable to new product versions are taught in addition to short-lived product knowledge (Hartmann et al., 2007). In addition, teaching materials should cover different levels of difficulty and be individually adaptable. These requirements gain importance in consideration of the usually high heterogeneity among students when working with technology, which was addressed by teachers in the survey as well as in the literature (Bearman et al., 2016).
There further was a demand for instructional material that should guide teachers in implementing GIS in the classroom and students in working with GIS. This demand likely relates to the complexity of GIS,

being a frequently mentioned disadvantage. Furthermore, students should not merely work through instruction without engaging with the content, wherefore overarching questions that encourage students to actively think about the content are necessary (Kerski, 2003; Walshe, 2018).
Participants were also looking for suitable data that could be easily accessed and integrated into a GIS and that fit curricular goals. Data is the basis for working with GIS and teaching students how to work with spatial data, which is the most frequently mentioned benefit of GIS in teaching. Data that is collected by students themselves can also be integrated, but this is time-consuming (Herzig, 2007; Johansson, 2003), which explains the demand for ready-to-use data. Teaching material should further be verifiable and therefore come along with clear learning objectives, which according to literature are crucial to manage students learning activities (Städeli & Caduff, 2019).

About 40% of the teachers indicated that they would like more opportunities to improve their **competencies** in relation to GIS. Most were interested in further training opportunities that would effectively prepare them to use GIS in the classroom. Teachers were also interested in time for independent training and preparation of the topic for classroom use. Moreover, the desirability of integrating GIS into teacher training was raised. Especially for teachers who do not use GIS, training seems to be necessary, as 69.4% of them indicated a lack of competencies. In other studies, it has been shown that implementing training opportunities can increase the use of technology by teachers. This is especially the case when schools organize them and teachers have received recent training (Gerick et al., 2017; Gómez-Fernández & Mediavilla, 2022).

There further was a demand for **curricular changes** that, on the one hand, attribute more time to geography and, on the other, anchor GIS in the curriculum. It has been shown within this study and in the literature that the anchoring of GIS in the curriculum can indeed have a positive influence on its application in the classroom, while available time did not have a significant influence on its use (Bednarz & Van der Schee, 2006). Therefore, mentioning GIS in the curriculum is assumed to have a greater influence and thus should be the focus of future efforts.

Also, technical aspects, such as the availability of software, changed functionality, and the seamless working of technology, were mentioned as means of support by some teachers. However, it has been shown that the availability of software in Switzerland is good, wherefore the goal should not be to improve the availability but rather to make teachers aware of the available options. In addition, technological problems that were often mentioned as a disadvantage of GIS in the classroom can be addressed by training teachers to deal with them or providing support in case of problems. This was also a demand by some of the teachers, who were interested in support from experts who either teach GIS lessons or are available as contact persons for technical problems. It has already been shown in the past that additional support can positively influence teachers' adoption of technology in the classroom (Gómez-Fernández & Mediavilla, 2022).

6.3.2 Conception of a Teaching Unit

With regard to the demands of teachers and the scope of this master's Thesis, it was decided to create a teaching unit that takes into account the claims made. It further seeks to foster the advantages mentioned by the teachers while at the same time minimizing the disadvantages named. The teaching unit, consisting of two independent modules, is discussed in the following.

Module 1: Introduction to GIS

The first module serves as a short theoretical introduction to what a GIS is. It takes twenty minutes and does not include any practical work with GIS software and, therefore, does not take a much time in class. The module conveys basic concepts of GIS that are not affected by technological advances, thus being applicable for long time periods. According to the literature, this is crucial when teaching with and about technology (Hartmann et al., 2007). It further demonstrates the relevance of GIS for solving current and future problems, thus establishing a link to reality, which according to Woolfolk (2014), can increase students' motivation. During the practical realization, no issues occurred. Based on the feedback from the students, they enjoyed hearing about GIS and could take away from the lesson what a GIS is. Thus, it seems that the teaching module fulfills its purpose of giving students a first insight into GIS.

Module 2: Urban Geography with ArcGIS Online

The second module takes two lessons and comprises a practical exercise where students work with ArcGIS Online and identify urban regions in Switzerland. It addresses the curriculum-relevant topic of urban geography, which according to the literature, has the potential to foster spatial thinking due to the connection to another geographic topic (Bearman et al., 2016; Kerski, 2003). The web GIS "ArcGIS Online" was chosen to reduce the technological complexity to a minimum. Web-based GIS have proven to be advantageous for educational purposes due to lower functionalities than desktop versions (Kerski & Baker, 2019). Further, it is already used by many teachers in Swiss high schools. For the purpose of guiding teachers in using ArcGIS Online, additional instructions and solutions for frequently occurring problems were provided in a teacher commentary. In order to avoid loss of time during the implementation, preprocessed data was used, and a step-by-step guide was designed to lead the students through the program. This also enables the students to work independently on the exercise. Thereby, they discover simple functions for data analysis, like filtering and summarizing points within a boundary, and further visualize the obtained results. Moreover, content-related questions were posed, where they had to analyze the visualized results and draw conclusions from them. According to Walshe (2018), this helps to get students to engage with the topic in more depth. In order to counteract heterogeneity among students, additional tasks were created that teachers can hand out to students who finish the tasks early.

Despite some minor technological problems, the teaching unit could be held as intended. These problems occurred on the one hand due to errors on the part of the students. To fix them, a teacher must have a basic understanding of the teaching module and the program. On the other hand, questions arose due to an updated data set, wherefore, the instructions of one task did not apply anymore. This

highlights the rapid development of technology, which makes practical exercises quickly outdated. Therefore, they need to be regularly adapted to changes in order to remain operational.
In general, it could be observed that teachers have to supervise the students while working with GIS intensively. Since the lesson was conducted with half a class, no problems occurred. However, if this is not possible, it could lead to an excessive demand on the teacher. In order to prevent this, students should work in teams and be encouraged to support each other.
Heterogeneity in the students' pace of work was also noted, which is why additional tasks for fast students are important. In general, it was found that, as described in the literature, certain flexibility and good problem-solving skills of the teacher are required when technology and inquiry-based learning methods are used, as lessons can be planned less effectively (Herzig, 2007; Kerski, 2003).
Overall, a high level of student activity and motivation was observed during the lesson. This could be due to the independent work on the exercise, as based on the student feedback, they especially appreciated the free working time. This finding is in line with the literature, which states that autonomous work can increase the motivation of students (Woolfolk, 2014). Further, based on the student's feedback, it can be assumed that the content goals set for the teaching unit have been achieved.

6.4 Limitations and Future Research

In general, some limitations arise for this Thesis, which will be presented in the following. Possibilities for future research are also outlined.

A clear limitation of the survey conducted is that it is based on voluntary responses and therefore does not represent the views of all geography teachers at Swiss high schools. As noted in a similar study, it can be assumed that teachers who use GIS in the classroom are more likely to participate in the survey (Kerski, 2003). Therefore, the results may be somewhat biased, giving a more positive picture of GIS use than is actually the case.
Furthermore, the coding scheme used to analyze the open-ended questions may be prone to subjectiveness, as the codes were not solely derived from the literature but also based on the data resulting from the survey. Therefore, individual perceptions of the importance of topics may have influenced the generation of codes.
A further limitation arises for the discussion. Based on the literature and subjective perception of importance, the relevant findings were presented and discussed. However, it is important to be aware that this is not all-inclusive, and further conclusions can be drawn from the findings.

Another constraint resulted from the limited time available within the scope of this Thesis. Therefore, it was only possible to focus on one of the teachers' demands, which in this case was the design of a teaching unit adapted to the teachers' needs. However, other means of support, such as further training and the inclusion of GIS in the curriculum, are crucial for the widespread implementation of GIS in the classroom. Therefore, future initiatives and research should also focus on improving teachers' competencies and integrating GIS into the curriculum. The current revision of the national curricula for cantonal schools provides an opportunity for the latter.
In addition, the teaching unit was only created in German and can therefore currently only be used in the German-speaking part of Switzerland.

There are also limitations to the practical implementation and testing of the teaching unit. As it has only been tested with a single half-class, it is not possible to say whether it could be worked through equally effectively in other settings, for example, with a whole class. It is also difficult to assess how teachers with little experience in the field of GIS will be able to implement it and whether the measures taken to facilitate its use are sufficient. Therefore, the teaching unit should be tested by more teachers in the future and adapted based on their feedback. If the unit works, additional teaching materials in this form, tackling other curriculum-related topics, can be developed based on the elaborated structure.
Furthermore, it would be interesting to find out how effective the knowledge transfer is with the help of the created teaching unit. Previous studies that have already looked at the effectiveness of GIS in the classroom have found that students engage more deeply with the content but that the time required is usually also greater (Demirci, 2015; Kerski, 2003).
It was also found that not only the availability of software and teaching materials can be a barrier to the use of GIS but also teachers' awareness of where to find these resources. Therefore, in addition to providing teachers with more resources, raising their awareness of what is available is essential.

In this study, the focus was on high school education, which affects only a small percentage of people. Since in Switzerland, a large part of the population is in contact with GIS on an almost daily basis, future research should also focus on the introduction of GIS in Swiss schools at lower grades.
Furthermore, it was focused only on geography teachers. As GIS can also be applied in other subjects such as biology, history, and chemistry, it may be of future interest to find out how GIS is used in other areas of education (Khudiakova, 2008; Kohloshyn et al., 2017).

Chapter 7 Conclusion

Information about the earth's surface has been critical to many aspects of human life since time immemorial (Unwin et al., 2012). In recent decades, however, technological advances have changed how people use and process spatial information in their professional and personal lives (Zawacki-Richter & Latchem, 2018). Among these developments are GIS, which have demonstrated their potential to use spatial data analysis and visualization to solve current and future problems, not least during the COVID-19 pandemic (Bearman et al., 2016; Geraghty & Kerski, 2020; Milson et al. 2012). Further, they have become increasingly important in everyday life through smart devices, navigation applications, and social media (Unwin et al., 2012; Waters, 2017). As a result of these developments, GIS was considered a more and more essential part of education and was, therefore, gradually integrated into teaching (Milson et al., 2012; Kohloshyn et al., 2017). While basic concepts of GIS can already be taught at lower levels, the in-depth study of GIS software and related data visualization and analysis is recommended for higher grades from high school onwards (Falk & Hoppe, 2004; Herzig, 2007). Since it has started being integrated into education, GIS has proven to be a helpful tool that promotes constructivist teaching methods (Falk & Hoppe, 2004; Herzig, 2007; Johansson, 2003), is relevant to real life (Bednarz, 2004; Walshe, 2018), and strengthens the students' practical competences (Johansson, 2003; Kerski, 2003). However, it has been unclear how GIS is currently used for geography education in Swiss high schools for data visualization and analysis, what factors influence its use, and how teachers can be supported in using it. For this reason, a survey was conducted among geography teachers in Swiss secondary schools to learn more about the current situation.

The survey revealed that about 50% of high school teachers use GIS in their teaching, with 40% of all teachers having students use GIS software for data visualization and analysis. The respondents indicated that they mainly employ GIS for teaching in the 9th and 10th school years. Furthermore, GIS is used both as the primary learning content and to teach other curriculum-relevant subjects. It appears that GIS is well suited for teaching topics from physical and human geography, but especially for interdisciplinary topics that combine aspects of both. Moreover, it was also found that the majority of teachers rely on web-based GIS applications.

Based on the results, it was found that of the external factors, the mention of GIS in the curriculum, the provision of GIS software at a school, and geography being a teacher's first subject proved a statistically significant correlation to the use of GIS. Other factors, such as whether GIS is part of a teacher's studies, teaching experience, and age, can be neglected. It can be assumed that the integration of GIS in the curriculum has a positive influence on the use of GIS, as teachers are more likely to use GIS when it is mentioned in the curriculum. Also, the provision of software by a school seems to increase the application of GIS in the classroom. It can be concluded that this is mainly due to teachers' enhanced awareness of the topic rather than the availability of software itself, as all teachers in Switzerland could have access to GIS software. Furthermore, geography being a teacher's first teaching subject, also appears to influence the use of GIS positively. This may relate to the overall better subject knowledge of those teachers.

Of the internal factors, a teacher's knowledge of GIS and how to use it in the classroom, the importance placed on GIS and working with spatial data, and the perceived availability of material showed a statistically significant correlation with the use of GIS. The perceived availability of time, GIS supporting spatial thinking, and the importance attached to data visualization and analysis and to GIS as a valuable tool for this do not seem to influence the use of GIS. It can be assumed that teachers who attach higher importance to GIS and working with spatial data are more likely to use it, as they, on average, agreed more strongly with those statements. It was also found that teachers who know more about GIS technologies and how to use them in the classroom appear more likely to apply them. Teachers using GIS further seem to be better aware of existing teaching materials than teachers who do not use it.

Regarding possibilities to support teachers in using GIS, it appeared that they were mainly interested in additional teaching material. Thereby, the material should be time efficient in use, relate to other curricular topics, cover different levels of difficulty, and come along with clear instructions and data. Thus, a teaching unit tackling those demands was created within the scope of this work. Some benefits of using GIS were evident during the implementation, such as high student motivation and independent learning. At the same time, drawbacks such as heterogeneity, a high effort for student support, and short life cycles of technology were apparent. The Latter could be minimized as the teaching unit was prepared concerning those issues.
Besides teaching aid, the respondents were also interested in possibilities for improving their competencies, such as further training and time for independent training. Moreover, curricular changes were demanded, and additional support from experts who support teachers during the use of GIS was requested.

In summary, there is still room for improvement in the use of GIS in Swiss high schools, as it is currently applied by only half of the teachers. To advance the use of GIS, not only must more instructional materials be created, but teachers must be made more conscious of where to find available resources. Furthermore, raising teachers' awareness of the importance of GIS can lead to increased use. In addition to further training possibilities, this could also be achieved by anchoring GIS in the curriculum, which has proven to influence the use of GIS positively.

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Appendix A

In the following, excerpts of the cantonal curricula are listed, which include GIS, data analysis, and data visualization.

***Table A.1**: Excerpts of the cantonal curricula including GIS, data analysis and data visualization and the according sources.*

Kanton	Section	GIS	Data Analysis	Data Visualization	Source
Aargau	"Daten in vielfältigen Darstellungsformen (Text, Ton, Bild, Film) analysieren" "Elektronische Informationsmittel (z.B. Web-GIS, Web-Datenbanken) nutzen"	1	1	1	(Departement Bildung Kultur und Sport, 2021, p. 37)
Bern (German)	"eignen sich grundlegende fachspezifische Fertigkeiten im Beschaffen, Strukturieren, Analysieren, Interpretieren, Darstellen und Vermitteln von geografischen Informationen an. Dafür werden Karten, Profile, Diagramme, Statistiken, Bilder, Texte und Grafiken interpretiert, selbst entworfen und **Geografische Informationssysteme (GIS)** angewendet"	1	1	1	(Erziehungsdirektion des Kantons Bern, 2016, p. 98)
Bern (French)	"Lire, analyser et construire des cartes thématiques ainsi que, selon les cas, des coupes-synthèses et des croquis." "Choisir et se servir des technologies de l'information et de la communication."	0	1	1	(Direction de l'instruction publique et de la culture, 2020, p. 47)
Basel-Landschaft	"Der Geografieunterricht vermittelt systematisches Grundlagenwissen in den Natur- und Sozialwissenschaften, wobei auf verschiedene geografische Arbeitsmethoden zurückgegriffen wird, z. B. Feldforschung, Daten-, Text-, Bild- und Kartenanalyse sowie digitale Informationstechnologien (bspw. **Geografische Informationssysteme GIS)**"	1	1	1	(Basel-Landschaft, 2021, p. 61)
Basel-Stadt	"Kartographische und andere raumbezogene Daten lesen, interpretieren und bewerten" "Elektronische Informationsmittel (UB, Internet, Online-Datenbanken, Statistische Ämter, Digitale Globen, **GIS**) nutzen und für eigene Recherchen, Stellungnahmen und Vorträge einsetzen"	1	1	1	(Erziehungsdepartement des Kantons Basel-Stadt, 2020, p. 40)
Fribourg (German)	"Geografische Darstellungsmethoden anwenden, thematische Karten, Profile, Diagramme, Statistiken, Modelle, Bilder und Texte interpretieren und z.T. selbst entwerfen; Ergebnisse geographischer Untersuchungen verständlich darstellen und weitergeben"	0	1	1	(Amt für Unterricht der Sekundarstufe 2, 2020, p. 1)
Fribourg (French)	"Appliquer des méthodes de représentations géographiques, interpréter et produire des cartes thématiques, des profils, des diagrammes, des statistiques, des modèles, des images et des textes ; restituer et représenter de façon compréhensible les résultats de recherches géographiques"	0	1	1	(Service de l'enseignement secondaire du deuxième degré, 2020, p. 1)
Genève	"A l'aide des méthodes et connaissances spécifiques à la discipline, l'enseignement de la géographie conduit à s'interroger sur les processus qui structurent le territoire, à les analyser dans le but de mieux les comprendre et, surtout, à guider l'action dans l'avenir."		1		(Département de l'instruction publique, 2019, p. 43)
Glarus	"Grafiken lesen und analysieren" "sind in der Lage, geografische Untersuchungen zu verstehen, zu formulieren und darzustellen." "Kartografie, GIS-Anwendungen"	1	1	1	(Regierungsrat des Kanton Glarus, 2019, pp. 79, 80, 83)
Graubünden	"Die Grundfertigkeit des Kartenlesens wird kontinuierlich gefördert und soll Schülerinnen und Schüler schliesslich befähigen, Karteninhalte zu interpretieren, räumliche Sachverhalte selber zu skizzieren und auch mittels Datenverarbeitung darzustellen."		1	1	(Kanton Graubünden, n.d., p. 109)
Luzern	"Methodische Inhalte Darstellen, vergleichen und interpretieren" **GIS as part of supplementary subject:** "Die Bedeutung von Geografischen Informationssystemen (GIS) als Instrument der Geografie kennen lernen"	0	1	1	(Dienststelle Gymnasialbildung, 2021, p. 84)

Nidwalden	**GIS as part of supplementary subject:** "Quantitative Geografie/Geografische Informationssysteme - Datenverarbeitung (GIS)"	0	0	0	(Amt für Berufsbildung und Mittelschule, 2020, p. 90)
Solothurn	"bestimmen geeignete Methoden zur Bearbeitung, Analyse und Interpretation von Daten und Sachinformationen und setzen diese Methoden adäquat ein" "vertiefen ihre Kompetenzen und ihre Kenntnisse in der Nutzung Geografischer Informationssysteme (GIS) und weiterer digitaler Analyse-Instrumente (z. B. Google Earth)"	1	1	1	(Kanton Solothurn, 2019, p. 184)
St.Gallen	"sind fähig, geographische Darstellungsmethoden anzuwenden, thematische Karten, Profile, Diagramme, Statistiken, Modelle, Bilder und Texte zu interpretieren und zum Teil selbst zu entwerfen" "Kartographische Darstellung geographischer Informationen: Thematische Karten" "Der Einsatz des Computers ist im Geographieunterricht in vielfältiger Weise möglich und sinnvoll"		1	1	(Gymnasien des Kantons St.Gallen, 2010, pp. 76, 77, 80)
Thurgau	"geographische Darstellungsmethoden anwenden und erarbeitete Themen überzeugend präsentieren (durch Texte, Graphiken, Vorträge etc.)" "das Zusammenspiel menschlicher Tätigkeit mit naturgeographischen Elementen analysieren und interpretieren."		1	1	(Kanton Thurgau, n.d., p. 73)
Total: 15	**Sum**:	6	14	13	

Appendix B

Appendix B contains details information on the survey questions asked to the participants in English. The same questions were also asked in German, French and Italian, but are not added to the appendix to avoid redundancy.

SC = Single Choice

MC = Multiple Choice

OQ = Open Question

Survey on the use of GIS software at Swiss high schools

Description of survey and welcome message:
This survey is being conducted as part of Stéphanie Wismer's Master's Thesis at the University of Zurich. It will take about 10 - 15 minutes in total. The aim is to find out how widespread and currently used Geographic Information Systems (GIS) are in lessons at Swiss high schools. Based on the results, a concept will be developed in the next step, which should facilitate the use of GIS in high schools. To participate in the survey, it is not important if you already use GIS in your lessons or not.

The use of GIS in the classroom is considered to be the following: A system that enables the collection, processing, organization, analysis and/or visualization of spatial data is used (e.g., ArcGIS, QGIS or map.geo.admin.ch from swisstopo). The mere viewing of online maps is not considered as GIS use in the classroom in the context of my work and in this survey.

Thank you for taking the time to participate in the survey!

Survey Data policy message:
Participation in the survey is voluntary. Your decision to participate in the survey or not will not affect any current or future relationship with the University of Zurich or the researchers involved. Any information collected through the survey will be kept confidential and anonymous. By participating in the survey, you agree that results of the survey may be published anonymously in the scientific community. If you have any questions or are interested in the results, please feel free to contact me at any time (stephanie.wismer@bluewin.ch).

Survey data policy checkbox label:
I hereby confirm that I have read and understood the terms and conditions of the survey and agree to be bound by them.

Question block 1: Attitudes toward GIS and its use in high schools

Indicate how strongly you agree with the following statements on a scale of 1-7 (1 = I strongly disagree, 7 = I strongly agree)

Statement / Agreement	1 – I strongly disagree	2 – I do not agree	3 – I rather do not agree	4 – Neutral	5 – I rather agree	6 – I agree	7 – I strongly agree	Don' t know / No answer
1. There is enough time to use GIS in class.								
2. I know the latest GIS technologies.								
3. I use GIS in my teaching.								
4. There is enough material available to integrate GIS in the classroom.								
5. I know how to use GIS in the classroom.								
6. GIS improves students' problem-solving skills.								
7. GIS is an important part of teaching geography								
8. GIS improves students' spatial thinking skills.								
9. Students should learn the basics of spatial data in high school.								
10. GIS facilitates the teaching of spatial data visualization and analysis.								
11. GIS can help to teach students how to work with geographic data.								
12. Visualizing and analyzing spatial data is an important part of teaching geography.								

