Geographic Information Systems
in inquiry-based secondary geography education

Theory & Practice

Tim Tobias Favier
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Tim Tobias Favier

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Preface

In 2006, a geography teacher in secondary education in The Hague named Marijke was facing the yearly inquiry project with her graduating class. Unsatisfied with the low domain-specific quality of the end products and the rampant plagiarism in the previous years, she decided to take a completely different approach this time. Marijke had just read an enthusiastic article about Geographic Information Systems (GIS). Now she was wondering whether she could organize a GIS-supported inquiry project with her class. A vision popped up in her mind: students would investigate real issues in their city, such as spatial segregation, the causes of air pollution, and the factors which determine the distribution of different types of services. They would be free to choose a topic and formulate inquiry questions. They would use real geodata provided by the Municipality of The Hague and the Province of South Holland to construct maps that show the answers to their inquiry questions. It would be like doing real geographic inquiry.

As Marijke had never designed and conducted such an inquiry project before, she asked around for help. The Municipality of The Hague and the Province of South Holland sent her CDs with large sets of digital maps and other geodata, and ESRI, market leader for GIS software, provided GIS software and offered to organize GIS training for the students.

The project took off in February 2007. Two groups of 16-year old students constructed inquiry plans, visualized and analysed geodata in GIS, and wrote a small report about the outcomes of their investigations. Figure 0-1 presents an example of an inquiry project that focused on playgrounds in two neighbourhoods in The Hague. The student who constructed this map, Myrthe, formulated the following inquiry question: “Is the distribution of playgrounds fair?” Myrthe constructed two GIS maps to answer her questions: one of the distributions of children and playgrounds in the Bezuidenhout neighbourhood; and one of the distributions of children and playgrounds in the Schildersbuurt neighbourhood. She concluded in her report: “The Schildersbuurt has far more playgrounds than Bezuidenhout. However, Schildersbuurt has much more children. So it is fair. […] Besides, most of the houses in Bezuidenhout have a garden, so there is less need for playgrounds there.”

The students encountered many problems during the inquiry project. As they had never worked with GIS before and hardly knew anything about conducting geographic inquiry, some had no idea how to formulate inquiry questions on their topic. Marijke often had to give so much support that it almost seemed as if she had formulated the inquiry questions and created the maps herself. Myrthe turned out to be one of the few students who were able to complete the project with almost no support from the teacher. At the end of the project, Marijke concluded that her vision had not yet come true. Although she was convinced about the potential of GIS for supporting inquiry projects, she had many questions about how to design and conduct the inquiry project in an optimal way.

Marijke is not the only teacher who has had problems with the implementation of GIS in his/her class. Many teachers have had to face similar problems since GIS was introduced in secondary geography education. This dissertation tries to contribute to knowledge development on GIS-supported inquiry-based teaching and learning, in order to help geography teachers raise their inquiry projects to a higher level.
Figure 0-1: Example of a map created by a student in the inquiry project in The Hague

Playgrounds in two neighbourhoods in The Hague, The Netherlands

Legend

★ Playground  ·  House with children
Chapter 1: Introduction

In the past decade, more and more geography teachers, teacher trainers, and scientists in the field of geography education have become interested in the possibilities of using Geographic Information Systems (GIS) in teaching and learning geography. This dissertation reports about the results of a PhD study on GIS in secondary geography education. The PhD study aimed to develop a theoretical framework for GIS-supported inquiry-based geography education, and to explore how optimal GIS-supported inquiry-based geography education can be realized in practice. But, before we can have a detailed look at the aims and research questions of the PhD research, we first need to know what is understood by ‘geographic inquiry’, ‘inquiry-based education’, and ‘GIS’. These concepts will be explained in Section 1.1. Next, Section 1.2 sets out the research problem. The section explains that little is known about how to teach geography with GIS, and that in order to stimulate the diffusion of GIS in secondary geography education, we need both new theoretical and new practical insights. Then, Section 1.3 discusses the aims and research questions of the PhD research. Next, Section 1.4 describes the context in which the PhD research was conducted, and the relevance for science and practice. Finally, Section 1.5 presents the basic outline of the dissertation.

In order to avoid confusion, the term ‘research’ is from now on only used for the research conducted by the PhD student, and the term ‘inquiry’ is used for the research conducted by students in secondary education, and for the research conducted by professional geographers in business, government, and science.