Question block 2: The use of GIS in the classroom

13. SC: Is the teaching of GIS skills in the curriculum of the canton/school in which you teach?
    - ○ Yes
    - ○ No
    - ○ Don't know / No answer

Conditional Question Complex
14. SC: Does your school provide GIS software? a. Yes b. No c. Don't know / No answer
If 16 a is selected
15. MC: What GIS software is provided? ○ ArcGIS Desktop ○ ArcGIS Online ○ Map your World ○ QGIS ○ Other: ____________________

Conditional Question Complex

16. SC: Do you use GIS in your lessons?
    a. Yes
    b. No

If 18 a is selected

17. MC: What GIS software do you use?
    - ArcGIS Desktop
    - ArcGIS Online
    - Map your World
    - QGIS
    - Other: ______________________
18. MC: At what grades do you use GIS in your classroom?
    - Lower secondary school (1-2 year)
    - Upper secondary school (3-4 year)
    - Upper secondary school (5-6 year)
    - Other: ______________________

Conditional Question Complex

19. MC: In what context do you use GIS in the classroom?

a. Geography in the basic subject
b. Geography as a supplementary subject
c. Geography in project weeks
d. In another subject
e. Other: ______________________

If 21 d is selected

1. OC: In which subject have you used GIS in class?

20. SC: Do you use GIs as method in your teaching (e.g., GIS for teaching other learning content)?
    - Yes
    - No
    - Don’t know / No answer
21. SC: Do you use GIS as learning content in your teaching (i.e., GIS and relevant concepts are the main subject of the lesson?
    - Yes
    - No
    - Don’t know / No answer
22. OC: For teaching what topics do you use GIS?
23. SC: Do you prepare lesson materials using GIS software?
    - Yes
    - No
    - Don’t know / No answer
24. SC: Do the students use GIS software in your lessons?
    - Yes
    - No
    - Don’t know / No answer
25. MC: What material do you use for teaching with GIS?
    - Self-created teaching materials
    - From existing teaching materials
    - From colleagues
    - Other: ______________________

If 18 b is selected

Conditional Question Complex

26. SC: Have you used GIS in your teaching in the past?
    a. Yes
    b. No

If 28 a is selected

27. SC: Have you used GIS as a method in your teaching (e.g., GIS as a tool to teach other learning content?
    - Yes
    - No
    - Don't know / No answer
28. SC: Did you use GIS as learning content in your teaching (i.e., GIS and relevant concepts are the main subject of the lesson?
    - Yes
    - No
    - Don't know / No answer
29. OC: For teaching what topics did you use GIS?
30. Have students used GIS software in your classes?
    - Yes
    - No
    - Don't know / No answer
31. MC: For what reasons do you no longer use GIS in your classroom?
    - Too little available teaching material
    - Too little time
    - Too high costs
    - Topic is not so relevant compared to other topics
    - Too few training opportunities
    - Too few competencies
    - Dependence on the functioning of the technology
    - No technology provided
    - Bad experience
    - Too much effort
    - Other reasons: ________________________
32. OC: Under what circumstances would you use GIS for your teaching again?

If 28 b is selected

33. MC: For what reasons do you not use GIS in your classroom?
    - Too little available teaching material
    - Too little time
    - Too high costs
    - Topic is not so relevant compared to other topics
    - Too few training opportunities
    - Too few competencies
    - Dependence on the functioning of the technology
    - No technology provided
    - Bad experience
    - Too much effort
    - Other reasons: ________________________
34. OC: Under what circumstances would you use GIS for your teaching?

Conditional Question Complex
35. SC: Do students analyze geographic data in your classes? a. Yes b. No c. Don't know / No answer
If 37 a is selected
36. SC: Do students use GIS software for analyzing geographic information? ○ Yes ○ No ○ Don't know / No answer

Conditional Question Complex
37. SC: Do students visualize geographic data in your classes? a. Yes b. No c. Don't know / No answer
If 39 a is selected
38. SC: Do students use GIS software for visualizing geographic information? ○ Yes ○ No ○ Don't know / No answer

Question block 3: Open Questions

39. OC: How do you think teachers could be supported in using GIS in the classroom?
40. OC: What advantages can GIS have in the classroom?
41. OC: What challenges can GIS bring to the classroom?"
42. OC: Do you have any additional remarks?

Question block 4: Demographic information

43. MC: In which canton(s) do you teach?
    - List with all cantons of Switzerland
44. What subject(s) do you teach?
    - List with the following subjects: *Biology, Chemistry, English, French, German, Geography, History, Greek, Computer Science, Italian, Latin, Mathematics, Pedagogy/Psychology, Philosophy, Physics, Romansh, "Religion, Culture and Ethics", Russian, Spanish, Economics and Law.*

Conditional Question Complex
45. Do you teach geography as your first subject? *a.* Yes *b.* No *c.* Don't know / No answer
If 47 a is selected
46. SC: What specialization did you take in your degree? ○ List of specializations: *General Geography, Physical geography (e.g. soil science, glaciology), Human geography, remote sensing, geographic information science and systems, geology, earth system science, I have not done any specialization* ○ Other: ______________________

47. Were Geographic Information Systems (GIS) and related Science (GIScience) part of your degree program?
    - Yes
    - No
    - Don't know / No answer
48. SC: How many years have you been teaching?
    - Less than one year
    - 1-3 years
    - 4-6 years
    - 7-18 years
    - 19-31 years
    - More than 31 years
49. SC: How old are you
    - Less than 25 years
    - 15-24 years
    - 35-44 years
    - 45-54 years
    - 55-64 years
    - More than 65 years

Appendix C

Appendix C contains detailed information on how many answers were received from teachers for each canton and how many of them use GIS. As two teachers were employed in two cantons, 148 answers were received.

Table C.1: *GIS use per canton (Number of respondents = 146)*

Canton	GIS Use: No	GIS Use: Yes	Total Answers	GIS Use [%]
Aargau	8	5	13	38.5
Basel-Land	2	2	4	50
Basel-Stadt	3		3	0
Bern	7	15	22	68.2
Freiburg	5	1	6	16.7
Genève	6		6	0
Graubünden	4	3	7	42.9
Luzern	5		5	0
Neuchatel	1	4	5	80
Nidwalden	1		1	0
Obwalden	1	2	3	66.7
Sankt Gallen	1	6	7	85.7
Schwyz	2	2	4	50
Solothurn	1	2	3	66.7
Thurgau	1		1	0
Ticino	3	1	4	25
Uri	1		1	0
Valais	2	1	3	33.3
Vaud	6		9	0
Zug	2	3	5	60
Zurich	10	29	39	74.4
Total:	72	76	148	52.1

Appendix D

Appendix D contains all answers to the open question from the survey coded with the coding scheme.

Table D.1: *Categories for the question: For which topics can GIS be used in the classroom?*

Interdisciplinary Topics	1	Spatial planning
	2	Cartography
	3	For many purposes
	4	Natural hazards
	5	Change detection
	6	Resources and Raw materials
Physical Geography	7	Geomorphology
	8	Landscape and urban ecology
	9	Hydrogeography
	10	Biogeography
	11	Climatic geography
	12	Soil geography
Human Geography	13	Urban geography
	14	Population geography
	15	Economic geography
	16	Social geography
	17	Geographical development re-search
	18	Political geography
Application Competencies	19	Data visualization
	20	Data analysis
	21	Research projects
Other	22	No answer

Table D.2: *Categories for the question: What bene-fits can GIS bring to the classroom?*

Data Literacy	1	Data visualization
	2	Data analysis
	3	Data handling
	4	Data collection
Skill Acquisition	5	Dealing with technology
	6	Spatial thinking
	7	Linking/deepening
	8	Handling maps
	9	Solving problems
	10	Critical thinking
Didactic Aspects	11	Inquiry-based learning
	12	Digital teaching
	13	Individualization
	14	Interdisciplinarity
	15	Project work
	16	Different method (variety)
Relevance	17	Preparation for university / Sci-entific work
	18	Practical relevance
	19	Relevant to everyday life
	20	Future-oriented
Motivation	21	Variety
	22	Use of technology
	23	Interest
	24	Topicality
Other	25	No answer
	26	Other Responses

Table D.3: *Categories for the question: What challenges can GIS bring to the classroom?*

Time exposure	1	Time
	2	Time in class
	3	Too much time spent on method and technology
	4	Time for preparation
Technology	5	Problems
	6	Screen time
	7	Availability
	8	Control
	9	Cost
	10	Fast change
Complexity	11	Complexity
	12	Complexity for students
	13	Complexity for teachers
	14	Work through instructions
Teacher Competence	15	Competencies of teachrs
	16	Supervision of students
	17	Education
Heterogeneity	18	Student Competence
	19	Work pace
	20	Interests
Other	21	Find material
	22	Expense and income
	23	No answer
	24	Other Responses

Table D.4: *Categories for the Question: Under what circumstances would you use GIS for your teaching (again)?*

Teacher Competence	1	Further training
	2	Independent training
	3	More competencies
	4	Education
Material	5	Available teaching material
	6	Available data
Curriculum	7	More time in class
	8	Part of the curriculum
Setting	9	Teaching other topics
	10	Project weeks
Technical Aspects	11	Available hardware
	12	Functionalities of the software
	13	Available software
	14	Technology is working
Other	15	No answer

Table D.5: *Categories* for *the Question: How do you think teachers could be supported in using GIS in the classroom?*

Material	**1**	Available teaching material
	2	Available instructional material
	3	Available data
	4	Curriculum related material
Teacher Com-petence	**5**	Further training
	6	Time for independent training
	7	Education
Curriculum	**8**	More time in class
	9	Part of the curriculum
Technical As-pects	**10**	Available software
	11	Functionalities of the software
	12	Technology is working
	13	Available hardware
Support	**14**	Support by specialists
	15	Cooperation
	16	Additional support person
Other	**17**	Support is sufficient
	18	No answer

Table D.6: *Coding of the answers to the question: For which topics can GIS be used in the classroom? (Number of respondents = 92).*

ID	Answers: For which topics can GIS be used in the classroom?	Interdisciplinary Topics						Physical Geography						Human Geography						Competencies			Other
		1	2	3	4	5	6	7	8	9	10	11	12	15	16	17	18	19	20	21	22	23	24
1	- Orientieren im Raum - Wüstenbildung		1					1															
2	Ökologie, Raumplanung	1									1												
5	Diverse			1																			
9	Kartierung von selbst erhobenen Daten (Gefahrenkarten, Mietpreise, Einzugsgebiete, Standortqualität, Raumnutzung,...) Isochronenkarten Heatmaps		1		1															1			
13	Erdbebenverteilung, Standortanalyse (z. B. für Windkraftanlagen)							1	1												1		
14	Obergymnasium: - Standortanalysen, z.B. Windkraftstandorte in der Schweiz - Landschaftswandel mit Satellitenbildern, z.B. tropischer Regenwald in Brasilien - Kartierungsarbeiten: Lärm in urbanen Gebieten; wirtschaftliche Nutzung von Gebäuden Untergymnasium: - Plattengrenzen, Vulkanismus und Erdbeben					1		1	1											1	1		
39	Verständnis wecken, dass "einfache Landkarten" mit Informationen verknüpft werden können.	1	1				1																
18	Naturgefahren, Raumplanung, Rohstoffe, Eiszeiten	1			1		1	1	1														
19	Raumplanung, Naturrisiko, Landnutzungs- und Umweltveränderungen				1	1																	
90	Eigentlich für fast alles - Steine kartieren, Stadtgeo, Bodenkunde, Raumplanung sowieso	1	1	1				1					1	1									
24	Umweltgefahren, Geologie, Vegetation, Gletscher				1			1		1	1												
29	Ich finde es sehr nützlich bei naturwissenschaftlichen Forschungsprojekten im Feld z.B. Hydrologie oder Bodenkunde.									1			1									1	
31	- räumliche Daten visualisieren, z.B. Armut, Einkommen, Bevölkerungsdichte usw. - Swisstopo Anwendungen: messen, berechnen usw.														1	1				1	1		
32	Je nach dem was online an Materialien zur Verfügung steht, kann GIS grundsätzlich für fast alles angewendet werden. Hauptsächlich finde ich es spannend eigene Daten zu er-heben, einzulesen, zu visualisieren und danach zu analysieren. Bsp. Lärmdaten erfassen Ich habe auch schon fertige Einheiten mit den SuS angeschaut Bsp. Thema Erdbeben, Ernährungssicherheit (Schnittstelle Fernerkundung)			1				1						1		1				1	1		
34	Umgang mit räumlichen Daten -> methodische Ebene																			1	1		
37	Raumplanung und Lärmmessung viele weitere Anwendungsmöglichkeiten	1		1										1									
44	Umweltmonitoring, Gentrifizierung					1								1									
48	Darstellung von bevölkerungsgeografischen Daten .														1					1			
51	in generale per le competenze di analisi e interpretazione																				1		
55	Visualisierung von Unterrichtsthemen, um räumlichen bezug herzustellen																			1			
58	Geologie: Visualisierung von Erdbeben, Vulkanische Aktivitäten, Plattengrenzen Humangeografie: Migrationsbewegungen, Wirtschaftliche Aktivitäten							1							1	1				1			
60																							1

ID	Answers: For which topics can GIS be used in the classroom?	Interdisciplinary Topics						Physical Geography						Human Geography						Competencies			Other
		1	2	3	4	5	6	7	8	9	10	11	12	15	16	17	18	19	20	21	22	23	24
61	Alles mögliche, je nach Bedarf: Kartografie, Naturgefahren, Raumplanung, Geologie der CH, Bevölkerung...	1	1	1	1			1							1					1			
62	Kartographie, Raumplanung		1																				
67	räumliche Analysen (z.B. Erdbeben), Stadtgeografie							1						1							1		
69	Raumplanung, globale Disparitäten, Stadtgeografie, Wirtschaftsgeografie...	1												1		1	1						
72	Zur Erfassung und Analyse räumlicher Strukturen.																				1		
73	Stadtgeographie Feldforschung Hydrologie									1				1								1	
74	Ressourcen (z.B. Palmöl, Rohöl etc.) Demografie Stadtgeografie						1							1	1								
77	Geologie, Stadtentwicklung, Raumplanung	1						1						1									
78	Kleines Forschungsprojekt im Nahraum (Lärm / Tempertaur / Neophyten u.a.m.)										1			1								1	
80	Plattentektonik, Erdbeben, Vulkanismus							1															
22	Diversers: Stadthitze (Temperaturverteilung), Verteilung von verbauten Gesteinsarten etc...			1				1						1									
91	Bevölkerung, Armut, Landwirtschaft, Bodenbedeckung, Bodenform, Basisdaten, Niederschlag, Biodiversität u. Tierwelt, Tourismus, Wasser/Bewässerung/Wasserkraft Hydrologischer Atlas der Schweiz Digitaler Atlas der Schweiz: z.B. Bevölkerungsentwicklung, Altersstruktur Geologie, Naturgefahren, Klimawandel Kurzum: Es gibt kaum ein geografisches Thema, bei dem sich GIS nicht eignen würde.			1	1			1	1	1	1	1	1	1	1	1	1						
93	Vulkanismus, Erdbeben, Plattentektonik Abholzung Regenwälder, Infrarotauswertungen (es fehlen jedoch gute Daten oder auswertbare Daten).						1	1								1							
94	Zeitliche Veränderung (z.B. Gletscherrückgang), Erstellung thematischer Karten					1				1										1			
95	Erdbeben, Zusammenhang Herdtiefe und Plattengrenzenart. Noch nie gemacht aber evtl. möglich: Simulation Meeresspiegelanstieg, Analyse Bevölkerungsdaten (woher die Daten?)					1		1		1					1								
97	Analysen im Lebensraum								1		1				1						1		
98	Raumplanerische Aspekte naturräumliche Grundlagen bzw. deren Verknüpfung	1																					
101	Geologie, Bevölkerungsgeografie, Klimatologie, Ökologie, Wirtschaftsgeografie...							1			1	1			1	1							
106	Klimathemen. Zu jedem Thema bei dem Opendata zur Verfügung stehen. Siedlungsentcklung Zürich. Glaziologie und Pionierpflanzen im Gletschervorfeld. USA und Siedlungsentwicklung. Tornados in den USA. Geologie der Schweiz. Wasserfussabdruck. Globalisierung. Entwicklung und Unterentwicklung, sowie Entwicklungstheorien.						1			1	1	1		1			1	1					
107	Die Frage iat schon mal, wie GIS definiert wird. Map.geo.admin erlaubt beispielsweise gute historische Kartenvergleiche für die Raumplanung. Google Maps erlaubt es Rundgänge zu machen...Aber ist das schon GIS? Mit QGIS kann man vieles, bspw. Wirtschaftliche Zahlen darstellen auf Länderniveau.					1										1	1						
109	Geologie Raumplanung Energiepolitik	1						1											1				
111	Standortfragen (Standortfaktoren)								1														
114	Umwandlung von Daten in selbst erstellte Karten, Präsentation von Themen in StoryMaps	1						1						1		1				1			

ID	Answers: For which topics can GIS be used in the classroom?	Interdisciplinary Topics						Physical Geography						Human Geography						Competencies			Other
		1	2	3	4	5	6	7	8	9	10	11	12	15	16	17	18	19	20	21	22	23	24
115	Wirtschaftsgeografie, Humangeografie, Raumplanung, Stadtentwicklung																						
118	-																						
119	Naturkatastrophen, Ländermerkmale (Disparitäten), Topografie				1			1									1						
120	alle Lehrplaninhalte			1																			
121	SOL Project work																					1	
122	Raumverteilungen: Geologie, Wirtschaftsgeografie u.v.m.							1								1							
124	planification de trajet / compréhension des courbes de niveau		1																				
125	Démographie, météorologie, géologie, cartographie		1					1				1			1								
126	Kartenkunde, Kartierung geografischer Inhalte		1																	1			
132	Für Projektarbeiten, zum Durchlaufen eines gesamten EVAP-Zyklus.																					1	
133	Partout			1																			
137	Globale Zusammenhänge Regionale Raumanalysen								1					1			1				1		
138	keine im Speziellen			1																			
141	Kartenkunde		1																				
143	aménagement du territoire	1																					
144	kein besonderer Themenbereich. Aber eher sozial- als naturwissenschaftlich.			1													1						
146	Hydrologie, Ökozonen, Bevölkerungsgeographie, Umweltthematiken, Ressourcenvertei-lung						1		1	1	1				1	1							
158	alle Themen, bei denen Daten gesammelt werden			1																	1		
150	keine Antwort																						1
151	Hydrologie, Géomorphologie et géologie : orthophotos, MNT, voyage dans le temps, in-ventaires divers. Climatologie et paysage ("la Terre vue du ciel"): analyse d'images satellites pour com-prendre comment le paysage a évolué depuis les premiers Landsat. Géopolitique : image de haute résolution pour le traitement d'un conflit (ex: développe-ment d'îles artificielles en mer de Chine, guerre en Ukraine) (cf. image MAXAR sur Google Earth ou dans programme open data). Cartographie pour placer des points de mesures par exemple acquise lors d'un projet.		1			1		1	1	1		1				1			1	1		1	
16	Geologie,Meteorologie, Entwicklung/Globalisierung, Bevölkerungsgeografie							1				1			1		1	1					
27	Geologie, Geomorphologie, Bevölkerung, Globalisierung							1							1		1						
163	Plattentektonik/Erdbeben, Migration, Tourismus, Humangeografie (SDG, Disparitäten)							1							1	1	1	1	1				
167	Glaziologie, Raumplanung, Kartografie, Stadtgeografie	1	1							1				1									
168	tous			1																			
170	Darstellung von Naturkatastrophen,Vulkanismus, Darstellung von Segregation usw.				1			1						1									
172	Globalisierung (Reisen dreier Generationen, Offshoring)																1	1					
174	Plattentektonik, Erdbeben, Vulkanismus, Palmölproduktion			1			1	1								1							

Table D.7: *Coding of answers to the question: What benefits can GIS bring to the classroom? (Number of respondents = 146).*

ID	Answers: What benefits can GIS bring to the classroom?	Data Literacy				Skill Acquisition						Didactic Aspects						Relevance				Motivation				Other	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	- Visualisierung von Daten - Verständnis von Aufbau von Karten	1							1																		
2	Gut für Raum- und Datenanalysen. Beantwortung von eigenen Fragestellungen der Lernenden.		1											1													
3	Zugang zu neuesten Methoden																1										
4	Siehe Fragestellungen																									1	
5	Es können eigene Untersuchungen durchgeführt werden.											1		1													
6	Vertiefung in einer Thematik, selber Lösungen suchen							1		1																	
8	Visualisierung, Einblick in einmaliges Gebiet	1																									
9	Sie wurden in der Umfragen genannt.																									1	
10	Räumliches Denken						1																				
12	keine Antwort																									1	
13	Blick hinter die Visualisierung und Analyse von räumlichen Daten	1	1																								
14	- computergestützter, individualisierter Unterricht als Methode - Themenvertiefung als auch neues Wissen über Datenmanagement- und visualisierung - alltagsrelevante Fragestellungen qualitativ und quantitativ beantworten können - interdisziplinärer Unterricht möglich (z.B. mit Biologie, Wirtschaft, Mathematik)	1		1		1		1					1	1	1					1							
15	?																									1	
39	Das weiss ich aktuell noch nicht;-). Werde GIS im Rahmen eines MINT-Moduls ab August während 8 Wochen à 2 Lektionen unterrichten. Bin selbst gespannt, was es bringen wird.																									1	
17	Die Sus können selbstständig arbeiten, in dem sie Daten bearbeiten, darstellen, analysieren und interpretieren. Dies fördert ein besseres Verständnis für geografische Daten und die räumliche Vorstellung. Zudem wird mit modernen technischen Mitteln und Programmen gearbeitet, was die SuS gemäss meiner Erfahrung schätzen.	1	1	1		1	1					1	1										1				
18	Darstellung, Arbeiten mit Ebenen, Ein-Ausblenden von Infos	1																									
19																										1	
20	-																									1	
21	Einsatz für Maturaarbeit. Digitaler Unterricht. Interfachliches Arbeiten.					1							1		1	1											
90	S*S sind gezwungen sich wirklich mit Inhalten auseinanderzusetzen, wenn Sie zB Gentrifizierungsmerkmale selbst erfassen müssen mit einem Tool wie Survey123.				1			1				1															
23	Weiss nicht																									1	
24	Abwechslung für die Lernenden und interessanter Einsatz von Software zur Analyse und Visualisierung.	1	1										1									1	1				
25	.																									1	

ID	Answers: What benefits can GIS bring to the classroom?	Data Literacy				Skill Acquisition						Didactic Aspects						Relevance				Motivation				Other	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
147	Cela permet de chiffrer et de visualiser des changements d'échelle, ce qui est profitable pour tous.	1	1																								
29	Ich denke Datenverarbeitung ist wichtig und fördert das logische Denken. Mit zwei Lektionen pro Woche, kann das zeitaufwendige GIS aber nicht immer miteinfliessen. Praktisch finde ich auch, dass es als "programmierter Unterricht" genutzt werden kann und die SuS sehr selbstständig arbeiten können. Für mich als Lehrperson bleibt Zeit mit kleineren Gruppen etwas anderes anzuschauen.			1								1															
30	Selbständige Auseinandersetzung mit raumbezogenen Daten			1								1															
31	- zukunftsorientiert! - praxisnah und "hands on"																		1		1						
32	Haben Sie doch schon genannt...																									1	
33	Weiss ich nicht.																									1	
34	Grundlage um methodische Aspekte zu thematisieren					1																					
36	-																									1	
37	Bezug Daten und Raum			1			1																				
153	Einsatz von neuen Technologien, die mittlerweile im Unterricht integriert werden sollten					1							1										1				
41	Offensichtliche Frage.																									1	
43	Compréhension de la complexité. Mise en relation des éléments composant le territoire. Outil d’analyse et de synthèse	1	1																								
44	Analyse und Visualisierung eigener gesammelter Daten bringt Mehrwert und Erkenntnisgewinne; das "selber machen" ist für SuS wertvoll	1	1		1							1		1						1					1		
45	Interesse wecken, Forschungsthema erarbeiten, Visualisierung	1																1						1			
48	Eine gänzlich andere Methode, als es die SuS sonst kennen; Abwechslung; für SuS grundsätzlich interessant, wenn auch etwas überfordernd																1					1		1			
49	Siehe oben (Visualisierung von geografischen Daten, selbst Daten erheben und visualisieren), Motivation für Aktivitäten hoch bei SuS	1	1		1																			1			
50	je ne sais pas																									1	
51	sviluppo di competenze nell'interpretazione e nell'analisi		1																								
54	Es Kann räumliches denken vermitteln						1																				
55	projektbezogenes/problemorientiertes Lernen & Arbeiten kann gefördert werden > grösseres zusammenhängendes Zeitfenster wäre hierfür aber notwendig									1						1			1								
56	Analyse von Daten, anwendungsorientiert.		1																1								
57	die S*S können selbstständig arbeiten											1															
58	Es kann helfen, räumliche Muster aufzuzeigen. Resp. die SuS können selber diese Erfahrung/Erkentnis machen, indem sie Aufträge mit GIS machen. Für die LP kann GIS als Instrument der Visualisierung dienen, oder aber ein gutes Tool, um die SuS kognitiv zu aktivieren	1					1					1															
60																										1	

ID	Answers: What benefits can GIS bring to the classroom?	Data Literacy				Skill Acquisition						Didactic Aspects						Relevance				Motivation				Other	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
61	Umgang mit digitalen Karten , Visualisierungen, mit digitalen Karten spielen und Freude entfachen, Umgang mit Daten, Vorbereitung auf Uni	1							1									1									
62	interaktiv, zukunftsrealistisch. Noch besser wäre, wenn berufsbezogene Beispiele zur Verfügung gestellt würden (Stadtplanungsbeispiele/Fallbeispiele, wo am Schluss geschaut werden kann, wie es in der Realität rauskam, die Schüler aber zuerst eigene Planungen machen können).											1							1		1						
63	Einen interessanten Einblick in die Arbeit von GeografInnen bieten.																		1					1			
64	Kombination von Informatik, die so wichtig geworden ist, und Geografie. Erweiterung der Visualisierungsmöglichkeiten von Daten.	1											1		1						1						
65	Nombreux.Développer des compétences informatique et géographiques très précises. Et très utiles. Réaliser un travail en amont sur une base de données. Permet de penser une certaine complexité. (Comment illustrer de la meilleure des manières un certain type de données) selon une problématique XVIIIuideXVIIIe. Et permet aussi de voir et comprendre l'évolution de celles-ci (données) Place les élèves en tant qu'ACTEURS. Ce sont eux qui construisent le savoir tout en étant XVIIIuide par l'enseignant. Mais c'est là toute la plus-value de ces outils et de ces logiciels. Cela rend par ailleurs les élèves beaucoup plus autonomes. Ensuite ils peuvent reproduire ce qu'ils ont fait en classe et l'appliquer à d'autres choses.	1		1		1						1		1	1			1									
66	Für die Vermittlung klassisch geografischer Inhalte keine kognitiven Vorteile; das geht prima ohne GIS. Aber GIS fördert wissenschaftliches Denken und Arbeiten, indem der Prozess von der Fragestellung über die Datengewinnung usw. bis zu Schlussfolgerungen und Darstellungen (nicht nur visuell, sondern als klare Aussagen – das ist das Zentrale!) verfolgt und durchgespielt werden kann. Die Arbeit mit GIS könnte motivieren (hat aber auch enormes Potential zu demotivieren!). Viele Berufe arbeiten mit GIS: hier könnte im Unterricht Verständnis für die Praxis geografischer Arbeit vermittelt werden.	1	1	1	1							1						1	1				1	1			
67	dynamische Darstellung von Daten/Karten (im Gegensatz zum Atlas) Problemlösungsprozesse darstellen (z.B Intersektion von Daten) verschiedene Layer für verschiedene Aufgaben (Abfragen machen) Darstellung von Daten als Grafik (selbst Grafiken/Karten herstellen, Symbole, Klassen, Farben, etc.)	1							1	1																	
68	Umgang mit Software schulen; ansprechende und "einfache" Visualisierung von Daten; Kartenkritik; Kritik an Wissenschaftskommunikation	1				1			1		1																
69	Räume und geografische Sachverhalte besser verstehen, indem Daten selbst ausgewertet und visualisiert werden können. Abwechslung im Unterricht, Fertigkeiten in verschiedenen Tools erlangen...	1	1			1	1	1				1										1					
72	GIS ermöglicht einen anderen Zugang zu geografischen Sachverhalten. GIS kann motivierend sein.							1														1	1				
73	Offene Lernform (wenn nicht nur nach Anleitung "geclickt" wird) Visualisierung von Daten (vor allem Daten, die während Feldforschung gesammelt worden sind)	1			1							1		1						1							

ID	Answers: What benefits can GIS bring to the classroom?	Data Literacy				Skill Acquisition						Didactic Aspects						Relevance				Motivation				Other	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
74	Motivation der Schüler/Schülerinnen																										
75	einfachere Visualisierung, Förderung der Informatik-Kompetenzen	1				1							1		1												
76	Visualisierung	1																									
77	Problemräume erfassen, Problemfragen bearbeiten , Ersatz von Maturaarbeiten, Fächerübergreifende Projekten (Wirtschaft/Recht, Physik, Mathematik, Ge-schichte)									1					1	1											
78	keine Antwort																									1	
80	Motivation der SuS bei der Visualisierung von geogr. Daten, Methodenkompe-tenz, Problemlösungsstrategien, etc.	1		1		1				1													1				
81	Interazione docente - studente																										1
82	Umgang mit digitalen raumbezogenen Daten lernen			1																							
83	Imparare l'utilizzo di uno strumento, comprendere l'aspetto spaziale dei dati, imparare ad analizzare dati spaziali		1			1	1																				
84	Visualisierung, räumliches Denken. Fehlvorstellungen, Aufdecken von Manipula-tionen mit visualisierten Daten.	1					1		1																		
85	Aktualität der Geografie gesellschaftsrelevantes Basiswissen							1													1						
86	Weiss es nicht																									1	
89	Sicheres Kartenmaterial, das vielfach verwendet werden kann: Erstellen von the-matischen Karten, analysieren von vorgegebenen Karten...	1	1						1																		
22	Habe ich schon angekreuzt, zu Beginn der Umfrage																									1	
91	Visualisierung. Analysieren lernen. Beurteilung von Sachverhalten.	1	1																								
92	Daten können besser analysiert und visualisiert werden. Zudem könnte man sehr gut fächerübergreifend arbeiten (z.B. mit Bio). Gis kommt heute in vielen, für die SuS oft auch unerwarteten Bereichen (z.B. Entwicklungshilfe, Katastro-phenhilfe,...), zum Einsatz. Dies den SuS zu vermitteln ist einfacher, wenn man Gis direkt anwenden kann und nicht nur darüber redet.		1												1					1	1						
93	Kann als Methode in verschiedensten Themenbereichen angewendet werden. SuS könnten auch eigene Fragestellungen beantworten. Daten suchen, Daten selber erheben, auswerten, anzeigen im Internet, usw.	1	1	1	1							1		1			1			1							
94	Räumliches Denken verbessern						1																				
95	Zusammenhänge selbst visualisieren und dadurch erkennen. z.B. zwischen Erd-bebenherdtiefe und Plattengrenzenart. zwischen Boden und Klima. zwischen Wohnort in der Nähe zu Strassen und Einkommen etc. Einen Einblick in GIS erhalten.	1	1					1																			
96	Weiss nicht																									1	
97	Praktisches Arbeiten, Prozessbegleitung, -beurteilung																	1	1								
98	Verknüpfung diverser sachinhalt							1																			
99	Einsatz neuester Technologien, Neue Möglichkeiten der Raumanalyse, Arbeit in vielfältigen und unterschiedlichen Kompetenzbereichen		1				1	1					1														

ID	Answers: What benefits can GIS bring to the classroom?	Data Literacy				Skill Acquisition						Didactic Aspects						Relevance				Motivation				Other	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
101	Visualisierung Konstruktivistischer Zugang zu neuen Themen	1										1		1													
103	Travailler de manière plus approfondie sur un thème. Approche expérimentale. Meilleure visualisation de problèmes ou phénomènes.	1						1								1											
104	Analyse de nombreuses données et meilleures visualisations de phénomènes géographiques	1	1																								
106	Die SuS arbeiten mit einem Programm, mit dem auch Profis arbeiten. Nur schon das führt dazu, dass die SuS sich ernst genommen fühlen. Dazu kommt noch, dass man mit echten Daten (Opendata), die auch im Moment für die Entscheidungsträgern Relevanz haben, arbeiten kann. Dadurch, dass jede(r) SuS eine eigenständige Karte erstellt, entsteht eine inhaltliche Tiefe in der anschliessenden Diskussion, welche so ansonsten nicht entstehen würde. Die Selbstwirksamkeit der SuS wird gestärkt, da sie schnell und unkompliziert einen Sachverhalt darstellen können. Die SuS konsumieren nicht nur Karten, sondern sie können auch Karten herstellen, was nur schon dadurch zu einer ganz anderen inhaltlichen Tiefe führt.					1		1	1			1		1					1	1			1		1		
107	Tool für Maturaarbeiten, räumliche Muster erkennen, Datenanalyse kann mit Raumbezug interessanter sein, ...		1				1									1											
109	Visualisierungen	1																									
111	SOL																									1	
113	Potrebbe avvicinare maggiormente gli allievi alla disciplina fornendo loro maggiore comprensione dei possibili sbocchi professionali al termine della formazione universitaria. Aiuterebbe inoltre a far capire l'importanza e presenza della geografia nella nostra società.																	1	1		1						
114	Geografie verliert sein etwas verstaubtes Image und zeigt, dass sie Lösungen für aktuelle Probleme anbieten kann												1								1						
115	Neue Themenfelder und Denkweisen, Vorbereitung aufs Studium, realitätsnahe Geografie							1										1		1							
117	Visualisierung von raumbezogenen (Mess-)Daten für eine bestimmte Erdregion bzw. Region in der Schweiz	1																									
118	-																									1	
119	Abwechslung, selbsständiges Arbeiten, Foschung (Maturaarbeit), Fernunterricht											1				1		1				1					
120	Ich sehe nur Vorteile. Eine Technologie, die gesamtheitliches Arbeiten fördert: evap-Prinzip (Daten erfassen, Daten verarbeiten, Daten analysieren und Daten präsentieren).	1	1	1	1													1									
121	Students can create their own maps and curate the content. Students can access up-to-date information and perform a simple analysis	1	1																	1							
122	Raumverhaltenskompetenz fördernd						1																				
123	Gute Vorbereitung fürs Studium. Ich gehe davon aus, dass ein aktueller Geostudent dies tagtäglich braucht, da ja die Forschung heutzutage kaum mehr Feldarbeit sondern nur noch Datenbearbeitung beeinhaltet.																	1									

ID	Answers: What benefits can GIS bring to the classroom?	Data Literacy				Skill Acquisition						Didactic Aspects						Relevance				Motivation				Other	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
124	Les SIG sont des outils pour la préparation des cours.																										
125	Utilisation nécessaire de nombreux concepts transversaux qui doivent être mis ensemble pour produire un résultat.							1										1									
126	Visualisierung , Analyse	1	1																								
127	kann ich nicht sagen																									1	
128	Je ne sais pas																									1	
129	-représentation mentale du territoire - complexité des données géographiques - évolution des phénomènes etc.			1			1	1																			
130	- Veranschaulichung von geografischen Daten - kritisches Hinterfragen von Darstellungen in den Medien - Arbeitsmethoden kennenlernen, die in vielen geografischen Berufsfeldern zum Alltag gehören	1				1					1								1								
131	?																									1	
132	Fördert die kritische Auseinandersetzung mit der Erhebung, Darstellung und Interpretation von räumlichen Daten.	1	1	1	1						1																
133	Variation des activités Développer la lecture de cartes Utilisation d'outils numériques					1			1								1					1					
135	Interdisziplinäre Arbeit, Visualisierung von Daten (neue Perspektiven und Erkenntnisse)	1	1												1												
136	IT-Kompetenz					1																					
137	Unterstützung digitales Lernen Individuelle Projekte					1							1	1													
138	Eigenständiges, aktives Denken Problemlösekompetenz									1		1															
139	professionelle Visualisierung – auch von eigenen Daten	1			1															1							
141	Interesse wecken für das Geographiestudium.																	1									
142	Umgang mit Daten. Wissenschaftliche Arbeitsweise			1														1									
143	large accès aux données, visualisation des données, personnalisation des recherches, analyse systémique des territoires	1		1								1															
144	Selbstwirksamkeit der SuS											1															
145	Anwendungskompetenz Software, visuelle Darstellungen von geografische Themen	1				1																					
146	räumliches Verständnis wir verbessert						1																				
158	Verknüpfen räumlicher Daten						1	1																			
148	Visualisieren von Daten;	1																									
149	Lösungsorientiert. Interessant, modern...									1							1				1			1			
150	keine Antwort																									1	

ID	Answers: What benefits can GIS bring to the classroom?	Data Literacy				Skill Acquisition						Didactic Aspects						Relevance				Motivation				Other	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
151	Pédagogie du projet, outil moderne, c'est l'élève qui réfléchit au processus et qui prend le temps d'observer en variant facilement les échelles cartographiques et les couches d'information.					1			1			1				1					1						
152	Komplexere Daten können verarbeitet werden, sofern die SuS im Umgang damit geübt sind können sie das auch in kürzerer Zeit erledigen			1																							
16	Relevanz von räumlichen Daten kann zum Ausdruck gebracht werden Visualisierung von realen Daten hat motivationalen Aspekt Selber tun - statt mit vorgefertigten Daten zu arbeiten	1		1	1		1					1								1					1		
154	La visualisation, la compréhension des statistiques.l	1	1																								
155	Aucune idée																									1	
156	Permet de faire un travail qui se rapproche de la démarche scientifique du géographe, plus concret																	1	1								
157	?																									1	
27	Fördert die Fähigkeit Fragestellungen zu formulieren und sie zu beantworten (wissenschaftliches Arbeiten)																	1									
159	Ca permet de montrer les nouvelles technologies aux élèves. Ça permet d'aller plus loin dans l'analyse. Ça permet de travailler avec des vraies données et actuelles, mise a jour		1			1							1							1							
160	Aide à la visualisation et la compréhension spatiale; permet de compléter l'analyse de phénomènes géographiques	1	1				1																				
161	ev. Motivation durch Umgang mit elektronischen Mitteln																						1				
162	-																									1	
163	neue Erkenntnisse in Bezug auf den Raum erhalten, selbstkritisches Denken fördern, neue Lösungen finden, besser verstehen, dass Raum in sehr vielen Bereichen eine grosse Rolle spielt		1				1			1	1																
164	Macht den Unterricht spannend, technische Affinität der S*S fördern, Raumbezug					1	1															1		1			
165	Abwechslung vom 'Alltagsunterricht'																					1					
166	Methodenkompetenz (jedoch anspruchsvoll) kurze aktuelle Umfragen sind möglich (Survey123)				1	1																					
167	Anwendung/arbeiten mit dem Computer Räumliches Denken / Problemlösung					1	1			1																	
168	je ne sais pas																										
169	Andere Art von Unterricht, mehr selbstbestimmtes, autonomes Lernen, Freude an räumlichen Fragestellungen und generell am Fach Geografie wecken, Erwerb von methodischen Fertigkeiten, die auch im späteren Berufsleben eingesetzt werden können, besseres Verständnis räumlicher Zusammenhänge usw.					1	1					1		1			1		1		1	1					
170	wie vorher von Ihnen beschrieben																									1	
171	Aktualitätsbezug zu einem relevanten Berufsfeld Veranschaulichung von Daten und Verteilungen	1																	1	1							
172	Nützlich im Hinblick auf Maturarbeit. Motivierend. Selbstständiges Lernen. Datenverarbeitung. Eigene Daten verwenden.			1	1							1				1				1							
174																										1	

***Table D.8**: Coding of answers to the question: What challenges can GIS bring to the classroom? (Number of respondents = 146)*

ID	Answers: What challenges can GIS bring to the classroom?	Time Exposure				Technology						Complexity				Teacher Competence			Heterogeneity			Other			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	- Braucht länger für Einführung		1																						
2	Zeitaufwand, Software zu komplex	1										1													
3	Technische Ausstattung, Ausbildung der Lehrpersonen							1										1							
4	Zeitaufwand	1																							
5	Grosse Unterschiede beim Arbeitstempo.																			1					
6	Zeit	1																							
8	Technik muss funktionieren, LP benötigt viel Kompetenz					1										1									
9	SuS verbringen generell schon sehr viel Zeit vor der Kiste. Vielleicht manchmal etwas zu viel. Aber dies lässt sich heutzutage kaum mehr vermeiden.						1																		
10	Im EF																								1
12	keine Antwort																							1	
13	Ich finde es schwierig, die SuS dahin zu bringen, dass sie selbst eine Fragestellung, der sie mit GIS nachgehen können, entwickeln können und dieser selbst nachgehen können. Bisher habe ich die Fragestellung, geeignete Layer und geeignete Analysefunktionen jeweils mehrheitlich vorgegeben. Aber dann besteht die Gefahr, dass sie wie in einem Rezeptbuch Schritt für Schritt die Anleitung durchgehen, ohne zu verstehen, was sie machen.														1										
14	- abhängig der GIS-Software zeitintensiv. Es braucht leistungsstarke Laptops oder Tablets - GIS Anwendungen sind für Schülerinnen und Schüler teilweise komplex und abstrakt. Deshalb lassen sich auch nie alle Schülerinnen und Schüler an einer allgemeinbildenden Schule wie dem Gymnasium dafür restlos begeistern. In Klassen der sprachlichen und musischen Profile sowie den Fachmittelschulen sollte man GIS meiner Meinung nach seltener einsetzen als in Klassen mit naturwissenschaftlichem Profil.			1				1					1								1				
15	?																							1	
39	Mit ArcGis Online ist es deutlich besser mit der Technik. Früher gab es mit der Desktop Version so viele Probleme. Das war ärgerlich, bis man diese Probleme gelöst hatte. Unterdessen ist prima. Für weniger technisch versierte SuS ist es anspruchsvoll.					1							1						1						
17	- Relativ zeitintensiv, bis alle SuS ihr Gerät und die Software bereit zum Arbeiten haben (45 Minuten Lektionen sind eher knapp, zudem hohe Anzahl SuS durch eine LP zu betreuen) - Technische Probleme können zum Verhängnis werden und eine vorbereitete Lektion kann im schlimmsten Fall nicht durchgeführt werden.		1	1		1																			
18	Komplex in der Anwendung, viel unproduktive Zeit, bis alles läuft, zu wenig Zeit in kurzen Lektionen (45min)		1	1								1													
19	Benötigt viel Zeit, Umgang mit starker Individualität	1																		1					
20	Einarbeitung in neue Programme für SuS aufwändig und teilweise mühsam oder gar mit Software-Komplikationen verbunden. Ins gibt so viele wichtige Themen in der Gg, dass es mühsam ist, Lektionen mit "Einführung in die Technologie und Programme" oder "Trouble-Shooting" zu verbringen.		1	1		1																			
21	Zeit. Kosten.	1								1															

ID	Answers: What challenges can GIS bring to the classroom?	Time Exposure				Technology						Complexity				Teacher Competence			Heterogeneity			Other			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
90	Es braucht relativ viel Zeit. Mit ArcGIs Online sind die Hürden deutlich niedriger um einzu-steigen, was es einfacher machen sollte, auch im Grundlagenfach GIS einzusetzen.	1																							
23	Technische Probleme Den SuS in kurzer Zeit genügend Grundwissen zu geben. Sinnvolle Projekte finden.		1			1																1			
24	Es ist sehr zeitaufwändig.	1																							
25	.																							1	
147	Le temps que cela prend et le manque de maîtrise des élèves.			1					1																
29	Zeitlich sehr aufwendig und schwierig prüfbar mit Noten.	1							1															1	
30	weiss nicht																								
31	- komplexe Sachverhalte und Tools, die nicht einfach in einer Doppellektion vermittelbar sind. -> Braucht sehr viel Zeit!		1																						
32	Viel Aufwand in der Vorbereitung Lehrperson muss sich das Tool selbst zuerst aneignen Zeitliche Ressourcen in der Gg knapp (wenig Lektionen) Inhalte können oft auch anders, gut vermittelt werden, warum also GIS einsetzen wenn die Zeit drängt?		1	1	1																		1		
33	Zu komplex um sinnvolle Resultate in kurzer Zeit zu erarbeiten.	1										1													
34	Lange Einarbeitungszeit für SuS. Gefahr, dass nur Anleitungen abgearbeitet werden.		1												1										
36	Zeitaufwand, Interesse	1																			1				
37	Aufzuwendende Zeit! Komplexität der Vorbereitung (Kursunterlagen und Programmadmi-nistration (Accounts erstellen etc.)) und Einsetzung der Programme	1												1											
153	Zeitaufwand und Nutzen	1																					1		
41	Zeitaufwand, Affinität der Studierenden und der LK.	1														1			1						
43	Cf réponses précédentes																							1	
44	Bedingt BYOD und eine funktionierende IT-Infrastruktur in der Schule; grosse Informatik-Niveau-Unterschiede zwischen den SuS; zeitintensive Betreuung fast nur in Projektunter-richt möglich;							1									1		1						
45	Zeit ist wohl das Hauptproblem (auch Einarbeitung für die Schüler*innen), wenn aber je-des Jahr etwas mit GIS gemacht würde, ginge das auch schneller mit der Zeit.	1	1																						
48	Überforderung, technische Hürden, Zeitmangel.	1				1						1													
49	Zeit Unterrichtsmaterial erarbeiten	1												1											
50	je ne sais pas																							1	
51	rischio di essere visti come fine e non come mezzo Come già detto prima, si rischia di dover investire un quantitativo eccessivo di ore lezione		1	1																					
54	Brauchst Zeit und geld. Die lehrpersonen mussen sich fut auskennen um bei problemen helfen zu können	1								1						1									
55	hoher Vorbereitungsaufwand; man muss aktuell bleiben				1						1														
56	Zu viel Zeitaufwand, den ich in den IB Klassen (getakteter Aufbau) nicht einbringen kann.		1																						
57	man muss es selber verstehen, man muss Ideen haben															1									