1.1 Background

1.1.1 Geographic inquiry

Media attention given to the geographic knowledge of young people (e.g. National Geographic Education Foundation, 2006) often reinforces the common view that learning geography is just about learning topographical knowledge (e.g. knowing where Iraq is on a world map) combined with a bit of factual knowledge about the properties of places and regions (e.g. knowing that the main religion in India is Hinduism). However, learning geography is so much more than learning facts. According to Haubrich (1992), geography is “the science which seeks to explain the character of places and the distribution of people, features, and events as they occur and develop of the surface of the earth”. Different authors stress that it is important to combine knowledge and skills in geography education (Van Westrhenen, 1987; Bednarz, 2000; Morgan, 2006; Van der Schee, 2007). Geography should not be seen as a ready-made product that can be handed over from the teacher to the students, but as an activity in which students can engage. The problems, tasks, and settings of geography education should be realistic and relevant to students. Students should learn how to do geography: they should develop the knowledge, skills, and motivation to engage in geographic inquiry. Geographic inquiry is hereby defined as the activities which are carried out when people study (A) the characteristics and functioning of the world around us, or (B) problems in the world around us. The term ‘the world around us’ refers to the object of the discipline of geography. The world around us is characterized by the presence of natural and human phenomena in space and time (in other words, the presence of spatial patterns and processes), and by the relationships between these phenomena. The subdivision into A and B coincides with the subdivision...
between (1) ‘fundamental geography’ and (2) ‘applied geography’. Geographic inquiry with a more fundamental focus aims to provide insight into what the world around us looks like, how it is organized, how it works, and why it works that way. Geographic inquiry with a more applied focus aims to provide insight into the nature of so-called spatial problems, which can be seen as problems in which the location on earth matters. The term ‘problem’ refers to a difference between the current situation and the desired situation. The term ‘spatial’ means that the intensity of the problem, the causes of the problem, and effectiveness of solutions for the problem vary from location to location. Those geographers who conduct geographic inquiry with an applied focus investigate the nature of spatial problems (i.e. why is there a difference between the current situation and the desired situation), policy regarding spatial problems, possible solutions for these problems, and the (expected) effects of these solutions. Following the distinction made above, inquiry on how sandbars migrate over riverbeds of lowland river systems will fall under the heading ‘fundamental geographic inquiry’. Inquiry on how to make the riverbed of a specific lowland river smoother so that it allows for more freight shipping will fall under the heading ‘applied geographic inquiry’, and inquiry on the reasons for chain migration for different ethnic groups in cities will fall under the heading ‘fundamental geographic inquiry’, while reasons on how to deal with spatial segregation in a specific city will fall under the heading of ‘fundamental geographic inquiry’. So simply put, fundamental geographic inquiry mainly aims to increase our knowledge about the characteristics and functioning of the world around us, while applied geographic inquiry methods mainly aims to develop knowledge about how to improve the world around us. However, the division between fundamental geographic inquiry and applied geographic inquiry is a very artificial subdivision though, aimed to show the width of geographic inquiry. The division is not sharp but more like a continuum in reality. Furthermore, geographic inquiry with a more fundamental focus often provides insights or raises questions for geographic inquiry with a more applied focus, and vice versa.

The question is: How does geographic inquiry fit with the aims of (secondary) geography education? The possible aims of (secondary) geography education can be described by different concepts, such as geographic consciousness, geographic citizenship, and spatial thinking. Now follows a short review on how these three concepts are defined in the literature, and how geographic inquiry is included in these definitions.

Van der Vaart (2001) used the concept geographic consciousness (in Dutch: ‘geografisch besef’) to refer to “a combination of a way of thinking and a certain geographic knowledge base”. Drawing on Hoekveld (1969), Van der Vaart (2001) distinguished three key competencies of geographic consciousness: (1) a geographic world view; (2) knowledge about spatial problems; and (3) skills in using the geographic approach. The first two competencies refer to the geographic knowledge base. The third refers to the skills needed to do geography: in other words, the skills needed to engage in geographic inquiry. This key competency refers to the ability to ask geographic questions, apply geographic thinking skills, use sources of geographic information, and conduct simple geographic inquiry (KNAG, 2003; KNAG, 2008).