ID	Answers: What challenges can GIS bring to the classroom?	Time Exposure				Technology						Complexity				Teacher Competence			Heterogeneity			Other			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
58	Technische Schweirigkeiten gibt es immer und man muss sich als LP sehr gut damit auskennen. Der Aufwand, mit GIS zu arbeiten, ist vergleichsweise sehr hoch. Gerade für mich als Junglehrer, der auch noch GG nur als Nebenfach studiert hat war es schwierig, die GIS Lektionen durchzuführen. Ich war sehr froh, dass meine Kolleg*innen da in den vergangenen Jahren eine Selbstlerneinheit zu GIS für unsere Teilzeitstudis auf die Beine gestellt haben. So musste ich sie nur noch durch diese hindurch Coachen. Aber hätte ich alles selber aufbauen müssen, wäre ich sehr wahrscheinlich an den Anschlag gekommen.				1	1										1									
60																								1	
61	Zeitaufwand, Komplexität (SuS sollen nicht einfach nur nach Kochbuch anwenden, sondern auch selber damit spielen, geht im regulären Unterricht zeitlich nicht auf), Betreuung	1											1		1		1								
62	Noch mehr Bildschirmzeit. Bei individuellen Fehlern der Schüler geht viel Zeit verloren, falls der Lehrer am Platz individuell korrigieren muss. Ablenkung durch Computerarbeit durch z.B. Mails, Games. Lösungen können zu schnell den Kollegen geschickt werden und diese denken dann weniger selbständig.						1		1								1								
63	Frust durch Komplexität.											1													
64	Zeitaufwändig; SuS müssen sich zuerst in die Tools einarbeiten, was nicht allen gleichermassen gelingt. Zu viel Zeit in die Methodik und somit zu wenig Zeit für das Inhaltliche.	1		1															1						
65	Pas assez de temps. Formation des enseignants. Sont-ils tous formés aux SIG ? Investissement dans le matériel très important.	1								1								1							
66	Vielfältige: Sobald sich technische Probleme einstellen oder Vorgehensweisen etwas komplizierter und damit fehleranfälliger werden, kann der Unterricht plötzlich "abstürzen", weil man sich intensiv mit Dingen beschäftigen muss, die nichts vermitteln (trouble shooting). Im Zeitalter von "Bring your own device" hat die Arbeit am PC ihren exotischen Reiz verloren; dann muss es gelingen, intellektuellen Reiz aufzubauen. Das war bis vor wenigen Jahren mit online GIS noch zu aufwändig (für die schlaueren SuS eben zu wenig reizvoll).					1	1												1						
67	die SuS brauchen lange, um sich in Programmen zurecht zu finden die benötigten Daten suchen ist nicht einfach Themen auf diese Art zu behandeln braucht mehr Zeit als konventioneller Unterricht		1	1																					
68	Viel Zeitaufwand; hohe Hürde für SuS; wenig Ertrag und Nutzen fürs Leben und den Alltag für SuS nicht ersichtlich; verschwendete Ressourcen; nur wenige SuS werden mit der Lernart angesprochen; ineffiziente Erarbeitung von Stoff	1	1	1									1								1		1		
69	Es ist sehr zeitaufwändig und wenn z.B. ArcGISonline nur einmal im Jahr gebraucht wird, muss die LP es immer wieder neu erklären. Es müsste eigentlich noch regelmässiger gebraucht werden aber dafür fehlt die Zeit.	1	1																						
72	Die Herausforderung besteht insbesondere darin, dass die Schüler*innen mit GIS zu einer wirklichen Auseinandersetzung mit räumlichen Fragen kommen. Denn die Gefahr besteht darin, dass bei komplexen GIS-Tools die Schüler*innen wie bei einem Kochbuch nur "Rezepte" einsetzen und die kreative Analyse von räumlichen Sachverhalten nicht durch die SuS selber erfolgt.												1		1										
73	Für SuS, die mit Google Earth aufgewachsen sind, sehen sie nicht sofort die Vorteile und Möglichkeiten von GIS. Manche SuS sind auch überfordert mit den technischen Aspekten. Als Lehrperson, die nicht so viel Erfahrung mit GIS hat, war ich erst skeptisch und war mir nicht sicher, ob ich mich traue GIS im Unterricht anzuwenden. Letztendlich kann man aber parallel mit den SuS lernen, man muss nur die Mut dazu haben.												1			1			1						

ID	Answers: What challenges can GIS bring to the classroom?	Time Exposure				Technology						Complexity				Teacher Competence			Heterogeneity			Other			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
74	Grosser Zeitaufwand	1																							
75	noch mehr Fokussierung auf den Bildschirm, Erlernen der Anwendung von GIS-Program-men, Zuverlässigkeit der technischen Infrastruktur			1		1	1																		
76	Zeitaufwand, Kompetenz LP	1														1									
77	Setzt ein hohes Niveau der SuS voraus. Einarbeitung kann für anfänglich SuS aufwendig.			1									1												
78	Bedienungsprobleme der Lernenden. Sytematisches Arbeiten der Lernenden.												1		1										
80	Zeitaufwand während Unterricht, geeignete Metadaten, technische Probleme		1			1																1			
81	Poco tempo a disposizione		1																						
82	Benötigt viel Zeit für Instruktionen		1	1																					
83	Il tempo di apprendimento di utilizzo del software è importante e necessita di un grande sforzo da parte degli studenti. Non sono certo i vantaggi possano ripagare lo sforzo d'ap-prendimento dello strumento. Non vi è sempre disponibilità di dati adeguati.			1																		1	1		
84	?																							1	
85	bruacht viel Zeit	1																							
86	Noch weniger manuelles arbeiten, viele Kulturfertigkeiten gehen verloren. Es läuft noch mehr über den Computer ..... Mit der Zeit ist es zu viel.						1																		
89	Bei BYOD sollte das Programm / die App bei allen funktionieren.					1																			
22	Aufwändig, bis man sich in der Software zurecht findet - v.a. ArcGIs Desktop											1													
91	Einsatz von Software benötigt Zeit: Sowohl bei der Vorbereitung für die Lehrperson als auch bei der Durchführung mit den Schüler*innen.		1		1																				
92	Da ich Gis nicht selber einsetze habe ich keine Erfahrungswerte, wie lange es dauert, bis die SuS Gis selbstständig beherrschen. Eine Problematik sehe ich darin, dass die SuS in ei-ner Klasse unterschiedlich schnell mit dem Programm zurechtkommen, d.h. einige brau-chen viel Betreuung durch die LP. Mit einer 25er Klasse wird das schwierig. Zeit ist sicher ein Faktor. Wir bringen jetzt schon den Lehrplan nicht durch...		1														1			1					
93	GIS entwickelt sich schnell, Unterrichtseinheit ändern sich zu schnell, es muss am Anfang stark geführt werden, die ganzen Unterrichtseinheiten können nicht jährlich angepasst werden. Gute Daten zu finden ist schwierig.				1						1				1										
94	Benutzerfreundlichkeit der Software											1													
95	Es braucht immer sehr viel Zeit. Es ist nötig (bzw. von grossem Vorteil) in kleinen Gruppen zu arbeiten. Es braucht viel Anweisung, Begleitung von der Lehrperson. Teilweise gerät der Inhalt etwas in den Hintergrund durch das Datenbeschaffen, Tools kennenlernen etc.	1		1													1								
96	Es ist zeitintensiv und man bildet die SuS auf irgendeiner Software aus, mit denen die meisten später nie mehr etwas zu tun haben werden.	1		1																					
97	Kleine (informatische) Fehler verursachen grosse Probleme. Frust.					1																			
98	Zu komplex											1													
99	Es ist schon viel Zeit vergangen, seit dem Studium.... Kompetenz der Lehrkraft ist somit eingeschränkt. Auch die technik und die Programme haben sich weiterentwickelt. Bräuchte relativ grossen Aufwand, um wieder up to date zu sein. Die Stundentotation ist für den Einsatz von GIS zu klein. An unserer Schule wird GIS deshalb in erster Linie im EF eingesetzt. Viele SuS würde GIS übrfordern. "Riecht zu sehr nach Informatik".		1		1						1		1			1									

ID	Answers: What challenges can GIS bring to the classroom?	Time Exposure				Technology						Complexity				Teacher Competence			Heterogeneity			Other			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
101	Braucht relativ viel Zeit. Schwierig, da man zeitlich sowieso immer etwas im Verzug ist.	1	1																						
103	Le temps à disposition. Le plan d'études à respecter. Apprendre aux élèves à utiliser SIG.		1	1									1												
104	Problèmes sanitaires (effets délétères de la surexposition aux écrans) et écologiques (incompatible avec le concept de durabilité enseigné à l'école).						1																		
106	Der Aufwand der Umschulung der Lehrerinnen und Lehrer ist gross, somit ist die Bereitschaft umzustellen sehr klein. Viele Lehrer:innen befürchten einen Kontrollverlust, wenn sie noch nicht so sattelfest sind. Da es keine Lehrmittel und Daten hat, welche sofort verwendbar wären, ist die Einstiegsstufe im Moment noch sehr hoch. Technische Probleme können immer wieder einmal entstehen.					1										1		1				1			
107	Zeitaufwand bei GIS Software immens, Lehrplan sowieso schon voll, mehr Bildschirmzeit,...	1	1	1			1																		
109	Zeitaufwand	1																							
111	Softwareprobleme, Umgang und Kennenlernen neuer, häufig komplizierter Software			1		1						1													
113	Svantaggi: imparare ad utilizzare i software dedicati. Necessità di una formazione di base per accedere al loro utilizzo senza una dotazione oraria sufficiente che comporterebbe una riduzione del tempo dedicato ad altri contenuti.		1	1																					
114	Es braucht viel Einarbeitungszeit und natürlich BYOD-Klassen, welche gewohnt sind, mit dem Computer zu arbeiten		1		1			1																	
115	Zeitaufwendig, relativ komplex für SuS	1											1												
117	. wie schon erwähnt: im Regelunterricht (45 min Lektion) viel Unterrichtszeit (mehrere Wochen) benötigt, ständige "Unterbrüche" von Lektion zu Lektion . zudem: im Regelunterricht (inkl. BYOD-Einsatz) eh schon zu beobachtende grosse individuelle Unterschiede bei Arbeitsfortschritten, der sich bei GIS-Einsatz noch stärker akzentuieren wird. -Gefahr der vermehrten Auseinandersetzung mit technischen Fragestellungen für die Visualisierung von raumbezogenen Daten als dem eigentlichen Ziel der Analyse von raumbezogenen Daten und Verständnis von raumbezogenen Prozessen und Zusammenhängen (... in der knapp bemessenen Unterrichtszeit)		1	1																1					
118	-																							1	
119	technische Probleme, nicht alle mögen es					1															1				
120	GIS ist, trotz deutlicher verbesserter Bedienung (arcGISonline, storymaps, ...) nach wie vor anspruchsvoll. Zu dem ist GIS im curriculum etlicher Student:innen der pädagogischen Hochschule Mangelware. Praktikant:innen bei mir hatten höchstens rudimentäre Kenntnisse. GIS steht und fällt mit dem Engagement der betroffenen Lehrkraft bzw. der Fachschaft der betreffenden Schule.													1		1		1							
121	It is time consuming and not reliable. The system (ArcGIS) often has glitches and is slow, which is frustrating in lesson time and for homework exercises. Some students are frustrated by the lack of functions in ArcGIS which are simple to perform in other mapping tools (Google or Apple Maps for example)	1	1			1							1												
122	zu viel und zu komplexe Informatik, schnell veraltet; z.T. zu teuer				1					1	1	1													
123	Technik abhängigkeit. Wenn es ein Problem gibt, ist die Unterrichtsstunde hin. Der zeitliche Aufwand für sämtlichen IT Gebrauch im Unterricht ist enorm. Von den 40min Unterricht geht häufig ein Drittel bis die Hälfte für Technik drauf, wenn man tatsächlich IT benutzt.		1	1		1																			

ID	Answers: What challenges can GIS bring to the classroom?	Time Exposure				Technology						Complexity				Teacher Competence			Heterogeneity			Other			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
124	inconvénients : SIG difficile à utiliser, coût, défis : ?									1		1													
125	Outils techniques par toujours simple à prendre en main.											1													
126	Zeitbedarf Komplexität, SuS dürfen nicht überfordert werden	1											1												
127	Herausforderungen: grosser zeitlicher Aufwand mit relativ geringemMehrwert.	1																					1		
128	Je ne sais pas																							1	
129	complexité d'utilisation des logiciels formation des enseignants manque de temps pour générer des séquences d'enseignement pertinentes				1							1						1							
130	Technikvermittlung statt Erarbeiten von Inhalten/Kompetenzen in der knappen Unter-richtszeit		1	1																					
131	?																							1	
132	Zeitaufwändig und nicht im klassischen Unterrichtssetting einbettbar resp. mit dem klas-sischen Rollenverständnis LP - SuS vereinbar.		1																						1
133	Trop de temps pour expliquer les aspects techniques des apps			1																					
135	SUS wollen weg vom Bildschirm, Natur im freien ist beliebter						1																		
136	Grosse Einstiegshürde, Zeit	1										1													
137	Hoher Zeitaufwand Grosser Aufwand für erstmalige Einführung	1			1									1											
138	Viel Zeitverlust für technische Schwierigkeiten					1																			
139	wie alles Technische – Fokus auf die Technik und weniger auf die Inhalte.			1																					
141	Sehr zeitaufwendig.	1																							
142	hoher Zeitaufwand bis Schüler "GIS-fit" sind damit es sinnvoll genutzt werden kann		1																						
143	prise en main et utilisation "technique" des SIG			1								1													
144	Sehr anfällig für Probleme, die dann sehr zeitintensiv zu lösen sind		1			1																			
145	nimmt sehr viel Zeit in Anspruch	1																							
146	S*S beschäftigen sich an elktronischen Endgeräten mit etwas anderem								1																
146	S*S beschäftigen sich an elktronischen Endgeräten mit etwas anderem								1																
158	das Denken tritt in den Hintergrund, Technik wichtiger, Probleme wälzen, die Methode oft wichtiger als der Inhalt Probleme, weil man nicht weiss, was das Programm im Hintergrund macht, Resultat ist nice und dann..?			1		1																			
148	Zeitraubend; was macht man, wenn es nicht funktioniert? Wie vorher schon gesagt: ste-hen genug Geräte zur Verfügung, auf welchen mit den notwendigen Programmen gear-beitet werden kann? (Bei uns bringt muss jeder sein eigenes Notebook mitbringen, der Besitz eines solchen Gerätes ist ausserdem nicht obligatorisch!)	1				1		1																	
149	Zu viel Aufwand, zu komplizierzt. Braucht zuviel Zeit.	1										1													
150	Zeit, Platz, Einzelbetreuung	1															1								
151	Maitrise de l'outil et anticiper les problèmes techniques. Le but c'est de faire de la géo-graphie et pas de l'informatique. Des guides step by step pour l'élève sont nécessaires.			1		1									1										

ID	Answers: What challenges can GIS bring to the classroom?	Time Exposure				Technology						Complexity				Teacher Competence			Heterogeneity			Other			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
152	Computer als Grundvoraussetzung. Kosten für Software							1		1															
16	Grosser Zeitbedarf teils grosse Schere zwischen einzelnen SuS bezgl. Arbeitstempo/Motivation/ ...	1																		1	1				
154	La complexité de la mise en place d'une activité.													1											
155	Aucune idée																							1	
156	Temps à disposition. Matériel à disposition. Pertinence de l'utilisation des SIG dans certaines séquences d'enseignement		1	1										1								1			
157	?																							1	
27	Zeit, Qualität der Daten, Einzelne Betreuung der SuS	1															1					1			
159	Faut savoir bien les utiliser pour ne pas perdre de temps en classe											1				1									
160	Trouver le temps de les intégrer aux cours alors que leur utilisation est complexe et que le nombre d'heures de cours est très limité		1									1													
161	zeitlich aufwändig grosse Herausforderung für SchülerInnen welche wenig IT-affin sind: Zeit besser einsetzen	1		1									1						1						
162	Cf. avant-dernière question																							1	
163	Einstiegshürden mit den Accounts Software verändert sich laufend ein wenig (z.B. User Interface) -> man muss ein wenig am Ball bleiben				1						1			1											
164	Braucht viel Zeit zum einführen, welche nicht vorhanden ist. Die Technik muss vorhanden sein und funktionieren. Als Einzellehrperson kann die Vermittlung schwierig sein – besser im Teamteaching, oder Einführung im Informatikunterricht. Wenn zu viel Zeit für das Tool verwendet wird, dann ist der thematische Mehrwert klein, was ein grosser Nachteil ist.		1	1		1		1									1								
165	hohe Fehlerquelle (technische Probleme), viel Zeitaufwand,	1				1																			
166	anspruchsvoll und oft zeitaufwendig, SuS brauchen höhere Frustrationstoleranz	1											1												
167	Braucht oft viel Zeit Man muss die Software selber beherrschen	1												1		1									
168	ils prennent du temps, on a besoin d'une salle d'informatique très difficile à trouver, les SIG ne correspondent pas forcément au PEC	1		1				1																	
169	Dazu fehlt mir die praktische Erfahrung. Eventuell die Abhängigkeit von technischen Systemen, die nicht immer einwandfrei funktionieren?					1										1									
170	ev. zu wenig Zeitressourcen		1																						
171	Sehr zeitaufwändig, Arbeitstempo sehr heterogen hoher Vorbereitungsaufwand	1			1									1						1					
172	Ablenkungspotenzial durch Arbeit am Computer. Frustrierend für SuS, da wegen kleinem Fehler ganzer Verschnitt, etc. nicht funktioniert. Zeitraubend.	1							1				1												
174	Die gleichen Nachteile, wie die Digitalisierung im Klassenzimmer allgemein. Die Schüler sitzen hinter den Tablets, aber die Kontrolle, was sie gerade machen, ist schwer. Alles, was an den eigenen Geräten abläuft, ist bei gewissen Schülern einfach verlorene Zeit, weil sie zu viel Ablenkung haben.						1		1																

Table D.9: *Coding of answers to the question: Under what circumstances would you use GIS in the classroom (again)? (Number of respondents = 72).*

ID	Answers: Under what circumstances would you use GIS in the classroom (again)?	Teacher Competence				Material		Curriculum		Setting		Technical Aspects				Other
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
3	Ich unterrichte derzeit mein 1.Fach Deutsch, für Geo müsste ich mich in der Fachschaft zuerst mit GIS auseinandersetzen			1												
4	Bei einer Aufstockung der Gg-Lektionen. Ich muss die Inhalte in zwei Jahren (von 4) vermitteln..							1								
6	Wenn ich mir wirklich Zeit nehmen würde, mich mit der Software auseinander zu setzen. Oder wenn mir eine Unterrichtsein-heit zur Verfügung gestellt würde.		1			1										
8	Gut ausgearbeitete kleine Projekte für SuS mit guter Erklärung und bisschen Hintergrundwissen ;)					1										
10	Weiterbildung Aufbereitete Fallbeispiele	1				1										
12	Falls mehr Unterrichtslektionen zur Verfügung stehen würden.							1								
15	Zwang								1							
17	1. Es ist sicherlich sinnvoll GIS in einer Doppellektion, im Rahmen des Ergänzungsfachs oder einer Fokuswoche einzusetzen, sofern die SuS keine geübten GIS-NutzerInnen sind. => so steht mehr Zeit für die tatsächliche Bearbeitung zur Verfügung. In der Regel wird das zwei-Lektionen-Fach Gg auf zwei einzelne Lektionen aufgeteilt. 2. Zudem wäre es hilfreich einen GIS-Kurs spezifisch für die Anwendung von GIS in Schulen zu besuchen (so viel ich weiss gibt es das schon...). 3. Da ich auch in der Privatwirtschaft gearbeitet habe, musste ich feststellen, dass viele Ingenieurbüros aus Kostengründen QGIS verwenden. Daher macht es evt. Sinn bereits frühzeitig QGIS anstelle der kostenpflichtigen Softwares wie ArcGIS Pro im Unterricht einzusezten (auch wenn ArcGIS Pro für Schulen gratis ist...). 4. Ich muss mich persönlich erst noch in den Unterrichtsalltag einarbeiten, sobald ich etwas mehr erfahren bin und alle Klassen-stufen unterrichtet habe, werde ich mich bestimmt auch dem GIS widmen und es in den Unterricht einbauen.	1	1								1					
20	Wenn es pannenfertige Unterrichtseinheiten gäbe, die technologisch einwandfrei funktionieren würden und für die SuS schnell verständlich und anwendbar wären :-)					1									1	
21	Software sollte für Schulen gratis zur Verfügung stehen. Einsatz während Projektwochen machen.										1			1		
23	Ich würde gerne eine Weiterbildung machen, aber eine eintägige Weiterbildung bringt nichts. Es müsste eine mehrtägige Wei-terbildunsein, über einen Zeitraum vereilt sein mit einem eigenen Projekt. Richtung CAS, aber vielleicht vom Aufwand doch kleiner.	1														
25	Wenn die Zugänglichkeit besser wird und die Inhalte schülergerechter verfügbar wären.					1										
147	Comme complément d'une thématique abordée, une partie du sujet serait vu au travers des SIG, mais pas comme thématique en soi.									1						
30	GIS war im Studium kein Thema. Weiterbildung wäre dringend nötig!	1			1											
33	Wenn ich mehr Zeit hätte, der Lehrplan ist zu dicht bepackt.							1								
36	-															1
153	Ohne grosse Vorbereitungszeit, die das Konzept und das Vortesten einer Aktivität beinhaltet. Vertrauen, dass es auch wirklich ohne grosse technische Probleme geht.					1									1	
41	Mehr Zeit im Lehrplan, nachhaltige Schulung der Lehrkräfte, Musterprobleme und Musterlösungen. Aktuellerweise ist GIS im-mer noch zu komplex für den Alltagseinsatz bei Zeitmangel. Ich fühle mich zu unsicher, um mich mit Gis zu Exponieren. Es müsste "primitiv-GIS und primitiv-Fernerkundung" geben. Das Problem ist ein ganz praktisches: Am Ende des Jahres brauche ich verwertbare Noten. Oder Geografen müssten ins Fach In-formatik einbezogen werden.	1		1		1		1								
43	Accès gratuit à une base de données (ofs) p.e., de qualité pouvant facilement être implantée sur le guichet carto fédéral. + si ce même guichet offrait des possibilités plus abouties et nombreuses de représentations des donnés, ainsi qu'un outil de dessin amélioré						1						1			
45	Mir fehlt die Zeit mich einzuarbeiten, obwohl ich es als sinnvoll erachte. Ich habe einmal eine kurze Weiterbildung dazu be-sucht, es danach aber nicht gleich angewendet und wieder vergessen.		1													

ID	Answers: Under what circumstances would you use GIS in the classroom (again)?	Teacher Competence				Material		Curriculum		Setting		Technical Aspects				Other
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
49	Umfangreiche Weiterbildung, um eigene Kompetenzen zu vertiefen und geeignetes Unterrichtsmaterial;															
50	Demander aux élèves de créer des cartes thématiques sur différents thèmes traités. Comparer des cartes sur un même thème mais avec enclassements différents ...									1						
54	Falls der Kann Waadt und/Oder das Gymnasium une unterstützen würde. Ich müsste auch eine Weiterbildung zum Auffrischen der Kenntnisse machen.	1		1												
56	Massgeschneidertes Material, das 1:1 angewendet werden kann. Dadurch, dass ich neu im IB-Diploma bin, raubt mir IB zu viel Zeit, um mir im GIS die notwendigen Kenntnisse anzueignen.		1			1										
57	Gute, einfache, benutzerfreundliche Unterrichtseinheiten, die zur Verfügung stehen würden					1										
63	Wenn ich genügend Zeit und eine einfach verständliche "Gebrauchsanweisung" (für die SuS und mich) zur Verfügung hätte.		1			1		1								
64	Mehr Zeit und mehr eigene Kompetenzen.		1	1				1								
65	Notamment afin que les élèves puissent cartographier et visualiser des données qu'ils auraient préalablement traitées.									1						
66	1. Wenn Geo in meinem Kanton mehr Lektionen erhielte. 2. Wenn ein GIS-Lehrmittel parallel zu einem Standard-Lehrmittel bestehen würde, so dass sich die Aufgaben direkt auf die Inhalte des Lehrmittels beziehen. 3. Wenn dazu Daten leicht verfüg-bar wären. 4. Wenn man mit Online-GIS auch sehr gut die Attributtabellen bearbeiten könnte. 5. Wenn selbsterstellte Datens-ätze oder Datensätze aus irgendwelchen Quellen relativ leicht ins Online-GIS eingespiesen werden könnten. (Vielleicht sind einige dieser Bedingungen schon gegeben, ich habe die Entwicklung in den letzten Jahren nicht mehr aufmerksam verfolgt.)					1	1	1					1			
68	Positives Erlebnis; vielschichtiges und interessantes Unterrichtsmaterial					1										
75	mehr eigene Zeit, vor allem mehr Unterrichtszeit, entsprechende Ausrüstung in der Schule, einfache und gut strukturierte Un-terrichtsmaterialien		1			1		1				1				
76	Gutes Projekt, das einfach mit überschaubarem Aufwand durchgeführt werden kann und das Interesse der SuS weckt.					1										
81	Nei laboratori di geografia										1					
82	- Einfache Anleitungen - Beispielsaufgaben, welche auf jede Region heruntergebrochen werden kann (Lokales visualisieren)					1										
83	Elaborazione carte tematiche, visualizzazione di dati									1						
84	Solide Weiterbildung mit vertretbarem Aufwand.	1														
85	mehr Zeit		1					1								
86	Mehr Lektionen in der Stundentafel							1								
81	Nei laboratori di geografia										1					
89	Wenn ich mehr Beispiele der Unterrichtsgestaltung mit GIS hätte.					1										
96	Bei einer höheren Stundendotation.							1								
99	Mehr Zeit, d.h. mehr lektionen in der Stundentafel für Geografie							1								
103	Je ne me suis pas intéressée au plan d'études comme je n'enseigne pas la géographie actuellement.															1
104	Je ne maîtrise pas les SIG donc il m'est difficile de répondre à cette question.															1
113	Nei laboratori di geografia e nel corso opzionale di geografia (3ª e 4ª liceo).										1					
117	zum Beispiel: . im Rahmen einer Projekt-/Arbeitswoche (... GIS braucht "viel Zeit" -> Standardrhythmus von 2 x 45 min Lektionen eher un-günstig dafür, viele technische Fragen/Support nötig, usw.) . im Rahmen eines Freifachangebots oder Begabtenförderungsprogramms . im Rahmen von Projekt-/Maturaarbeiten (... z.T. bereits stattgefunden) . im Rahmen von Kartenkunde-Thema einige "einfache" GIS-Anwendungen mit map.geo.admin.ch / zugmap.ch (... z.T. bereits stattgefunden)									1	1					
123	Software vorhanden und dazu ausgebildet. In meinem Studium wurde damals gis nur als Nebenschauplatz behandelt, also ei-gentlich gar nicht vermittelt. Interessierte sind dafür zwei Tage pro Woche nach Zürich an die ETH gefahren. Ich konnte mir das aus finanziellen und beruflichen (Werkstudent) Gründen nicht leisten.			1	1									1		

ID	Answers: Under what circumstances would you use GIS in the classroom (again)?	Teacher Competence				Material		Curriculum		Setting		Technical Aspects				Other
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
127	Bei einer sinnvollen und umfassenden Einführung.	1														
128	Pas d'idées précises mais peut-être sur des simulations d'aménagement du territoire pour des projets.									1	1					
129	aménagement du territoire géomorphologie hydrographie géographie des populations gestion des risques naturels évolution climatique etc.									1						
130	- wenn didaktisch aufbereitete Lerneinheiten zur Verfügung stehen würden, - wenn geeignete raumreferenzierte Datensätze zur Verfügung stehen würden.					1	1									
131	?															1
135	Weiterbildung: kurz, knapp mit Worksheets (nach Lehrplan) für SUS, direkt Einsatzbereit	1				1										
136	Zusätzliches Zeitgefäss							1								
139	sobald ich mehr Zeit habe, mich einzuarbeiten – es geht hier um den Initialaufwand .		1													
142	vorher Weiterbildung zu dem Thema machen	1														
145	Software steht zur Verfügung, mehr Zeit		1					1						1		
148	Ausreichende Schulung; notwendige technische Ausrüstung der Studierenden vorhanden. Bei uns muss jeder seine eigenen Geräte (Notebook u.ä.) mitbringen, die Schule stellt keine solchen Geräte zur Verfügung.	1										1				
149	Besseres Material. Besser Ausbildung. Bessere Technologie.					1							1			
152	Alle SuS verfügen über einen eigenen Computer Es steht eine Software bereit, welche leicht einzusetzen ist und zu der es eine gründliche Einführung gab Es besteht eine Austauschplattform von Ideen wie man mit GIS arbeiten kann	1										1	1			
154	Si la technologie est facilement accessible et en lien direct avec le contenu d'un cours.					1								1		
155	aucune idee															1
156	Travail par projet dans le cadre d'un cours d'option complémentaire.										1					
157	<Aucunes à part quelques ecusrions sur Google Earth									1						
159	Pour enseigner les thèmes liés à la ville ou les migrations ou changement climatique									1						
160	Si j'étais mieux formées aux SIG et que leur utilisation apportaient un avantage au sujet traité.			1						1						
161	Stehe kurz vor der Pension. Ist für mich nicht mehr relevant.															
162	- Une condition serait la clarté, la simplicité de ces logiciels et pour l'enseignant, et pour les élèves - Une seconde serait que les étudiant-e-s ne doivent pas nécessairement avoir chacun-e un ordinateur en classe Mais je demeure convaincu que l'enseignement de la géographie (thèmes, concepts, processus, cartographie...) peut se passer des SIG au niveau des lycées. D'autres types d'outils, de travaux et d'exercices existent et sont avérés par la pratique											1	1			
164	Nach einer Schulung / Update und konkreten Vorschlägen / fertigem Unterrischtsmaterial zu einem Thema im Lehrplan. Und wenn die Schule die notwendige Infrastruktur hat. Dann denke ich wäre es ein grosser Mehrwert. Ansonsten ist der Aufwand zu gross. GIS sollte zudem als Tool eingesetzt werden, mit welche in Lehrplaninhalt vermittelt werden kann und nicht im Zentrum stehen.	1				1				1		1				
165	Mehr Material, Weiterbildung, genug Zeit					1		1								
169	Wenn es für die Schweizerische Maturitätsprüfung verlangt würde.								1							
171	wenn wir im AG im 2. Schuljahr die 2. Wochenlektion wieder erhalten, welche uns zugunsten der Chemie gestrichen wurde – bei gleichbleibendem Lehrplan							1								

Table D.10: *Coding of answers to the question: How do you think teachers could be supported in using GIS in the classroom?*

ID	Answers: How do you think teachers could be supported in using GIS in the classroom?	Material				Teacher Competence			Curriculum		Technical aspects				Support			Other	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	- Einführung des Tools an Gymnasien durch Fachpersonen - Vorbereiten von Unterrichtsinhalten durch Fachpersonen	1													1				
2	Grundsätzlich braucht es zu viel Zeit um eine Profi-Software wie ArcGIS versiert anwenden zu können. Einfache Übungen und Fragestellungen, die z.B. mit kantonalen WebGIS gelöst werden können, fände ich hilfreich.	1					1												
3	Niederschwellige Fortbildungen																		
4	Weiterbildungen					1													
5	Pfannenfertige Sequenzen anbieten.	1																	
6	Bereitstellung von Unterrichtseinheiten																		
8	lokale Schulungen der LP, konkrete Unterlagen für SuS mit Lösungen für LPs, ev Tutorial für SuS	1				1													
9	Lerneinheiten gemeinsam entwickeln lassen. Entschädigung für Erarbeitung von Projekten.	1					1									1			
10	Weiterbildung					1													
12	keine Antwort																		1
13	Mit konkreten Ideen von GIS-Übungen (z. B. durch Zusammenstellen von passenden Layern und Analysefunktio-nen)	1																	
14	- Mehr Angebote im gymnasialen/universitären Weiterbildungsangebot für Lehrpersonen an Maturitätsschulen, z.B. von ArcGis Esri					1													
15	Zeitgefäss zur Verfügung stellen								1										
39	Unterstützung durch ESRI ist soweit schon prima. Allenfalls mehr Kurse an der PH oder Uni.							1										1	
17	- Im Idealfall sollte die Unterstützung praxisangewandt und so konkret wie möglich sein. So, dass es für die Lehr-personen möglichst "bequem" ist, GIS im Unterricht einzusetzen. - Zudem ist es sicherlich hilfreich, den Lehrpersonen die "Angst" vor dem Einsatz von GIS zu nehmen, in dem man ihnen Tipps und Tricks bei technischen Problemen / Unsicherheiten aufzeigt. - Die SuS-Anzahl pro Klasse sind in der Regel hoch (meist über 22 SuS). Eine zusätzliche Betreuungsperson in GIS-Lektionen wäre sehr hilfreich (insbesondere auch bei technischen Problemen, die sehr viel Zeit in Anspruch neh-men können)	1	1												1		1		
18	Massgeschneidertes Material mit Schritt-für-Schritt -Anleitungen zu Open Source Programmen zu aktuellen The-men	1	1																
19	Gute Lernaufgaben (kompetenzorientiert und mit Bezug zu relevanten Themen, mehr als nur bestehendes repro-duzieren), Schulung Anwendungskompetenz, Bereitstellung interessanter Daten zur Schweiz	1		1	1	1													
20	Siehe vorherige schriftliche Antwort.																		1
21	Weiterbildung und Software zur Verfügung stellen.					1					1								
90	Mehr Unterrichtszeit;-)								1										
23	Das grosse Problem ist, dass die zeitgefässe in der Schule nichtbestehen, dass die SuS sich wirklich in eine GIS-Aufgabe vertiefen können. 45 Minuten sind zu kurz dafür. Andereseits ist der Lehrplan auch ohne GIS schon voll.								1										
24	Mehr Zeit für den Geographieunterricht und damit mehr Zeit für den Einsatz von GIS. Gute und einfache Beispiele für den Einsatz von ArcGIS online.	1							1										
25	Zugänge für Lehrpersonen und Schüler einfacher und unkomplizierter gestalten. Die komplexen Funktionen an-schaulicher für die Schüler runterbrechen um damit aufbauend arbeiten zu können.	1	1																
147	des formations mais cela devrait être plus qu'une ou deux journées car l'investissement est grand et les outils sont parfois assez complexes.					1													

ID	Answers: How do you think teachers could be supported in using GIS in the classroom?	Material				Teacher Competence			Curriculum		Technical aspects				Support			Other	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
29	Ich finde die vorgeschlagenen Schüleraufgaben bei ArcGis sehr nützlich und wünschte mir noch mehr davon. Allenfalls könnte man diese inhaltlich (im Gegensatz zu methodisch) noch mehr ausbauen. Z.B. habe ich die Vulkanübung auf Hawaii schon durchgeführt. Ich finde sie toll, mir haben aber inhaltliche Zusatzaufgaben zu Vulkanismus, Katastrophenmanagement etc gefehlt. Auch wären Grundlagenunterlagen in einfacher Sprache und mit den Basics von GIS nützlich.	1	1		1														
30	Aus- und Weiterbildung. Konkrete Anwendungsbeispiele zusammenstellen.	1				1		1											
31	- konkrete Unterrichtseinheiten konzipieren - Karten-Pool errichten mit den wichtigsten Karten zu sozio-kulturellen räumlichen Phänomenen	1		1															
32	Kostengünstige Weiterbildungstage mit fix-fertigem Unterrichtsmaterial zum downloaden. Supportunterstützung (Bsp. ESRI) notwendig. Mehr Zeit im Unterricht (Praktikum Geographie mit Halbklassen).	1				1			1						1		1		
33	Unterrichtsfertige Sequenzen bereitstellen, die auf den Lehrplan abgestimmt sind.	1			1														
34	Unterrichtsmaterial bereitstellen -> Esri Schulprogramm	1																	
36	geplante Unterrichtseinheit / Lehrmittel / Weiterbildung	1				1													
37	Vorgefertigte, aber leicht anpassbare kurze Einstiegsübungen zu verschiedenen lehrplanbezogenen Themen.	1			1														
153	Beispiele von sinnvollen Aktivitäten, aktuelle Fragestellungen	1																	
41	Fortbildung über eine ganze Woche, nachhaltig, mit Beispielen, die sich 10 Jahre lang nutzen lassen und Programmen, die nicht alle 5 Minuten updates brauchen. Hosting der Daten auf schuleigenen Servern/ SchulGIS--Kompetenzzentren.	1		1		1													
43	Cf réponses précédentes																		1
44	Mehr Zeit/Gefässe bereitstellen (Kanton/Schule); gezielte Weiterbildungen für Lehrpersonen unterschiedlicher Niveaus anbieten					1			1										
45	Das wäre hilfreich! Es gibt auch einzelne Anleitungen online zu verschiedenen Themen, aber da könnte noch mehr gemacht werden. (z.B. Kurse wie man GIS mit konkreten Lehrplaninhalten des Kantons verbindet)	1	1		1														
48	Zuverlässigkeit der Anwendung muss gegeben sein; Ausbildung von Lehrpersonen; Problem liegt vor allem in zu wenigen Unterrichtslektionen, um GIS auch wirklich implementieren zu können.							1	1				1						
49	Weiterhin Weiterbildungsangebot, Unterrichtsmaterial (bereits vorhanden bei ESRI Schweiz)	1				1													
50	par une formation rapide sur l'utilisation du logiciel					1													
51	per poter utilizzare con gli allievi un software GIS/SIG occorrerebbe una versione estremamente semplificata del software, per ridurre al massimo l'"Einstiegshürde". Altrimenti lo sforzo non vale la pena (mit Kanonen auf Spatzen schiessen)											1							
54	Im Kanton Waadt reicht Die Zeit kaum, Die maturaklassen haben Nur in 2. Jahr Géographie. Ich glaube der aufwand lohnt sich dann nicht								1										
55	Unterstützung ist ausreichend bzw. gut > Webseiten; Faktor Zeit sowohl Vorbereitung wie auch Zeitfenster im Unterricht ist das Problem im Grundlagenfach						1		1									1	
56	1:1 Materialien, ohne grossen Aufwand abrufbar. Step by step Anleitung.	1	1																
57	motivieren und Möglichkeiten aufzeigen	1																	
58	Ich bin erst seit knapp einem halben Jahr Lehrperson und parallel noch in der Ausbildung. Habe deswegen auch noch wenig Erfahrung. Aber wir hatten gerade in Fachdidaktik einen Workshop mit esri, welche mir das Potential von GIS-Einsätzen auch für Exkursionen oder Projektaufträgen aufgezeigt hatten. Zum Beispiel das erstellen von Surveys, wo die SuS dann ihre erhobenen Daten eingeben können und räumlich analysieren können. Evtl. sehe ich auch Potential allgemein bei Visualisierungen von Dingen, die ich momentan evtl. noch "zu theoretisch" behandle.						1												
60																			1

ID	Answers: How do you think teachers could be supported in using GIS in the classroom?	Material				Teacher Competence			Curriculum		Technical aspects				Support			Other	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
61	Je nach Tool unterschiedlich. ArcGis z.B. ist massiv zu komplex und braucht somit zu viel Zeit im regulären Unterricht. Themengebundener Einsatz macht absolut Sinn. Wie wärs mit einem modernen Lehrmittel (gibt es ja sowieso nicht in brauchbarer Form)...? Für einige sind sicher fehlende Kenntnisse eine Hemmschwelle und der benötigte Zeitaufwand etwas Sinnvolles auf die Beine zu stellen.				1		1		1			1							
62	Mehrere einfache/einfachste Lehr-/Lerneinheiten z.B. map.geo.admin zur Verfügung stellen	1	1																
63	Indem man ihnen gute, simple Erklärvideos zur Verfügung stellen würde.		1																
64	Weiterbildungen. Esri macht es gut. Aber ich bin nicht mehr lange im Amt, habe viele Anläufe unternommen, aber nie so weit gekommen, dass ich es anwenden könnte.					1													
65	Investissement en temps et en argent ! Aussi par une institutionnalisation de cette pratique et de ses moyens/méthodes. (Rendre l'enseignement des SIG obligatoire). Par son introduction dans le plan d'études serait déjà pas mal.						1			1									
66	Lehrmittel erneuern, evtl. modular aufbauen. Bezüglich Kurse wurde und wird von ESRI vieles getan. Hier könnten evtl. auch die Universitäten noch etwas aktiver werden (und z.B. mit Verlagen zusammenarbeiten). Immer vorausgesetzt, es sind Online-GIS und vielfältige Daten günstig oder gratis verfügbar!	1		1	1			1			1								
67	einfache Manuals, Aufgabenstellungen auf frei zugänglichen Plattformen zu relevanten Lehrplanthemen bereitstellen, es fehlt den LP meist die Zeit, um gute Grundlagendaten zu suchen, um sinnvolle Aufgaben bereitzustellen	1	1	1	1		1												
68	Massgeschneiderte Anwendungen/ Apps und LP-Lernziel-inspiriertes Unterrichtsmaterial mit vernünftiger Länge	1			1							1							
69	Wir haben einfach zu wenig Zeit. Der Lehrplan ist dicht bepackt, praktisch jedes Themengebiet der Geografie ist wichtig und alltagsrelevant und sobald die LP Anwendungen jeglicher Art inkl. GIS durchführt, braucht es sofort extrem viel Zeit. So muss dann meist etwas anderes gestrichen werden. Das ist schade. Wir brauchen einfach mehr Lektionen, denn ich finde Anwendungen eigentlich wichtig, kann aber meist zu wenig Zeit darin investieren.								1										
72	Mit konkreten Unterrichtsvorschlägen.	1																	
73	Weiterbildungen. Lehrmittel zu gängigen Themen.	1			1	1													
74	Einfache Anwendungsaufgaben Vorbereitete Lerneinheiten Datensätze zu versch. Themen	1		1															
75	- Vorbereitung von gut strukturierten Unterrichtsmaterialien, die auch nicht allzu viel Unterrichtszeit brauchen - klare Angaben, wie man zur geeigneten Software zu günstigen Konditionen kommt - Weiterbildungsveranstaltungen bezüglich GIS auch für Lehrpersonen, die keine oder nur sehr wenig Erfahrung damit haben	1	1			1			1										
76	Anleitungen, die die Hemmschwelle Gis einzusetzen reduzieren. Oft fehlen auch Kompetenzen bei LP in GIS.		1																
77	Basismodule im Umgang mit GIS für Lehrer*innen und Schüler*innen erstellen (Lehrbücher, Onlinetools) Kostenlose Weiterbildungen vom Kanton anbieten. Finanzierung von Arcgis Kursen für den Kanton	1	1			1													
78	Unterstützung ist schon gut genug (Kurse, Webinare)																	1	
80	konkrete Unterrichtsbeispiele, Metadaten zur Verfügung stellen oder aufzeigen wo herunterladen	1	1	1															
81	Formazione continua e/o collaborazioni con i dipartimenti cantonali					1										1			
82	Beispielsaufgaben welche für jede Region anwendbar sind	1																	
83	Formazione continua, disponibilità di hardware e software, disponibilità di materiale didattico	1				1					1			1					
84	Einheitliche Software mit einfacher Handhabung.											1							
85	mehr Unterrichtszeit								1										
86	Mehr Lektionen								1										
89	Wie immer: Vorgefertigte, eventuell individuell anpassbare Unterrichtseinheiten	1																	

ID	Answers: How do you think teachers could be supported in using GIS in the classroom?	Material				Teacher Competence			Curriculum		Technical aspects				Support			Other	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
22	Hotline für Fragen, die immer im dümmsten Moment auftauchen...														1				
91	Einfache Anwendungsbeispiele für den Einstieg. Anwendungsbeispiele auf verschiedenen Anspruchsstufen.	1																	
92	Weiterbildungsmöglichkeiten schaffen, wo man sich WIRKLICH in das System einarbeiten kann (betreutes Üben über einen längeren Zeitraum). Damit meine ich nicht eine eintägige Weiterbildung, das hatten wir auch schon. Im Endeffekt war das eher frustrierend. Man lernte ein tolles Werkzeug kennen, dass man aber aufgrund der knappen Zeit nicht wirklich selber erforschen und ausprobieren konnte und somit auch nicht beherrscht und deshalb auch nicht im Unterricht einsetzen kann.					1													
93	Einfache (Buffer, Join, Summieren Punkte auf Fläche, Fahrzeitanalyse) über mehrere Jahre nutzbare Unterrichtsinhalte mit aktuellen Bildschirmfotos inkl. Daten. Nicht spezifisch auf die Gemeinde XY, sondern globale Beispiele. Es fehlt häufig an Daten. Manchmal fehlen Sachdaten, manchmal Vektordaten, dann könnte man die Daten auswerten. Es fehlt auch an der Unterrichtszeit. Mit ein paar Grundlagen könnten die SuS auch Maturaarbeiten oder weiterführende Projekte selber erstellen.	1		1					1										
94	Unterrichtseinheiten vorbereiten	1																	
95	1 - Schritt für Schritt Anleitung, wie tolle Analysen gemacht werden können. 2 - Datensätze zur Verfügung stellen. An georeferenzierte Datensätze zu kommen ist meistens das grösste Problem. Z.B. könnte man den Zusammenhang zwischen Klima und Böden analysieren. Dazu braucht man aber Daten zum Klima (Klimazonen, Niederschlag, Jahestemperatur) und zu den Böden. Diese Datensätze auf ArcGIS oder auf einer anderen Plattform, z.B. "georeferenzierte Datensätze für den analytischen Geografieunterricht", als CSV-Datei zum einfachen Download zur Verfügung stellen. Weil das Suchen nach diesen Datensätzen braucht sehr viel Zeit, die viele Lehrpersonen nicht haben. Daran scheiterten bei mir auch schon viele Projekte.	1	1	1			1												
96	Massgeschneiderte Unterrichtseinheiten	1																	
97	Anleitungen zum eigenen Erheben von Daten im Gelände. Arten von Daten, Grenzen der Darstellbarkeit, Gestaltungshinweise	1	1	1															
98	Programmierte Lernsequenzen	1																	
99	Weiterbildung, Bereitstellen von Unterrichtsmaterialien Bereitstellen von einfachen Tools, die zuverlässig laufen und funktionieren	1				1					1	1	1						
101	Mehr Weiterbildung, Austauschplattformen					1										1			
103	Proposer un logiciel facile d'utilisation dont l'apprentissage d'utilisation ne nécessite pas trop de temps. Proposer un logiciel gratuit pour que les élèves puissent l'utiliser chez eux, mais également plus tard dans leurs études.						1				1	1							
104	Formation continue. Échanges entre enseignants.					1										1			
106	Indem man den Lehrpersonen Workshops Online, aber auch mit Präsenzevents anbietet. Indem man GIS, wie den SWA in der PH-Ausbildung integriert und Unterrichtseinheiten in der Ausbildung mit GIS verlangt. Indem sich die entsprechenden Exponenten, sowie das geographische Institut und die Geamatik Abteilung der ETH vernetzt und das Thema publik macht.		1			1		1											
107	Gute Lernplattform mit Erklärvideos und frei zugänglichen Geo-Daten. www.gissargans.jimdofree.org Sowas als Beispiel. Daten, Anleitung und Videos auf einer Seite... Vermisse etwas, dass sehr wenig ähnliches gibt. Gleichzeitig haben halt Lehrpersonen auch ihre individuellen Präferenzen.	1	1	1															
109	Teil der Informatik an Geographie delegieren								1										
111	Leicht umsetzbare Unterrichtsmaterialien frei zur Verfügung stellen.	1																	
113	Servono corso di formazione specifici.					1													
114	Bei ESRI ist die Vielfalt der Themen, die man online findet, das Problem. Man verliert sich schnell im Angebot und fühlt sich überfordert. Angebote von ESRI Schweiz noch mehr auf die Lehrpläne der Schulen ausrichten und übersichtlich darstellen.				1														