Another concept that is sometimes used to describe the aim of geography education is geographic citizenship. Geography education plays an important role in citizenship education (Bednarz, 2003). The International Charter on Geographic Education of the International Geographical Union (IGU) states that “geographical education is indispensable to the development of responsible and active citizens in the present and future world” (Haubrich,
Geography education aims to contribute to the development of young people as independent and critical citizens by teaching them knowledge and skills which can help them to understand and form an opinion on phenomena and processes in the world, their continent, their country, and their immediate surroundings (Van den Berg, Bos Schaart, Kolkman, Pauw, & Van der Schee et al., 2009, p.11). These ideas about the aim of geography education can be summarized with the concept ‘geographic citizenship’. Geographic knowledge and geographic thinking skills are an important part of geographic citizenship. However, geographic citizenship is broader. It includes not only geographic knowledge and geographic thinking skills, but also attitudes and communication skills needed to come into action for making our world safer, better, and more sustainable in the future. Wertheimer and Kahn (2002) distinguished three strands of citizenship: personal responsible citizenship (for society); participatory citizenship (in society); and justice-oriented citizenship (about society), and Bednarz (2003) argued that geography education could benefit the development of the three kinds of citizenship.

Much attention has been given lately to spatial thinking. The book Learning to think spatially (NRC, 2006) described the importance of spatial thinking in everyday life and in many professional and scientific disciplines, in particular geography. In the book, spatial thinking is defined as “the knowledge, skills, and habits of mind to use concepts of space and representations, and processes of reasoning to structure problems, find answers, and express solutions to these problems”. According to the NRC, three things are important in spatial thinking: concepts of space; tools of representation; and processes of reasoning. The authors of the book (p.26) argued that: “Spatial thinking comprises broad sets of interconnected competencies that can be taught and learned”. The question is however: What exactly are the ‘concepts of space’, ‘tools of representation’, and ‘processes of reasoning’? Gersmehl and Gersmehl (2006) argue that: “What is missing from this report, even though it has an entire chapter on spatial thinking skills, is a concise list of those skills and an indication of what kind of performance would constitute a desirable level of ‘mastery’ of them.”

The three concepts described above address different aspects of the possible aims of (secondary) geography education. Each definition includes references to geographic inquiry, although not explicitly. In this dissertation, ‘geographic literacy’ and ‘geographic drive’ are used as umbrella concepts for the possible aims of secondary geography education. Geographic literacy is hereby defined as a combination of a certain level of geographic subject knowledge, and a certain level of geographic inquiry skills. In this definition, geographic subject knowledge refers to knowledge about the characteristics, functioning, and problems of the world around us, as far as the location on earth matters. Geographic inquiry skills refer to the skills that are needed for studying the characteristics, functioning, and problems of the world around us, thereby taking into account that the location on earth matters. Then, the geographic drive is defined as a certain level of geographic inquiry motivation. It refers to the willingness to study the characteristics, functioning, and problems of the world around us, thereby taking into account that the location on earth matters.

So, in this dissertation, the umbrella concept ‘geographic literacy’ is used for the knowledge and skills component, and the umbrella concept ‘geographic drive’ is used for the motivation component of the aim of secondary geography education (Figure 1-1). Van Rens (2005) stresses the importance of knowledge, skills, and motivation for learning to inquire. Engaging in inquiry may stimulate progression in knowledge, skills, and motivation, but knowledge, skills, and motivation are also a precondition for engaging in inquiry.
The first knowledge component (1.1) refers to knowledge about what the world around us looks like and how it is organized (factual knowledge) and how it works and why it works that way (system knowledge). The second knowledge component (1.2) refers to knowledge about spatial problems. It includes knowledge about the nature of the spatial problem (i.e. the causes of the undesired situation), policy regarding the spatial problem, possible solutions for the problem, and the (expected) effects of these solutions. The first skills component (2.1) refers to geographic inquiry methods that are similar to methods used in fundamental geography, for example, constructing theories and testing theories. The second skills component (2.2) refers to geographic inquiry methods that are similar to methods used in applied geography, for example, formulating potential measure and evaluating the effects of those measures. The third components (3.1 and 3.2) refer to the willingness to engage in geographic inquiry. According to the expectancy-value theory (Fishbein & Ajzen, 1975), people’s motivation for doing something is the product of the value attributed to the goal, and the expected amount of effort needed to achieve the goal. People can engage in geographic inquiry for different reasons. In fundamental geography, people engage in geographic inquiry out of curiosity: they want to learn about the characteristics and functioning of the world around us. In applied geography, people engage in geographic inquiry because of compassion for other people or the environment, because of fear for calamities, for pursuit of profit, or for practical reasons. The importance of motivation should not be overlooked, and geography education should also aim to stimulate progression in students’ motivation. Students should be willing to apply the knowledge and skills they have gained in school in their off-school and post-school lives. They should start asking questions when they notice something strange and be willing to answer such questions. They should be willing to engage in geographic inquiry by themselves.