ID	Answers: How do you think teachers could be supported in using GIS in the classroom?	Material				Teacher Competence			Curriculum		Technical aspects				Support			Other	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
115	Opensource-Schulungen und das Bereitstellen von Material und aufbereiteten Grundlagedaten.	1	1	1		1													
117	. Weiterbildungsangebote für LP (... existieren bereits) . Kursangebot/-begleitung/-führung durch einen externen Anbieter im Rahmen einer Projekt-/Blockwoche					1									1		1		
118	-																		1
119	Weiterbildung, Unterrichtsmaterial	1				1													
120	Zwei Punkte sind meiner Meinung nach relevant: - Die Schule muss Zeitgefässe zur Verfügung stellen um nicht nur im 2-Stundenrhythmus wöchentlich einmal da-ran arbeiten zu können. Meine Schule (Kanti Solothurn) hat, neben dem Ergänzungsfach, alle diesbezüglichen Gefässe gestrichen. Bis vor fünf Jahren konnten wir alle Klassen eine Woche lang in GIS einführen. Das fällt nun weg und im Normalunterricht ist der Einsatz von GIS relativ mühsam. Man beginnt eine Woche später fast wieder von vorne. - Der zweite Punkt ist die Lehrperson selbst. GIS ist relativ komplex und fordert die Lehrkraft. Das hält viele davon ab, sich in die Materie einzuarbeiten.						1		1										
121	Better materials. More easily accessible/usable data sets	1		1															
122	mit überzeugenden, leicht anwendbaren Fallbeispielen, in denen relevante geografische Allgemeinbildung ver-mittelt wird.	1	1		1														
123	Bezahlte Weiterbildungen, gutes Material, Gratis Hotline bei Problemen.	1				1									1				
124	?																		1
125	Formations spécifiques aux logiciels de cartographie					1													
126	Wer GIS einsetzen möchte, bekommt genügend Unterstützung.																	1	
127	Durch Weiterbildung					1													
128	Formation continue					1													
129	Avoir un logiciel libre facile d'utilisation, ainsi que des activités facile à mettre en place sur 45 minutes, notam-ment liées à la Suisse. Pour le moment j'utilise beaucoup map.admin.ch ou les géoportails des cantons ou encore google earth	1									1	1							
130	- lernplanbezogene Weiterbildung, - Bereitstellen von Materialien (z.B. auf swisseduc)	1				1													
131	?																		1
132	Mehr und diversere niederschwellige Unterrichtsskizzen.	1																	
133	Versions multi-plateformes + Applications simples + Formations courtes par vidéo + mentors à disposition par vidéo		1			1						1							
135	GIS an FH (Praktika) einbauen							1											
136	Zeitgefässe								1										
137	Konkrete Fallbeispiele	1																	
138	Einfache Unterrichtsmaterialien, die flexibel anpassbar sind.	1																	
139	Gute, attraktive Unterrichtsbeispiele	1																	
141	Zur Verfügung stellen von Übungen mit SCHWEIZ relevanten Daten in einem Webbasierten GIS-Software, die nicht zu komplex zu bedienen ist.	1		1								1							
142	Weiterbildung mit konkreten Anwendungsbeispielen in einem kleinen Rahmen					1													
143	mise à disposition de séquences pédagogiques qui utilisent des SIG cours de formation continue sur les SIG pour les enseignants	1				1													

ID	Answers: How do you think teachers could be supported in using GIS in the classroom?	Material				Teacher Competence			Curriculum		Technical aspects				Support			Other	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
144	Mehr Schritt-für-Schritt Anleitungen für LP. Oftmals wendet man kein GIS an, weil beim kleinsten Fehler alles zu- nichte gemacht werden kann (z.B. ging mal im letzten Moment die Collector App nicht mehr bei meinen SuS. Seit- dem verwende ich sie nicht mehr, weil Aufwand/Ertrag nicht mehr stimmen für mich.)		1																
145	verschiedene Unterrichtseinheiten mit einheitlicher Software	1																	
146	?																		1
158	Nicht zu viel auf GIS auslegen, ist nicht der Weisheit letzter Schluss, vielfach kein Mehrwert																		1
148	Schulung; Aufzeigen der Möglichkeiten; ev. Unterstützung durch Fachperson, wenn Schwierigkeiten auftauchen	1				1									1				
149	Weiterbildung					1													
150	Muss: Freeware, mehr Zeit; bessere Verfügbarkeit angepasster Datensätze			1					1		1								
151	Ils faut qu'ils maitrisent l'outil. Pour ma part, je les maitrise grâce à mes travaux de recherche à l'université (doc- torat) et dans le cadre de mandat réalisés dans des bureaux d'ingénieurs. J'ai pu ensuite "extrapoler" certains projets à l'enseignement. Cela demande beaucoup de temps pour créer des séquences. Map.geo ou Google Earth sont dans un premier temps plus facile à utiliser. Pour les SIG (ArcGIS, QGIS), cela nécessite des formations qui soient utilisables par les enseignants.					1	1												
152	Vorbereitete Einheiten zur Einführung von GIS im Unterricht Leicht zu bedienende und möglichst gratis zur verfügung stehende Software	1	1								1	1							
16	höhere Lektionendotierung des Fachs Geografie direkte Ansprechspersonen bei technischen Problemen (wo wie das Thomas Ingold anbietet)								1						1				
154	Nous n'avons que peu de temps à disposition, il faudrait que ce soit simple et pertinent à la fois.								1										1
155	Aucune idée																		
156	Mieux les former à utiliser les SIG					1		1											
157	Aucune idée mais avir des logiciels et une formation serait un bon début					1					1								
27	Einfache und kurze Unterrichtsbeispiele zu Verfügung stellen	1																	
159	Avec des formations. Personnellement je ne sais pas comment faire. C'est très dur pour moi. J'aimerais qu'on me montre et qu'on m'explique. L'idéal serait d'avoir aussi un exemple de séquence à réaliser en cours	1				1													
160	Par la formation continue et la mise à disposition de logiciels adéquats					1					1								
161	Bereitstellen von Unterrichtseinheiten/-ideen etc	1																	
162	J'avais suivi une formation de quelques jours il y a une dizaine d'années. Mais devant la complexité des tâches, j'ai simplement renoncé à utiliser cet outil en classe. Je demeure convaincu cependant qu'il est tout à fait pos- sible de donner des cours de géographie avec rigueur, nuance et qualité sans recourir nécessairement aux SIG. Mais je serais prêt à m'y intéresser si vraiment l'utilisation était peu coûteuse en temps et en qualité, et enrichis- sante et stimulante pour les étudiants. Enfin, au niveau des lycées neuchâtelois, nous n'avons que de 3 périodes de géographie DF en 2e année. Cela laisse peu de temps pour utiliser les SIG avec les étudiants. Un investissement en temps et en énergie avec sans doute des bénéfices pédagogiques et intellectuels bien faibles. Peut-être cela serait-il plus profitable dans les cours d'informatique.								1										
163	bessere Selbsterklärende Unterrichtsmaterialien, die einen Grossteil der Hürden abbauen und einen Mehrwert im Unterricht bringen (es soll sinnvoll sein, das GIS zu verwenden und nicht einfach einen statische Karte anzu- schauen)	1	1																
164	Schulungen (für jedes Niveau), Unterrichtsmaterial mit guten Anleitungen	1	1			1													
165	Einfache 'Wegweiser' /Gebrauchsanweisung -> mehr/diverse Tools		1								1								
166	Gutes Unterrichtsmaterial inkl. bereitgestellte Daten aus verschiedenen Regionen der Schweiz	1		1															

ID	Answers: How do you think teachers could be supported in using GIS in the classroom?	Material				Teacher Competence			Curriculum		Technical aspects				Support			Other	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
167	Informieren Einfache Software GIS in Lehrplan integrieren Mehr Gg Lektionen					1			1	1		1							
168	leur présenter ce qui existe					1													
169	Das ist eine Frage, mit der ich mich noch nicht beschäftigt habe und die für die Vorbereitung auf die Schweizerische Maturität nicht zur Debatte steht.									1									
170	Materialien zur Verfügung stellen Weiterbildungskurse	1				1													
171	einfacherer Zugang zu Software (frei zugänglich), vorstrukturierte Anwendungsmöglichkeiten	1									1								
172	Es fehlt die Zeit: Einfachere GIS-Programme oder ganz kurze, vorgefertigte Übungen.	1							1			1							
174	Es hat wahrscheinlich schon recht viele Angebote und Hilfestellungen. Mich persönlich müsste man vielleicht in einem Weiterbildungswochenende "dazu zwingen", für alle Schüler einen Schulaccount zu erstellen und ein paar Einheiten vorzubereiten. Weil der Wille ist da, aber auf der Prioritätenliste oft weit unten. Das liegt aber weniger am Unterstützungsangebot von GIS, sondern der konstanten Überforderung der Berufs allgemein. Ich müsste die Unterrichtseinheiten dann immer auch gleich auf Englisch haben, weil es je eine deutschsprechende und eine englischsprechende Parallelklasse gibt. Wahrscheinlich würde es helfen, wenn man das mit Fachschaftskollegen gemeinsam machen könnte, aber ich bin eine Ein-Personen-Fachschaft. Erfahrung hilft sicher, und die kommt mit der Zeit, aber in kleinen Schritten. Super finde ich, wenn (wie bei Esri) schon Schritt-für-Schritt-Anleitungen vorhanden sind. Denn meine eigene GIS-Zeit im Studium ist auch schon ein paar Jahre her. Da der kantonale Lehrplan schon ein stattliches Alter hat, hat GIS leider auch noch keinen hohen Stellenwert. Das ändert sich aber mit der aktuellen Überarbeitung wahrscheinlich.	1	1			1	1			1						1			

Appendix E

Appendix E contains the teaching unit consisting of two independent modules and the according teacher commentaries and solutions. Both teaching modules are in German.

Modul 1: Einführung Geografische Informationssysteme (GIS)

1. Was ist ein GIS?

Ein Geografisches Informationssystem (GIS) ermöglicht die Erfassung, Verwaltung, Modellierung, Analyse, Visualisierung und Interpretierung von raumbezogenen Daten. Durch die Darstellung von Daten auf einer Karte, können räumliche Muster einfacher erkannt werden (Abb. 1).

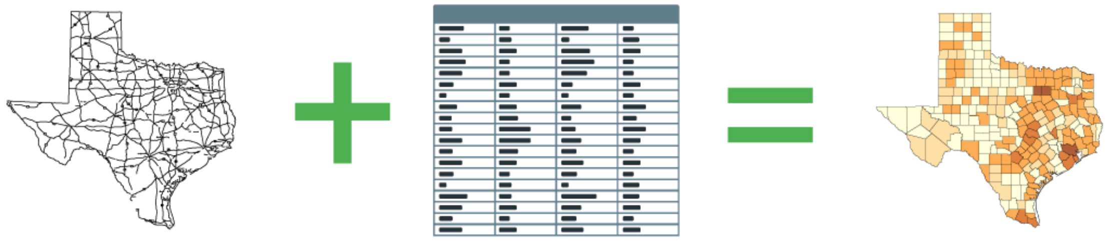

Abb. 1: *Die Darstellung von Daten mit Raumbezug als Karte (Sailer, 2022b).*

Geografische Phänomene können auf unterschiedliche Arten dargestellt werden. Abhängig vom behandelten Thema gibt es besser und weniger gut geeignete Darstellungsformen (Abb. 2). Bei Verwendung einer ungeeigneten Darstellungsmethode können sogar falsche Schlüsse gezogen werden.

Abb. 2: *Unterschiedlich kartografische Darstellungsformen eines Phänomens (Sailer, 2022b).*

Ein GIS bietet die Möglichkeit, eine Grundkarte mit weiteren Lage- und Sachinformationen zu ergänzen (Abb. 3). Diese Kartenebenen können beliebig ein- und ausgeblendet werden und werden als Layer bezeichnet. Unterschiedliche Analysefunktionen können vom/von der Nutzer*in verwendet werden, um zusätzliche Erkenntnisse aus den Daten zu gewinnen. Die interaktive Auseinandersetzung mit den Daten kann so für jede*n individuell nach den eigenen Bedürfnissen gestaltet werden (Sailer, 2022b).

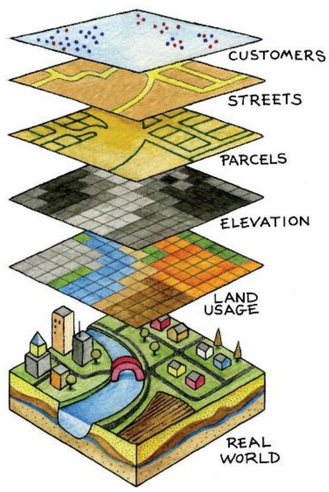

Abb. 3: *Kombination von unterschiedlichen Ebenen zu einer Karte* ***Invalid source specified.***

Aufgabe 1: Erarbeiten Sie in Ihren eigenen Worten eine Definition davon, was ein GIS ist. Die Definition sollte nicht länger als zwei Sätze sein.

2. Geodaten

Ein GIS arbeitet mit unterschiedlichen Geodaten. Geodaten sind digitale Informationen, welchen eine bestimmte räumliche Lage auf der Erdoberfläche zugewiesen werden kann (z.B. mithilfe von Koordinaten). Dies können beispielsweise Gebäude, Flüsse und Gemeindegrenzen, aber auch Topografie und Höhenangaben sein. Daten mit Raumbezug nennt man auch **geokodiert** oder **georeferenziert**.

Geodaten werden als Geometriedaten (**Vektor- oder Rasterdaten**) und den dazugehörige Sachdaten (auch **Attribute** genannt) gespeichert. Ein GIS arbeitet mit zwei unterschiedlichen Typen von Geodaten, dem Rastermodell und dem Vektormodell (Abb. 4). Beide Modelle sind hierbei vereinfachte und abstrahierte Abbildungen der Realität, die lediglich diejenigen Aspekte enthalten, die für den Verwendungszweck relevant sind.

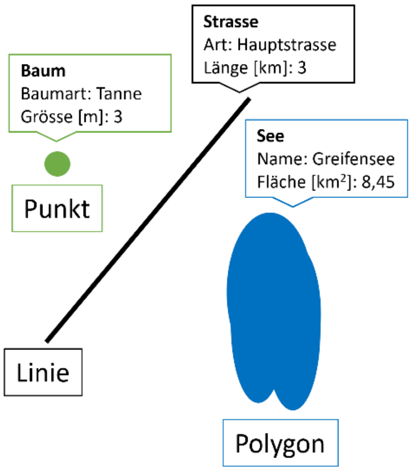

***Abb. 4**: Geometrische Grundelemente des Vektormodels und die dazugehörigen Attribute.*

Vektormodell / Vektordaten

Das Vektormodell wird verwendet, um Objekte darzustellen die diskret im Raum vorkommen und somit klar abgrenzbar sind. Das heisst, ein Objekt (oder auch eine Entität) kommt an einem spezifischen Ort vor, und kann mehrere Eigenschaften haben. Dies trifft beispielsweise auf ein Haus zu, welches an einer bestimmten Stelle steht, und Attribute, wie z.B. die Anzahl Zimmer oder die Farbe der Fassade, besitzt. Es gibt drei geometrische Grundelemente: Punkt, Linie und Polygone. Diese können zur Abbildung unterschiedlicher Entitäten verwendet werden (Abb. 5). Vektordaten brauchen meist wenig Speicherplatz, verfügen aber über eine komplizierte Datenstruktur, da jedes Objekt im Raum verortet werden muss.

Rastermodell / Rasterdaten

Mit einem Raster werden **kontinuierliche Daten** abgebildet. Das heisst, an jedem Punkt im Raum existiert ein Wert für die dargestellte Eigenschaft. Ein Raster besteht aus einer Matrix von Zellen (oder Pixeln), die in Zeilen und Spalten angeordnet sind. Jede Zelle enthält einen einzigen Wert, der Informationen wie z.B. die Landbedeckung darstellt (Abb. 6). Satellitenbilder sind ebenfalls eine Form von Rasterdaten. Rasterdaten sind meist sehr speicherintensiv, da sie für jede Zelle einen Wert Speicher müssen.

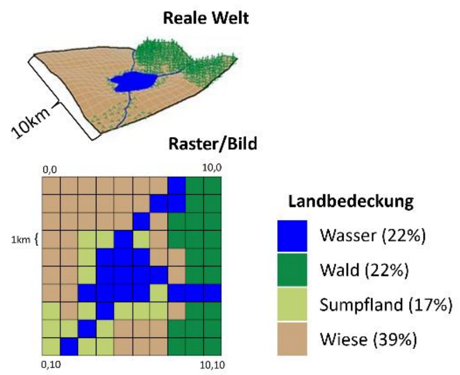

***Abb. 5:** Rasterdaten als Abbildung der realen Welt.*

Vektor (Punkt)

Attribute — Geometrie/ Koordinaten

ID	Baumart	Grösse [m]	X	Y
1	Tanne	3	8.31	47.46

Raster

Attribut — Geometrie/ Rasterposition

ID	Landbedeckung	Spalte	Reihe
1	Wiese	0	0

***Abb. 6:** Exemplarische Datentabelle eines Vektorpunkt (Baum aus Abb..4) und einer Rasterzelle (Abb. 5)*

Sachdaten / Attribute

In einer (Attribut-)Tabelle oder Datenbank werden zusätzliche Informationen eines Objekts gespeichert, die über die Geometriedaten hinausgehen. In Abbildung 4 wären das beim Punkt beispielsweise die Baumart und die Grösse, in Abbildung 5 die Landbedeckung (Abb. 6).

Aufgabe 2:
Notieren Sie sich, welcher Datentyp am besten für die Darstellung der untenstehenden Beispiele Geeig-net ist.

Beispiel	Vektor			Raster	Bemerkung
	Punkt	Linie	Polygon		
Fluss					
Temperatur					
Strassen					
Häuser					
Kantonsgrenzen					
See					

Quellenverzeichnis

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Modul 1: Lehrpersonenkommentar: Einführung GIS

In diesem Skript finden Sie zuätzliche Anmerkungen und die Lösungen zur Unterrichtseinheit «Einführung in Geografische Informationssysteme (GIS)».

1. Anmerkungen

Das Unterrichtsmodul eignet sich dazu, den Lernenden eine kurze Einführung ins Thema GIS zu geben. Das Modul nimmt etwa 20 Minuten in Anspruch. Für die Durchführung wird lediglich das Skript benötigt, welches die Lernenden durcharbeiten können. Es kann zur Einführung vor der Arbeit mit GIS genutzt werden, beispielsweise vor der Durchführung des Unterrichtsmoduls «Urbane Gebiete der Schweiz mit ArcGIS Online identifizieren». Es eignet sich ab dem 9. Schuljahr.

2. Lösungen

2.1 Aufgabe 1

Aufgabe 1: Erarbeiten Sie in Ihren eigenen Worten eine Definition davon, was ein GIS ist. Die Definition sollte nicht länger als zwei Sätze sein.

Ein Geografisches Informationssystem (GIS) ermöglicht

- die Erfassung, Verwaltung, Modellierung, Analyse, Visualisierung und Interpretierung von raumbezogenen Daten.
- die interaktive Erkundung von digitalen Karten und die Analyse der Daten nach individuellen Bedürfnissen

2.2 Aufgabe 2

Aufgabe 2: Notieren Sie sich, welcher Datentyp am besten für die Darstellung der untenstehenden Beispiele geeignet ist.

Lösungen:

Beispiel	Vektor			Raster	Bemerkung
	Punkt	Linie	Polygon		
Fluss		x			Nicht flächendeckend, Linien
Temperatur				x	Flächendeckend
Strassen		x			Nicht flächendeckend, Linien
Häuser	x		x		Nicht flächendeckend, Punkte oder Polygon (je nach Generalisierungsgrad)
Kantonsgrenzen			x		Nicht flächendeckend, geschlossene Form

Modul 2: Urbane Gebiete der Schweiz mit ArcGIS Online identifizieren

Der Begriff der Stadt lässt sich weder wissenschaftlich noch umgangssprachlich eindeutig definieren. Übergänge von städtischen und ländlichen Siedlungen sind meist fliessend. Dennoch unterscheiden sich Städte aufgrund grundlegender Merkmale von ländlichen Siedlungen. Historisch gesehen haben sich Städte durch Sonderrechte ihrer Bürger*innen, sowie ihrer geschlossenen Bauweise von ländlichen Regionen abgehoben. Statistisch gelten Gemeinden in der Schweiz ab 10'000 Einwohnenden als Stadt. Formal zeichnen sich Städte durch eine grosse Flächenausdehnung, sowie eine hohe Strassen- und Gebäudedichte aus. Funktional üben Städte zentrale wirtschaftliche, soziale, kulturelle und politische Funktionen aus. Ihre erbrachten Güter und Dienstleistungen werden auch dem Umland zur Verfügung gestellt. Weitere Merkmale wie Bevölkerungs- und Arbeitsplatzdichte, funktionale Gliederung (Geschäfte, Wohnquartiere etc.), eine starke Umweltbelastung und mehr, erlauben es, Städte von nicht städtischen Siedlungen abzugrenzen (Egli, 2016, p. S.272 ff.).

In dieser Unterrichtseinheit werden Sie mithilfe von ArcGIS Online selbständig Schweizer Gemeinden nach ihrer Urbanität in drei Kategorien (urban, suburban und rural) einteilen. Die Urbanität werden Sie basierend auf den Merkmalen der Einwohnerzahl, der Bevölkerungsdichte und der Anzahl Bahnhöfe pro Gemeinde ermitteln. Ziel ist es eine Karte zu erstellen, auf welcher jede Gemeinde einer der drei Kategorien zugeordnet wurde.

Lernziele:

- Sie kennen unterschiedliche Faktoren, welche die Urbanität eines Gebietes beeinflussen und können diese beschreiben.
- Sie können räumliche Verteilungsmuster von urbanen, suburbanen und ruralen Gebieten beschreiben und mögliche Ursachen für diese ermitteln.
- Sie können mithilfe ArcGIS Online einfache räumliche Datenanalysen durchführen.
- Sie können mithilfe von ArcGIS Online räumliche Daten visualisieren.

3. Übersicht: ArcGIS Online

Im folgenden Kapitel finden Sie Abbildungen der Benutzeroberfläche von ArcGIS Online und dazugehörige Beschreibungen. Diese Abbildungen sollten, während dem Bearbeiten der Übung, als Hilfestellung genutzt werden. Die Nummern werden in der Übung als Referenz zu den Abbildungen genutzt.

1.1 ArcGIS Online: Startseite Headpannel

1. **Karte:** Neue Karte erstellen.
2. **Inhalt:** Eigene Dateien wie z.B. Karten und Layer.

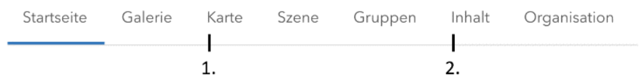
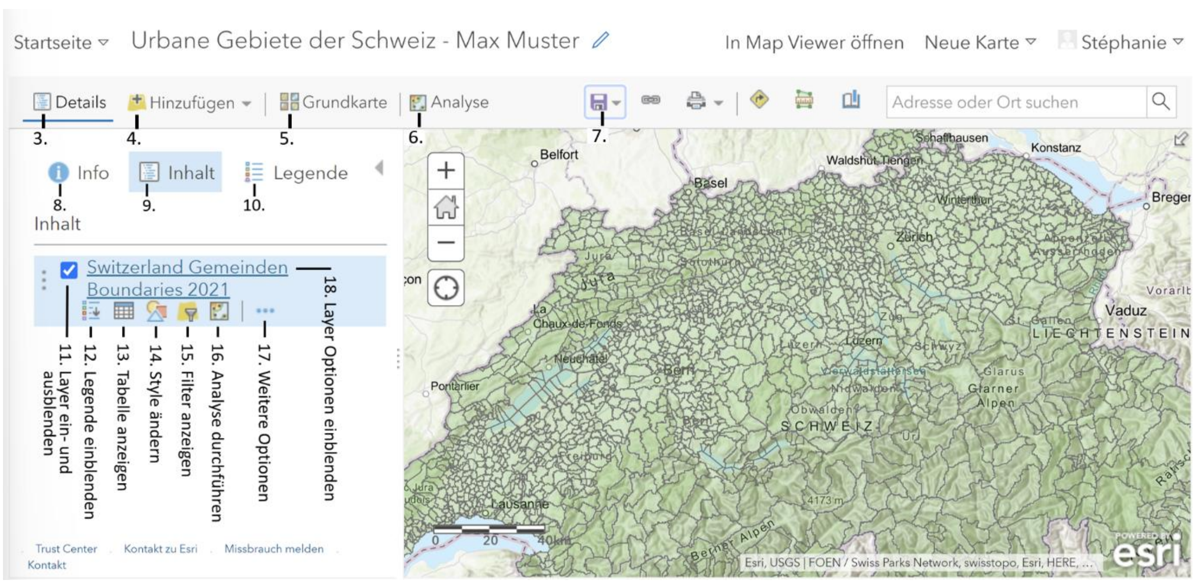


Abb. 1: *Screenshot des Headpanels der Startseite von ArcGIS Online.*

1.2 ArcGIS Online: Map Viewer Classic



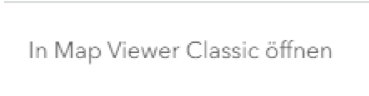
3. **Details:** Side Panel ein- und ausblenden.
4. **Hinzufügen:** Layer zur Karte hinzufügen.
5. **Grundkarte:** Grundkarte ändern.
6. **Analyse:** Analysefunktionen, um Layer zu analysieren.
7. **Karte speichern:** Aktuelle Karte speichern.
8. **Info**: Übersicht über Karteninformationen.
9. **Inhalt**: Übersicht über Layer der Karte.
10. **Legende**: Legende der eingeblendeten Layer.
11. **Layer ein- und ausblenden:** Layer der Karte ein- und ausblenden.
12. **Legende einblenden:** Legende des Layers einblenden.
13. **Tabelle anzeigen:** Datentabelle des Layers anzeigen.
14. **Style ändern:** Darstellung (z.B. Farben, Klassen…) des Layers ändern.
15. **Filter anzeigen:** Filter basierend auf Daten des Layers anwenden.
16. **Analyse durchführen:** Analysefunktionen auf den Layer anwenden.
17. **Weitere Optionen:** Zusätzliche Optionen, um z.B. den Layer umzubenennen oder zu entfernen.
18. **Layer Optionen:** Layer Optionen werden eingeblendet, wenn auf den Layer Namen geklickt wird.

***Abb. 2**: Screenshot der Benutzeroberfläche des Map Viewer Classic's von ArcGIS Online und Beschreibung der wichtigsten Funktionen.*

4. ArcGIS Online: Übung

2.1 Karte erstellen und speichern

1. **ArcGIS Online öffnen:** Öffnen Sie ArcGIS Online über folgenden Link (https://www.arcgis.com/index.html) und melden Sie Sich mit Ihrem Benutzernamen und Passwort an.
2. **Erstellen einer neuen Karte:** Klicken Sie auf «Karte» (1). Falls die Benutzeroberfläche nicht wie in *Abb. 2* aussieht, klicken Sie oben rechts auf «In Map Viewer Classic öffnen».



3. **Speichern einer Karte:** Klicken Sie auf «Karte speichern» (7) > «Speichern». Geben Sie der Karte

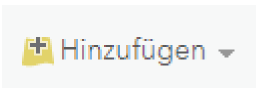
den Namen «*Urbane Gebiete der Schweiz – Vorname – Nachname* ». Vergeben Sie Tags die es Ihnen erleichtern, die Karte wieder zu finden (z.B. Stadtgeografie, Schweiz). Speichern Sie Ihre Karte während dem Arbeiten regelmässig, um Ihre Resultate nicht zu verlieren.

***Tipp**: Wenn Sie das Browserfenster aus Versehen schliessen, finden Sie Ihre gespeicherte Karte unter Inhalt (2).*

2.2 Daten hinzufügen & vorbereiten

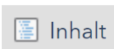
Im Einführungstext wurden verschiedene Merkmale die typisch für eine Stadt sind erwähnt. Im Folgenden werden Sie Schweizer Gemeinden in drei Kategorien (urban, suburban und rural) einteilen. Dafür verwenden Sie Daten zu den Merkmalen: Einwohnerzahl, Bevölkerungsdichte und die Anzahl der Bahnhöfe pro Gemeinde (öffentliche Verkehrsvernetzung). In diesem Teil werden Sie die Daten zur Karte hinzufügen und diese für die spätere Berechnung eines Urbanitätsindex vorbereiten.

4. **Layer Hinzufügen:** Klicken Sie auf «Hinzufügen» (4) > «Living-Atlas Layer durchsuchen».
   a. Suchen Sie den Layer «*Switzerland Gemeinden Boundaries 2021*» und fügen Sie ihn mithilfe des «+» Symbols zur Karte hinzu.
   b. Suchen und fügen Sie den Layer «*Public Transport Switzerland and Lichtenstein*» zur Karte hinzu.

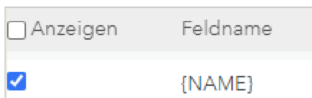


   c. Klicken sie auf den Pfeil, um zur Kartenübersicht zurückzugelangen.

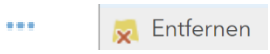
   d. Klicken Sie auf «Inhalt» (9), um zur Übersicht über die Layer der Karte zu gelangen.



5. **Namen der Gemeinden einblenden:** Klicken Sie auf den Layer «Switzerland Gemeinden Boundaries 2021» (18)> «Weitere Optionen» (17) > «Pop-up Konfigurieren» > «Attribute konfigurieren». Wählen Sie nun das Kästchen neben dem Feldnamen «*Name*» an, um den Gemeindename anzuzeigen, wenn man auf eine Gemeinde klickt.

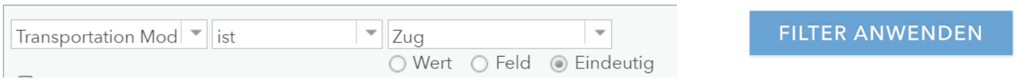


6. **Layer entfernen:** Klicken Sie auf «Weitere Optionen» (17) > «Entfernen» um den Layer «*Public Transport Switzerland and Lichtenstein – Tracks*» zu entfernen.

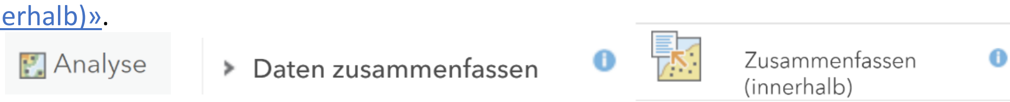


7. **Filter anwenden:** Für Sie ist nur die Anzahl der Bahnhöfe pro Gemeinde von Interesse. Andere ÖV-Stationen (z.B. Bushaltestellen) sollen nicht berücksichtigt werden. Aus diesem Grund werden Sie alle Bahnhöfe herausfiltern.
   a. Klicken Sie auf den Layer «Public Transport ... - Stops» (18) > «Filter» (15).

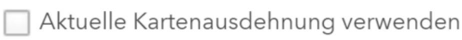
   b. Wählen Sie im ersten Feld «*Transportation Mode*», im zweiten «*ist*». Wählen Sie «Eindeutig» an, und wählen sie mithilfe des Dropdowns «*Zug*». Klicken Sie auf «Filter anwenden». Stellen Sie sicher, dass noch Punkte auf Ihrer Karte dargestellt werden.



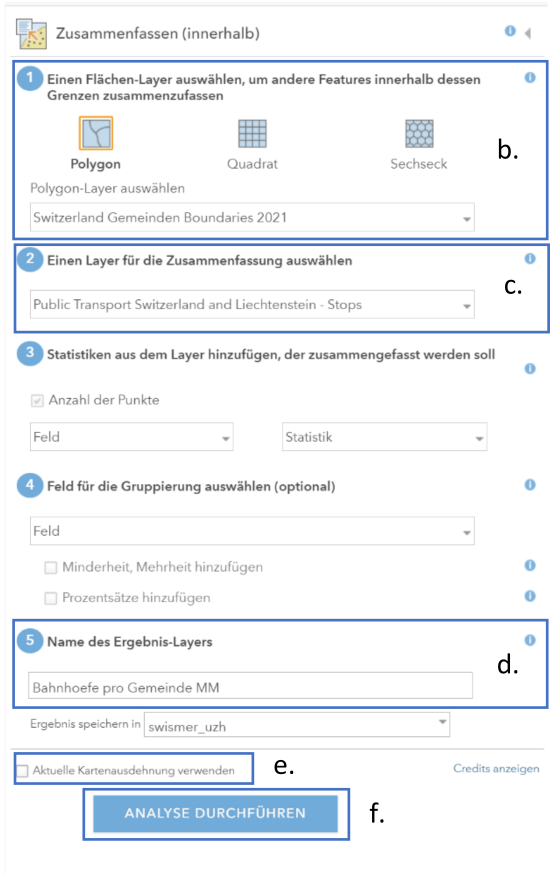
8. **Daten zusammenfassen:** Mithilfe einer Analysefunktion werden Sie nun herausfinden, wie viele Bahnhöfe es in jeder Gemeinde der Schweiz gibt.
   a. Klicken Sie auf «Analyse» (6)> «Daten Zusammenfassen» > «Zusammenfassen (innerhalb)».

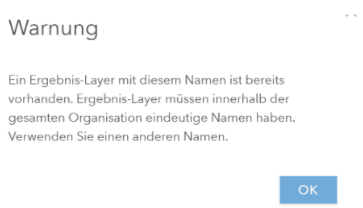


   b. Wählen Sie bei **1** den Layer «*Switzerland Gemeinden Boundaries 2021*».
   c. Wählen Sie bei **2** den Layer «*Public Transport Switzerland and Lichtenstein – Stops*»
      WICHTIG: Stellen Sie sicher, dass nicht alle Punkte, sondern nur die Bahnhöfe, angezeigt werden!
   d. Geben Sie bei **5** den Namen «*Bahnhoefe pro Gemeinde + Ihre Initialen*» ein.
   e. Entfernen Sie das Häkchen bei «*Aktuelle Kartenausdehnung verwenden*».

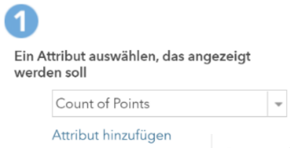


   f. Klicken Sie nun auf «Analyse durchführen».
      i. Die Analyse kann einige Zeit in Anspruch nehmen.
      ii. Wenn zweimal derselbe Name eingegeben würde, erscheint untenstehende Fehlermeldung. Ergänzen Sie in diesem Fall bei **5** (Siehe d) den Layernamen mit zusätzlichen Buchstaben Ihres Namens, bis die Fehlermeldung verschwindet.

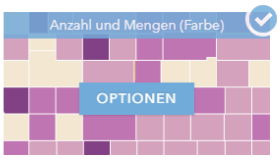




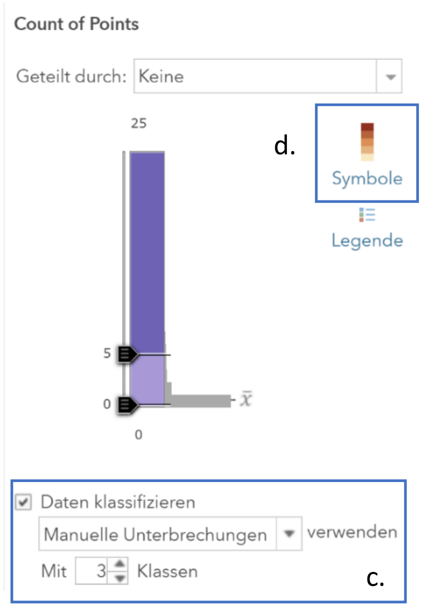
9. **Darstellung ändern:**
   a. Klicken Sie auf den neuen Layer «Bahnhoefe pro Gemeinde + Ihre Initialen» (18)> «Style ändern» (14) und wählen Sie bei 1. als Attribut, welches angezeigt werden soll, die Anzahl der Bahnhöfe (Count of Points) aus.



   b. Wählen Sie als Darstellungs-Style «Anzahl und Mengen» > «Optionen».



   c. Wählen Sie «Daten klassifizieren» an und erstellen Sie **3** Klassen. Überlegen Sie Sich hierbei, wie die Klassen am besten gesetzt werden, um die Urbanität von Gemeinden abzubilden. Notieren Sie Sich die gewählten Klassen.
   d. Unter Symbole können Sie die Farbe der Gemeinden, sowie die Stärke der Umrisslinie verändern.
   e. Klicken Sie auf «OK» > «Fertig»



2.3 Urbanitätsindex berechnen

In diesem Teil werden Sie basierend auf den unten aufgeführten Merkmalen einen Urbanitätsindex berechnen. Dafür werden Sie zuerst Urbanitätsgrenzen für jedes Merkmal festlegen. Danach werden Sie basierend auf diesen Grenzen, den Merkmalen Werte (1 = urban, 2 = suburban, 3 = rural) zuweisen, um am Schluss einen durchschnittlichen, gerundeten Urbanitätsindex zu berechnen.

- **Einwohnerzahl:** Statistisch gesehen gilt eine Gemeinde in der Schweiz als Stadt (urban), sobald Sie eine Einwohnerzahl von 10'000 Personen erreicht (Egli, 2016, p. S. 273). In Agglomerationen, also suburbanen Gebieten, leben durchschnittlich 6'500 Personen (ARE, 2003).
- **Bevölkerungsdichte:** Urbane Gebiete sind geprägt von einer hohen Bevölkerungsdichte, während sich rurale Gebiete durch tiefere Bevölkerungsdichten ausprägen. In der Schweiz beträgt die durchschnittliche Bevölkerungsdichte 215 Einwohner pro Km^2. Durch natürliche Umstände konzentriert sich ein Grossteil der Bevölkerung jedoch im Mittelland, wo man eine durchschnittliche Bevölkerungsdichte von ca. 400 Einwohner pro km2 antrifft (Glatthard, 2020). In Städten findet man wiederum viel höhere Bevölkerungsdichten bis weit über 1000 Einwohner pro Km^2.
- **ÖV-Vernetzung:** Der Verkehrsanschluss gibt ebenfalls Aufschluss über die Urbanität eines Gebiets. Dazu gehören neben dem Strassennetz auch die Vernetzung durch öffentliche Verkehrsmittel (Egli, 2016, p. S. 273f.).

Aufgabe 1: Ermitteln Sie basierend auf den Texten zur Einwohnerzahl und Bevölkerungsdichte, die Grenzwerte für die drei Klassen (urban, suburban, rural). Für die ÖV-Vernetzung können Sie die in Aufgabe 8c ermittelten Grenzen einfügen.

	Einwohnerzahl	Bevölkerungsdichte	ÖV-Vernetzung
Urban	>9’999		
Suburban			
Rural			

***Beispiel**: Die Gemeinde Cham hat eine Einwohnerzahl von 17'151 und fällt folglich für diesen Faktor in die Kategorie «urban (1)». Sie verfügt über eine Bevölkerungsdichte von 897.02 Personen pro Km^2 und fällt für diesen Faktor in die Kategorie «suburban (2)». Sie verfügt über 2 Bahnhöfe, und fällt für diesen Faktor in die Kategorie «suburban (2)». Berechnet man den Durchschnitt erhält man den Wert 1.67, welcher auf 2 gerundet wird. Somit kann die Gemeinde Cham als suburban klassifiziert werden.*

10. **Tabelle anzeigen:** Klicken Sie auf den Layer «Bahnhoefe pro Gemeinde + Ihre Initialen» (18) > Tabelle anzeigen» (13)

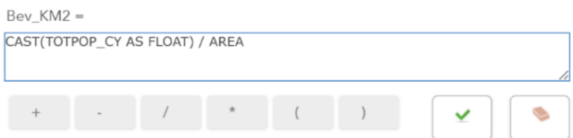
11. **Felder Hinzufügen:** Klicken Sie in der Attributtabelle Rechts auf «Optionen» > **«**Feld hinzufügen». Fügen Sie fünf neue Felder basierend auf den untenstehenden Informationen hinzu:

	Feld 1[1]	**Feld 2**[2]	**Feld 3**[3]	**Feld 4**[4]	**Feld 5**[5]
Feldname	Bev_Km2	Index_Einw	Index_BevKm2	Index_Bahnhof	Index_Urb
Anzeige-name	Bevölkerung / Km2	Index Einwohnerzahl	Index Bevölkerung/Km2	Index Bahnhof	Index Urbanität
Typ	Double	Double	Double	Double	Double

[1]Feld 1: Wird die Bevölkerungsdichte speichern.
[2]Feld 2: Wird den Index der Einwohnerzahl speichern.
[3]Feld 3: Wird den Index der Bevölkerungsdichte speichern.
[4]Feld 4: Wird den Index der Bahnhöfe pro Gemeinde speichern
[5]Feld 5: Wird den Durchschnitt der drei Indexe speichern.

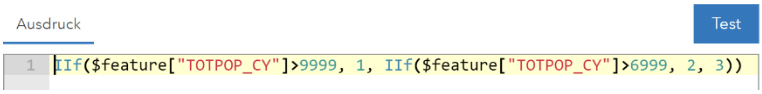
12. **Bevölkerungsdichte Berechnen mit SQL:**
    a. Klicken Sie auf das Feld «Bevölkerung / Km2» > «Berechnen» > «SQL»

    b. Oben Nun kann die Einwohnerzahl (TotPOP_CY) durch die Fläche (AREA) geteilt werden. Die Felder können unten Links ausgewählt werden. Oder kopieren Sie:
        - *CAST(TOTPOP_CY AS FLOAT) / AREA*
    c. Scrollen Sie nach unten und klicken Sie auf *«Berechnen».*



13. **Indexe zuweisen mit Arcade:**
    Einwohnerzahl:
    a. Klicken Sie auf das Feld «Index Einwohnerzahl» > «Berechnen» > «Arcade»

    b. Fügen Sie folgenden Code als Ausdruck ein. Stellen Sie sicher, dass der Bullet Point nicht mitkopiert/gelöscht wird. Klicken Sie auf «OK».
    - *IIf($feature["TOTPOP_CY"]>9999, 1, IIf($feature["TOTPOP_CY"]>6999, 2, 3))*



> ***Tipp**: Sie finden in Abb. 3 und Abb. 4 eine Erklärung wie der untenstehende Code funktioniert.*

Bevölkerungsdichte:
a. Klicken Sie auf das Feld «Index Bevölkerung/Km2» > «Berechnen» > «Arcade»
b. Fügen Sie den folgenden Code als Ausdruck ein und klicken Sie auf «OK»
- *IIf($feature["Bev_KM2"]>999, 1, IIf($feature["Bev_KM2"]>399, 2, 3))*

> ***Hinweis**: Stellen Sie sicher, dass Sie den Bullet Point (falls mitkopiert) löschen.*

Bahnhöfe pro Gemeinde: Die Urbanitätsgrenzen für die Anzahl der Bahnhöfe pro Gemeinde haben Sie selbständig gesetzt. Fügen Sie nun im Code Ihre ermittelten Werte ein.
a. Klicken Sie auf das Feld «Index Bahnhof» > «Berechnen» > «Arcade»
b. Fügen Sie den ergänzten Code als Ausdruck ein und klicken Sie auf «OK»

- *IIF($feature["Point_Count"]> Grenze urban, 1, IIf($feature["Point_Count"]> Grenze suburban, 2, 3))*

> ***Hinweis**: Stellen Sie sicher, dass Sie alle pinken Elemente gelöscht haben!*

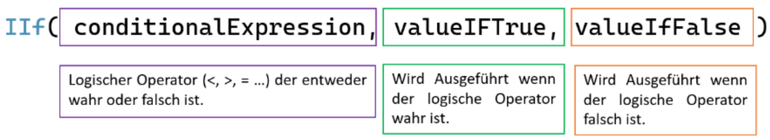


Abb. 3: *Erklärung der Funktionsweise einer IF-Schleife*

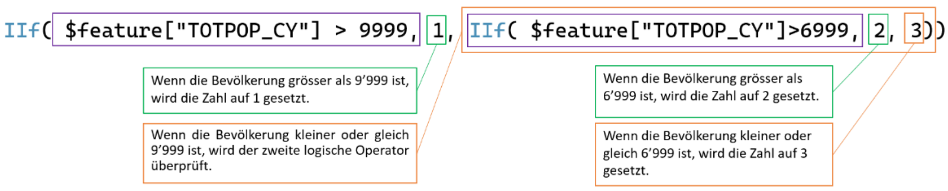
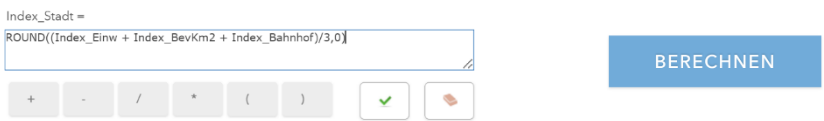


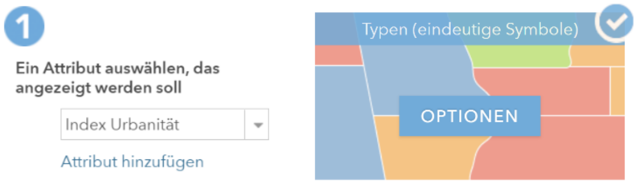
Abb. 4: *Erklärung einer IF-Schleife am Beispiel der Einwohnerzahl*

14. **Felder mit SQL miteinander verrechnen:** Sie werden nun die durchschnittliche Urbanität basierend auf den drei erstellten Indexen berechnen.
    a. Klicken Sie dafür auf das Feld «Index Urbanität» > «Berechnen» > «SQL»
    b. Klicken Sie bei den Funktionen auf «Round(,)» damit der Index gerundet wird.
    c. Summieren Sie nun die drei Indexe auf und teilen Sie die resultierende Zahl durch 3, um den Durchschnitt zu bekommen. Oder kopieren Sie:
    - *ROUND((Index_Einw + Index_BevKm2 + Index_Bahnhof)/3,0)*

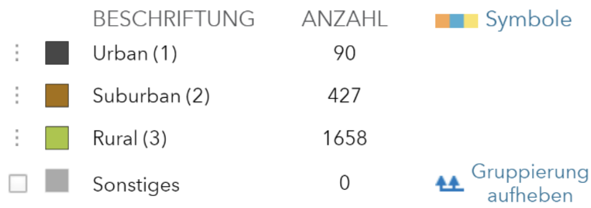


2.4 Kartendarstellung ändern

15. **Darstellen des Urbanitätsindexes:**
    a. Stellen Sie nun das Feld «Index Urbanität» auf der Karte dar (Siehe 9a).
    b. Wählen Sie als Darstellungsstyle «Typen (eindeutige Symbole)» > «Optionen»



    c. Wählen Sie zu den Kategorien passende Farben und benennen Sie diese um (1=urban, 2=suburban, 3=rural).



Aufgabe 2: Schauen Sie Sich die erstellte Karte an und beantworten Sie die folgenden Fragen schriftlich.
a) Wie sieht die Verteilung von urbanen, suburbanen und ruralen Gemeinden in der Schweiz aus?
b) Wie lässt sich diese Verteilung erklären?
c) Reichen die verwendeten Faktoren aus, um Aussagen über die Urbanität von Gemeinden zu machen? Wieso?