The descriptions of the umbrella concepts ‘geographic literacy’ and ‘geographic drive’ contain the addendums “as far as the location on earth matters” and “thereby taking into account that the location on earth matters”. These addendums connect geographic literacy and geographic drive to geographic awareness, which is hereby defined as, based on ideas by Trimp (2010), the awareness that the location on earth matters. In this definition, ‘location’ is used as a
shorthand. Being geographically aware does not mean being aware that the coordinates or longitude/latitude matter. Instead, it means being aware that the values of properties are different from location to location, that places and regions function in spatial networks, that there are flows of people, products, and money between places and regions, and that the situation of places and regions in respect to other places and regions matters. Geographic awareness also includes the awareness that the perception of locations varies from person to person.

Geographic awareness is more elusive than geographic literacy and geographic drive. The umbrella concept is more difficult to operationalize: more difficult to turn into educational standards; more difficult to turn into tasks; and more difficult to assess. This dissertation therefore focuses on geographic literacy and geographic drive from now on. However, it should be noted that although stimulating progression in students’ geographic literacy and students’ geographic drive is seen as the main aim of secondary geography education in this dissertation, it is not seen as the exclusive aim. Progression in geographic literacy and in geographic drive is connected to progression in more domain-general skills, such as critical thinking skills (e.g. skills in distinguishing between facts and opinions). Such skills are needed in order to engage in geographic inquiry. However, they are not domain-specific. In this dissertation, communication skills are seen as part of geographic inquiry skills as long as they focus on presenting and reporting about the results of geographic inquiry. Using maps to communicate about the characteristics, functioning, and problems of the world around us in general is not considered to be part of geographic inquiry, although it is an important aspect of ‘doing geography’.

Now that we have a definition of the umbrella concepts ‘geographic literacy’ and ‘geographic drive’, we are ready to have a look at the kind of education which can stimulate progression in students’ geographic literacy and geographic drive. The next sub-section explains what is understood by ‘inquiry-based education’ in this dissertation.

1.1.2 Inquiry-based education

In the past few decades, more significance has been attached to the development of inquiry skills (e.g. Kent, 2006). Inquiry-based education is a kind of education which aims to stimulate progression in students’ disciplinary subject knowledge, disciplinary inquiry skills, and self-regulation skills by engaging in activities ‘like researchers do’ (Van Joolingen, De Jong, Lazonder, Savelbergh, & Manlove, 2005). Inquiry projects, such as the one described in the Preface, are a typical form of inquiry-based education.

Inquiry-based education connects to constructivist learning theories. According to these learning theories, students learn best in collaborative learning environments in which students learn by working on problems in authentic contexts (Jonassen, Campbell, & Davidson, 1994; Hmelo-Silver, Duncan, & Chinn, 2006; Guthrie, McRae, Coddington, Klauda, & Wigfield et al., 2004). Constructivism emphasizes learning by engaging students in minds-on and hands-on inquiry-based activities (Wilson, 1994). Students should be active learners, and teachers should be coaches rather than instructors. Knowledge is not seen as a fixed commodity that can be delivered from teachers to students. Instead, the central idea is that learning processes are most effective when students actively make sense of the subject matter themselves. Constructivism has two main strands: cognitive constructivism and social constructivism. Cognitive constructivism focuses on cognitive thinking skills and learning strategies, and underlines the
role of the individual student in the learning (Martin & Sugerman, 1997). According to cognitive constructivism, learners construct their own knowledge through assimilation and accommodation. Assimilation is a process in which new knowledge and skills acquired from experience are incorporated into existing cognitive structures, while accommodation is a process in which the existing cognitive structures are modified and adapted in response to actual experience. Social constructivism focuses on the learning that takes place through interaction between students (Van Oers, Waldekker, Elbers, & Van der Veer, 2008). According to Vygotskian theories, social processes are considered to be very important in learning (Gasper, 1999). Students should have the possibility to negotiate ideas and to reflect on their own and each other’s thoughts.

Geographic inquiry projects can be scored on a scale with open inquiry on one side to guided inquiry on the other side. In open inquiry, students are completely free to find out what they want to investigate and how they want to investigate this. In guided inquiry, students engaged in well-planned and well-coached inquiry activities. The handouts and the teacher tell the students how to conduct the investigations (Kuhlthau, Maniotes, & CKaspari, 2007).

New interactive technologies make it easier to design geographic inquiry projects (NRC, 1999; Hill & Solem, 1999). GIS is an example of such technologies. The next sub-section explains what is understood with ‘GIS’ in this dissertation.