Aufgabe 3: Fügen Sie den Layer «Spatial Division Within Switzerland» zur Karte hinzu (Siehe 4, S.3) und beantworten Sie folgende Fragen schriftlich.
a) Inwiefern unterscheidet sich die Verteilung von urbanen Gebieten von Ihrer eigenen Karte?
b) Was könnten die Ursachen für die gefundenen Unterschiede sein?
c) Welche Kriterien wurden vom Bundesamt für Statistik (BFS) zur Gliederung verwendet? Recherchieren Sie auf der folgenden Seite: https://www.bfs.admin.ch/bfs/de/home/grundlagen/raumgliederungen.assetdetail.2543323.html

Quellenverzeichnis

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Glatthard, Jonas. 2020. *Es hat noch Platz in der Schweiz.* 21. 08. Zugriff am 12. 10 2022. https://www.swissinfo.ch/ger/es-hat-noch-platz-in-der-schweiz/45948160.

Modul 2: Lehrpersonenkommentar: Urbane Gebiete der Schweiz mit ArcGIS Online identifizieren

In diesem Skript finden Sie zusätzliche Anmerkungen, die Lösungen zur Unterrichtseinheit «Urbane Gebiete der Schweiz mit ArcGIS Online identifizieren», sowie Zusatzaufgaben. Die Anmerkungen sollen Sie bei der Vorbereitung und während der Durchführung des Unterrichts unterstützen. Die Lösungen sind als Anstoss zu sehen und können individuell ergänzt werden.

1. Anmerkungen

Die Unterrichtseinheit eignet sich als Einstieg ins Thema der Stadtgeografie und nimmt etwa 2 Lektionen in Anspruch. Hierbei nimmt die Übung in etwa 80 Minuten in anspruch. Sie ist ab dem 9. Schuljahr geeignet. Zum Lösen der Aufgaben braucehn die Lernenden einen ArcGIS Online Account. Falls Ihre Schule noch über keinen Schulaccount verfügt, kann dieser unter folgendem Link angefragt werden. Ansonsten brauchen die Lernenden keine speziellen Vorkenntnisse. Sie sollten jedoch bereits mit Kartenmaterial gearbeitet haben und in der Lage sein diese zu interpretiern.
Am Ende des Dossiers befinden sich ausserdem zwei Zusatzaufgaben zur Binnendifferenzierung.

1.1 Durchführungsmöglichkeiten

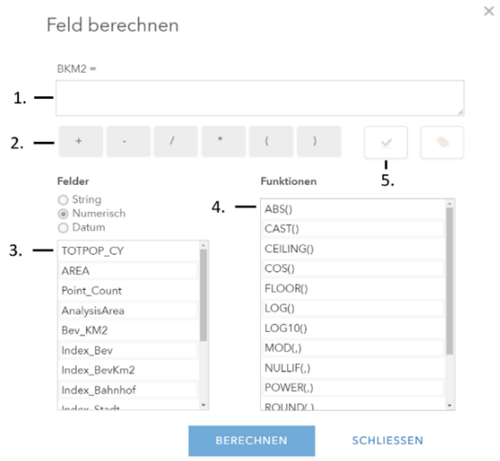
Untenstehend finden Sie einige Ideene, wie die Unterrichtseinheit Durchgeführt werden kann. Diese können nach belieben angepasst werden:

- **Unterrichtseinstieg:** Falls den Lernenden zu Beginn ein genereller Einblick ins Thema GIS gegeben werden will, eignet sich dafür das Skript und die Powerpoint «Einführung in GIS». Dieser Einstieg nimmt in etwa 20 Minuten in Anspruch, und zeigt den Lernenen Einsatzgebiete von GIS und befasst sich mit dem Thema der Geodaten. Ansonsten kann der Einführungstext aus der Übung als Einstieg genutzt werden.
- **Unterrichtsform:** Die Lernenden können die Übung in Einzel- oder Partnerarbeit durchführen.
- **Unterrichtsabschluss:** Zum Unterrichtsabschluss ist ein Unterrichtsgespräch bei welchem wichtige Erkenntnisse zusammengetragen und besrpochen werden geeignet.

1.2 SQL

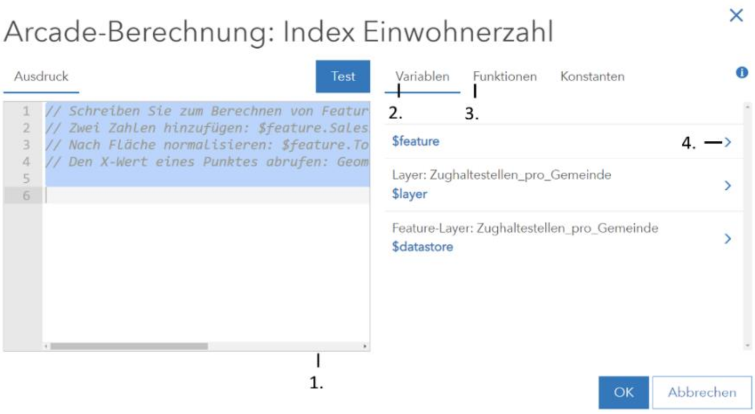
Bei Schritt 14 und 16 müssen die Lernenden mithilfe von SQL die Bevölkerungsdichte, respektive den Urbanitätsindex berechnen. Untenstehend finden Sie eine Übersicht über das SQL-Interface.

1. **Kommandozeile:** Hier können Rechenoperationen durchgeführt werden.
2. **Operatoren:** Hier können Operationszeichen aus-gewählt werden
3. **Felder:** Hier können die Felder der aktuellen Tabelle ausgewählt werden
4. **Funktionen:** Hier können mathematische Funktionen (z.B. ROUND(,), um eine Zahl zu runden) ausgewählt werden.
5. **Überprüfen:** Hier kann die eingegebene Operation überprüft werden.



1.3 Arcade

Bei Schritt 15 müssen die Lernenden einen Programmierbefehl nach Arcade kopieren. Untenstehend finden Sie eine Übersicht des Arcade Interfaces, sowie eine Liste möglicher Ursachen, wieso es bei der Ausführung zu einer Fehlermeldung kommen könnte.



1. **Kommandozeile/Ausdruck:** Hier kann der Code eingefügt werden.
2. **Variablen:** Hier können Variablen (e.g. Felder aus der Tabelle) ausgewählt werden.
3. **Funktionen:** Hier können Funktionen (z.B. IIF) ausgewählt werden.
4. **$feature:** Mit einem Klick auf den Pfeil werden alle Felder der aktuellen Tabelle, auf welcher die Berechnung durchgeführt wird, angezeigt. Diese können ausgewählt werden um Code zu schreiben (z.B. $feature[Point_Count] (Anzahl Bushaltestellen)).

Unten aufgeführt sind mögliche Ursachen von Fehlermeldungen. Diese werden mit einem Kreuz auf der linken Seite angezeigt, welches eine Fehlermeldung zeigt, sobald man es mit der Maus berührt:

- **Der Bullet Point wurde mitkopiert** (Einwohnerzahl, Bevölkerungsdichte, Bushaltestationen)
  ```
  2  o  IIF($feature["Point_Count"]> 5, 1, IIf
  ```
- **Nicht alle pinken Elemente wurden gelöscht** (Bushaltestationen)
  ```
  2  IIF($feature["Point_Count"]> 5an  1, IIf
  ```
- **Ein Komma wurde aus Versehen mitgelöscht** (Bushaltestationen)
  ```
  2  IIF($feature["Point_Count"]> 5 1, IIf
  ```
- Mögliche Lösung für den angepassten Code der Busstationen: *IIF($feature[«Point_Count»]> 5, 1, IIf($feature[«Point_Count»]> 0, 2, 3))*

2. Lösungen

2.1 Aufgabe 1

Aufgabe 1: Ermitteln Sie basierend auf den Texten zur Einwohnerzahl und Bevölkerungsdichte, die Grenzwerte für die drei Klassen (urban, suburban, rural). Für die ÖV-Vernetzung können Sie die in Aufgabe 8c ermittelten Grenzen einfügen.

Anmerkung: 215 Einwohner pro Km^2 ist lediglich die durchschnittliche Bevölkerungsdichte der Schweiz und nicht der Grenzwert für Agglomerationen.

Lösung:

	Einwohnerzahl	Bevölkerungsdichte	ÖV-Vernetzung
Urban	>9’999	>999	>5
Suburban	6’500 – 9’999	400-999	1-5
Rural	<6’500	<400	0

2.2 Aufgabe 2

Aufgabe 2: Schauen Sie Sich die erstellte Karte an und beantworten Sie die folgenden Fragen schriftlich.

d) Wie sieht die Verteilung von urbanen, suburbanen und ruralen Gemeinden in der Schweiz aus?

e) Wie lässt sich diese Verteilung erklären?

f) Reichen die verwendeten Faktoren aus, um Aussagen über die Urbanität von Gemeinden zu machen? Wieso?

Anmerkung:

- Hier kann von der Lehrperson ein Fokus gesetzt werden (z.B. konzentrieren Sie sich auf den Raum Zürich, Umkreis Ihrer Wohngemeinde (Skala 10km)), damit ein grösserer Alltagsbezug für die SuS entsteht.
- Die Lösungen sind grob für die ganze Schweiz geschildert.

Lösungen:

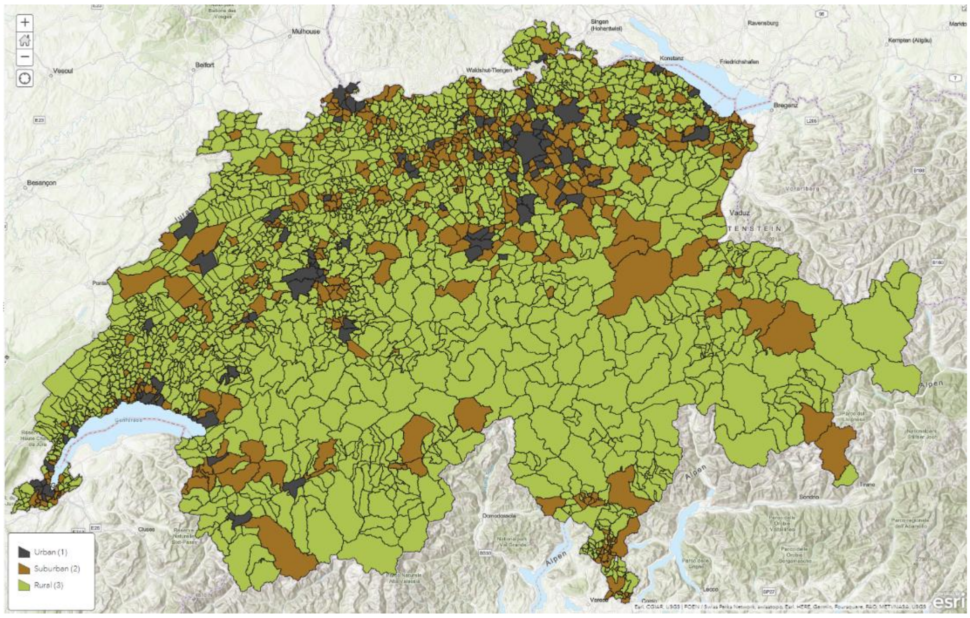


Abb. 1: *Screenshot der auf ArcGIS online erstellten Urbanitätsverteilung der Schweiz (mögliche Lösung, kann variieren je nachdem, wo man die Grenzen bei den Bahnhöfen setzt).*

a:

- Alpenraum grösstenteils rural, mit Ausnahme von Talregionen (z.B. Wallis, Graubünden).
- Mittelland, vor allem Raum Zürich aber auch Rund um Basel, Luzern und Aargau, vermehrt urban und suburban.
- Rund um den Genfersee vermehrt urbane und suburbane Gebiete.
- Rund um grosse Städte (z.B. Zürich, Genf, Basel) gibt es eine erhöhte Zahl an urbanen/suburbanen Gebieten.

b:

- Die Landschaft/Topografie hat einen grossen Einfluss auf die Verteilung der Städte. Grosse Teile des Alpenraums sind unbewohnbar.
- Rund um urbane Gemeinden sammeln sich viele weitere urbane/suburbane Gemeinden. Dies wird oft durch das grosse Arbeitsplatzangebot der Städte verursacht. Menschen ziehen in die Nähe von Städten, um zu arbeiten. Es kommt zu grossen Agglomerationsräumen um die Stadt(Siehe Zusatzaufgabe 1). Hat diese Bewegung noch ein beschreibendes Fremdwort?

c:

- Die verwendeten Faktoren geben einen ersten Eindruck über die Verteilung von urbanen, suburbanen und ruralen Gebieten. Jedoch haben viele weitere Faktoren einen Einfluss darauf, ob eine Gemeinde urban ist. Beispielsweise (Egli, 2016, p. S.274):
  - Grössere Siedlungen mit kompaktem Siedlungskörper (Vor allem im Stadtkern, überwiegend mehrgeschossige Häuser)
  - Hohe Arbeitsplatzdichte & starke Umweltbelastung
  - Funktionale Gliederung (Geschäftszentren, Industrieareale, Verkehrsareale, Wohnquartiere), Erwerbstätige arbeiten grösstenteils im zweiten und dritten Sektor
  - Differenzierte soziallräumliche Gliederung
  - Viele wohnen im Umland und pendeln täglich in die Stadt zur Arbeit
  - Versorgungs- und Dienstleistungsfunktionen der Stadt reichen bis ins Umland hinaus

2.3 Aufgabe 3

Aufgabe 3: Fügen Sie den Layer «Spatial Division Within Switzerland» zur Karte hinzu (Siehe 4, S.3)

d) Inwiefern unterscheidet sich die Verteilung von urbanen Gebieten von Ihrer eigenen Karte?

e) Welche Ursachen könnten die Unterschiede haben?

f) Welche Kriterien wurden vom Bundesamt für Statistik (BFS) zur Gliederung verwendet? Recherchieren Sie auf der folgenden Seite: https://www.bfs.admin.ch/bfs/de/home/grundlagen/raumgliederungen.assetdetail.2543323.html

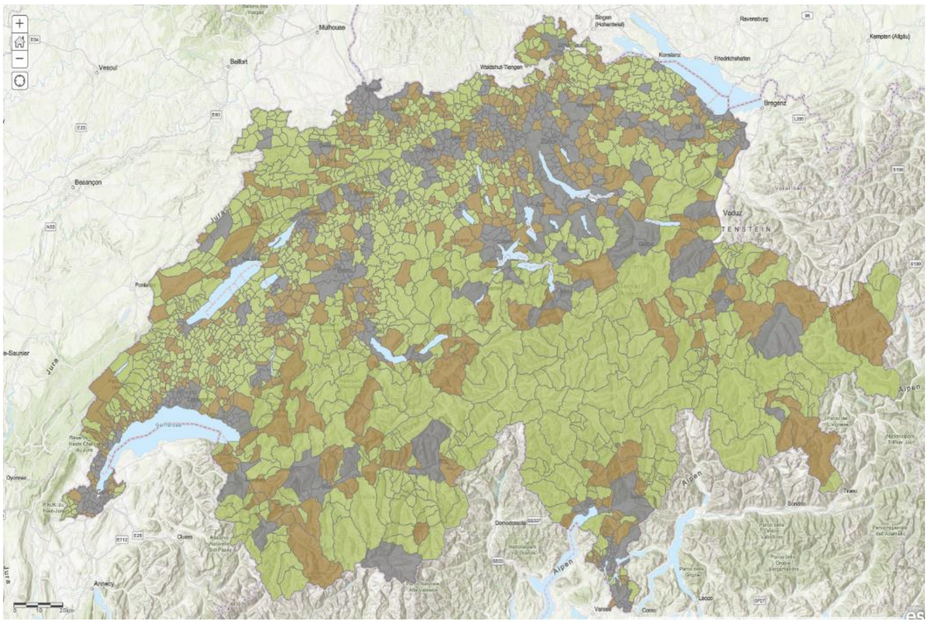


***Abb. 2:** Screenshot des "Spatial Division Within Switzerland" Layer.*

Lösung:

a:

- Insgesamt decken sich die urbanen/suburbanen Gemeinden ziemlich gut mit der Klassifizierung des BFS. Man erkennt ähnliche räumliche Muster und Verteilungen.
- Generell sind urbane/suburbane Gebiete stärker ausgedehnt als in der selbst erstellten Karte. Vor allem rund um Grossstädte (Zürich, Basel, Genf, etc.), dehnt sich der urbane/suburbane Raum stärker aus.

b:

- Je nachdem, wo die Grenzen für urbane, suburbane und rurale Gebiete gesetzt werden, kann die Klassifizierung variieren. Zudem hätte man durch die Gewichtung einzelner Faktoren möglicherweise ein genaueres Bild erzielt. Wie könnte man dies gewichten?
- Es gibt noch viele weitere Merkmale die städtischen Räume ausmachen, die von uns nicht berücksichtigt wurden. (Das BFS hat weitere Merkmale zur Klassifizierung genutzt)

c:

Anmerkung:
- Auf der Website gibt es ein PDF, welches Aufschluss über die verwendeten Faktoren gibt, dieses kann den Lernenden auch direkt zur Verfügung gestellt werden (BFS, 2017)
- Im PDF wird auf ein weiteres Dokument verwiesen, welches in der Lösung ebenfalls miteinbezogen wird (dies wird nicht von den Lernenden erwartet) (BFS, 2012).

Lösung:
Das BFS hat in 3 Schritten Gemeindetypologien mit unterschiedlich vielen Kategorien erstellt. Von der Gemeindetypologie mit 9 Kategorien, wurde schlussendlich die «Stadt/Land-Typologie» abgeleitet, welche aus den drei Kategorien städtisch, intermediär und ländlich besteht (angeschaute Karte).

Folgende Merkmale wurden zur Klassierung verwendet (BFS, 2017, p. S.2 ff.):
- Schritt 1: Unterscheidung gemäss «Raum mit städtischem Charakter» berücksichtigt morphologische Kriterien (Dichte) wie auch funktionale Kriterien (Pendlerbewegungen) (BFS, 2017, p. S.6). Kriterien sind (BFS, 2012, p. S.15):
  - Ständige Wohnbevölkerung
  - Anzahl Beschäftigte
  - Logiernächte in Hotels und Kundenbetrieben
  - Pendlerströme
- Schritt 2: Unterscheidung nach Dichte, Grösse, Erreichbarkeit (BFS, 2017, p. S.6)
- Schritt 3 (Wurde für die Stadt-Land-Typologie nicht-verwendet): Unterscheidung nach sozioökonomischen Kriterien: Vollzeitäquivalente nach Wirtschaftssektoren/im Verhältnis zur Wohnbevölkerung (BFS, 2017, p. S.9):
  - Tourismus: Verhältnis Übernachtungen zu Wohnbevölkerung
  - Primärer Sektor: Anteil
  - Sekundärer Sektor: Anteil
  - Tertiärer Sektor: Anteil

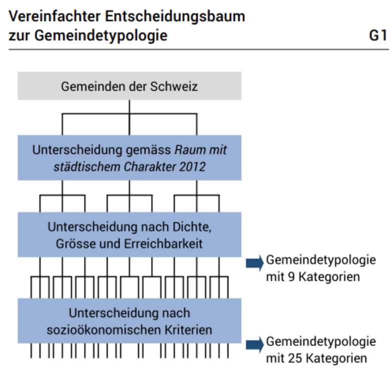


Abbildung 1: Vereinfachter Entscheidungsbaum zur Gemeindetypologie des BFS (BFS, 2017, p. S. 2)

T2 Verwendete Daten

Kriterium/Daten	Quelle
Ständige Wohnbevölkerung zum 31.12.2012	BFS, STATPOP
Anzahl Beschäftigte zum 31.12.2011	BFS, STATENT
Logiernächte in Hotels- und Kurbetrieben 2010/2012	BFS, HESTA
Pendlerströme 2011	BFS, STATPOP und STATENT (verknüpft)
Gemeindegrenzen: Gebietsstand: 01.01.2014	BFS, SWISSTOPO

Quelle: BFS © BFS, Neuchâtel 2014

Abbildung 2: Vom BFS Verwendete Daten zur Definition des Raums mit städtischem Charakter (BFS, 2012, p.

3. Zusatzaufgaben

Zwei mögliche Zusatzaufgaben mit Lösungen für Lernende die schneller mit der Bearbeitung der Aufträge fertig sind:

Zusatzaufgabe 1: Binnenwanderung (Zu und Abwanderung in den Schweizer Gemeinden)
Studieren Sie (Zweierteam? Grössere Gruppe?) die folgende Karte, welche die Zu- und Abwanderung Schweizer Gemeinden darstellt und beantworten Sie die folgenden Fragen schriftlich:
Statistischer Atlas Schweiz: Karte zur Binnenwanderung

a) Wie sieht die Zuwanderung/Abwanderung in den grossen Städten der Schweiz aus (Baden, Basel, Bern, Chur, Genf, Lausanne, Lugano, Zürich)?
b) In welchen Gebieten (urban, suburban, rural) sind Zu- und Abwanderung besonders hoch?
a) Was sind mögliche Gründe für die räumliche Verteilung von Zu- und Abwanderung?

Lösungen:

a) Differenz der Binnenwanderung in Städten ist abnehmend. Mehr Abwanderungen.
b) Vor allem in Suburbanen aber auch ruralen Regionen findet man einen Zuwachs. In sehr abgelegenen Regionen (Tälern) dominiert die Abwanderungen.
c) **Stadtflucht**: Coronapandemie: Wunsch nach Freiheit und Platz (Homeoffice), Finanziell**:** Es ist teuer in der Stadt zu wohnen (Miete und Steuern).
   Landflucht: Arbeitsplätze**:** Angebot in urbanen Regionen ist grösser, Freizeitangebot**:** In urbanen Gebieten ist (v.a. für Junge) das Freizeitangebot grösser

Zusatzaufgabe 2: Siedlungsentwicklung
Finden Sie mithilfe von map.geo.admin.ch heraus, wie sich Ihr Wohnquartier in den letzten 50 Jahren verändert hat. Sie werden dafür eine Karte von 1972 mit derjenigen von 2021 vergleichen. Verwenden Sie dafür den folgenden Link. Beantworten Sie die Fragen und halten Sie Ihre Erkenntnisse schriftlich fest.

a) Wie hat sich Ihr Wohnquartier in den letzten 50 Jahren entwickelt?
   i. Was hat sich verändert?
   ii. Was ist gleichgeblieben?
b) Was hat sich im Laufe Ihrer Lebzeit verändert? Können Sie Sich an Veränderungen erinnern?

Lösungen

a)
   i. Die Siedlungsfläche ist stark gewachsen und die Landwirtschaftsfläche ist geschrumpft. Vor allem in an grosse Städte angrenzenden Bereichen ist die Siedlungsfläche gewachsen, während es in grossen Städten selbst (z.B. Zürich) weniger Potenzial zur Ausdehnung gab (Baufläche bereits grösstenteils genutzt).
      - Darstellung der Karte hat sich verändert.
   ii. Die Waldfläche ist grösstenteils gleichgeblieben.
b) Individuell: Mehr und höhere Gebäude, weniger Landwirtschaftsfläche, neue Läden/Schulen…

Quellenverzeichnis

BFS. 2012. *Raum mit städtischem Charakter 2012.* Erläuterungsbericht, Neuchâtel: Bundesamt für Statistik (BFS).

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Egli, Hans-Rudolf. 2016. *12 Stadt.* Bd. 4. überarbeitete Auflage, in *Geografie: Wissen und verstehen - Ein Handbuch für die Sekundarstufe II*, von Hans-Rudolf Egli, Martin Hasler und Matthias Probst, 271-298. Bern: hep verlag ag.

Personal Declaration of Independence

I hereby declare that the submitted Thesis is the result of my own, independent work. All external sources are explicitly acknowledged in the Thesis.

Zurich, January 30, 2023

Stéphanie Wismer