1.1.3 GIS

1.1.3.1 Towards a definition for GIS from the educational point of view

The term ‘GIS’ was used for the first time in 1963 by Roger Tomlinson (Tomlinson, 1998), as the abbreviation of ‘Geographic Information System’. In that time, GIS was seen as a combination of hardware, software, and digital geodata, which is data about the world around us with one or more geospatial references. Burrough (1986, p.6) defined GIS as “a collection of tools for collecting, storing, and visualizing spatial data about the world around us”. Since then, hardware capacities have increased, the software has become more powerful and user-friendly, and digital geodata have become more plentiful. In addition, the number of problems that GIS is able to address has expanded dramatically (DiBiase, DeMers, Johnson, Kemp, & Luck et al., 2006). Professional geographers adopted GIS enthusiastically, seeing it as an effective substitute for paper maps (Goodchild, 1988). GIS and other geospatial technologies are now widely used in business (e.g. in asset management, marketing, logistics, agriculture, and engineering), government (e.g. in traffic management, spatial planning, disaster management, environmental impact assessment, military logistics, and crime fighting), and science (e.g. in climatology and archaeology) (Scholten, Van Manen, & Van der Velden, 2009). The early 21st century saw the emergence of new technologies in which GIS is integrated with the Internet (e.g. Google Maps) or other geospatial technologies such as GPS (e.g. car navigation systems). In this way, GIS became available for the public at large. Since then, the use of these technologies in daily life has increased significantly. Nowadays, many people use geospatial technologies to inform themselves about spatial issues in their neighbourhood, plan a route, etc. (DiBiase et al., 2006). A more recent trend is the integration of GIS and social media.
Definitions of GIS in the educational literature are often comparable to definitions of GIS in the geo-ICT literature. For example, NRC (2006) defined GIS as “integrated software systems for the handling of geospatial information: for its acquisition, editing, storage, transformation, analysis, visualization, and indeed, virtually any task that one might want to perform with this particular information type.” From the context of secondary geography education, GIS is usually seen as a specific kind of software for teaching and learning. In this dissertation, GIS is therefore defined as a type of user-controlled interactive software for teaching and learning which offers tools for visualizing, creating, manipulating, reading, querying, summarizing, analysing, and presenting digital geodata in digital geospatial representations. This definition combines the kind of tools that the software offers (‘tools for visualizing, creating, manipulating, reading, querying, summarizing, analysing, and presenting digital geodata’) with a goal (‘teaching and learning’). It also contains general characteristics of the software (‘user-control’ and ‘interactivity’). The terms ‘geodata’ and ‘geospatial representations’ will be explained in Chapter 5.

GIS can be much more than database or spreadsheet software, as it offers the possibility to work with geodata in geospatial representations. Myrthe (see the Preface) used GIS to construct maps of the distribution of playgrounds and the distribution of children. GIS can, however, also be much more than mapping software, as it offers tools for geodata querying and analysis. Myrthe could have used GIS to select the playgrounds and the children in the two neighbourhoods and let GIS count the total number of playgrounds children and total number of children in those neighbourhoods, in order to determine whether the distribution of playgrounds was fair. However, she did not do so. Instead, Myrthe tried to answer her inquiry questions by analysing the maps visually.

GIS is applied in many educational disciplines, such as biology education, history education, and economics education. However, its main field of application is geography education, and this dissertation focuses on the use of GIS for teaching and learning geography at the level of secondary education.

1.1.3.2 Different types of GIS software

There are many different types of GIS software, and they can be classified in different ways. First, GIS software can be classified on the basis of how they are offered to the user, and be divided into: (1) Desktop GIS; (2) WebGIS; and (3) Mobile GIS. Desktop GIS software requires installation on the computer or network; WebGIS software is offered via the Internet; and Mobile GIS software is software for PDA’s. Second, GIS software can be classified on the basis of the number of tools they offer to the user into, and be divided into: (1) full GIS; and (2) limited GIS. Full GIS software, also called high-end GIS software, offer extensive sets of tools for creating, manipulating, reading, querying, summarizing, analysing, and managing geodata. Limited GIS software, also called low-end GIS software, offer only a few tools. They usually offer zoom tools and an identity tool, and the possibility to add map layers (from a database) and switch those map layers on and off. They do not offer tools for geodata querying and geodata analysis, and only allow the user to query and analyse map layers visually. The difference implies that users of limited GIS software are usually only consumers of information, while users of full GIS software are also actively working with the geodata.