Education through Maps

The Challenges of Knowing and Understanding the World

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Abstract

The overall purpose of this thesis is to study, in relation to geography education and with a historical perspective, the challenges of knowing and understanding the world. The cases are all from Sweden. In the first paper, educational ideas in the nineteenth and early twentieth centuries are studied, and the results indicate that some of the previously criticised educational ideas that were perceived as resulting from the ideas of nineteenth century regional geography in fact can be observed in earlier centuries and were criticised during the nineteenth century. In the second paper, school children's ability to locate geographical names on outline maps is compared with children's ability to complete the same task 45 years earlier. A total of 1,124 students were included in the latter study, and the results were compared with those from a study of 1,200 students from the same town conducted in 1968. The results raise questions regarding the picture of the continuous decline in children's school results and show, for example, that children today are better at locating continents on a world map. The final paper identifies a new aspect of map reading difficulties. These difficulties in map reading are increasingly important in our global society, i.e., how the edges of the world map cohere. The paper shows that many map readers, children and adults, respond according to the idea of linear peripheral continuity, which indicates that the proposed continuation is along the straight line that continues tangentially to the original route when it crosses the edge. In general, this understanding leads to incorrect interpretations of the continuation of world maps.

Key words: cartography, geography education, map projections, maps, place location knowledge, world maps, Sweden

List of Papers

Paper I

Hennerdal, P. (2015). Educational ideas in geography education in Sweden during the nineteenth and early twentieth centuries: The relationship between maps and texts. *International Research in Geographical and Environmental Education 24*(3), 258–272. doi:10.1080/10382046.2015.1034460

Paper II

Hennerdal, P. (forthcoming). Changes in place location knowledge: A follow-up study in Arvika, Sweden, 1968 and 2013. *International Research in Geographical and Environmental Education.*

Paper III

Hennerdal, P. (2015). Beyond the periphery: Child and adult understanding of world map continuity. *Annals of the Association of American Geographers 105*(4), 773–790. doi:10.1080/00045608.2015.1022091

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Stockholm, July 2015
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1. Introduction

The academic field of geography is essentially the study of the world, both nature and society. Geography education in elementary schools to some extent concerns teaching students about this academic field. However, geography education also concerns helping students develop their worldview (Tani 2011, 35). In fact, the idea that geography education helps students develop their worldview existed long before it existed an academic field of geography (Molin 2006, 23 & 37). Worldview can be divided into two different aspects: someone's image of the world, *Weltbild*, and someone's philosophy of life, attitudes or *Weltanschauung*. Although both of these aspects are important in geography education, the component that connects geography education with someone's philosophy of life has varied over time in Sweden, according to studies by Olsson (1986, 64–65), and has developed from nationalism to global solidarity since the end of the nineteenth century. One's image of the world is often considered to be linked to a symbolic representation of geography such as a map, and the concept appears to overlap to some extent with the concept of mental maps (Rinschede 2007, 88). The types of knowledge, skills and values that should be taught in geography education have been debated for a long time (Lidstone 2003). This thesis focuses on the component of geography education that attempts to help students develop their image of the world.

This thesis is a compilation thesis comprising a comprehensive summary and three papers. The purposes of the comprehensive summary are to present a background for the three papers, discuss methodologies, and present a summarising discussion of the thesis. The three papers relate to quite separate fields. The first paper is in the field of educational history and reviews previous statements regarding geography education in Sweden from the past (e.g., Olsson 1986), relating geography education to historical sources and to American educational history (e.g., Dryer 1924). The second paper is in the field of empirical studies of educational achievements regarding place location knowledge. The background comprises previous studies of this type, large international studies (e.g., Gallup Organization 1988) and comparisons over time (e.g., Bein, Hayes, & Jones 2009). The third paper is in the field of empirical cartographic studies. Except for previous cartographic studies (e.g., Battersby & Montello 2009), the background also comprises the field of cognitive psychology (e.g., Piaget & Inhelder 1956; Atit, Shipley, & Tikoff 2013).

Because the fields related to each of the three papers are separated in this manner, no joint international research background is presented in this comprehensive summary. Instead, the background is presented in each paper. The background presented in this comprehensive summary focuses on geography educational research from a Swedish perspective and on presenting a background of map projections in preparation for reading Paper III.

1.1 Previous Research on Geography Education in Sweden

> The field of geography education is sadly lacking in empirical data that might inform and underpin decisions about standard setting, curriculum design, materials development, teaching strategies, and assessment procedures (Downs 1994, 57).

This quote is from the beginning of the article *The need for research in geography education: It would be nice to have some data* by Downs (1994). Ten years later, Bednarz and Bednarz (2004) noted that research in geography education had been changing for the better in the United States. In Sweden, Bladh and Molin (2012, 59) wrote in 2011 (the year I started this thesis) that "Geography didactics is an unexplored field in Sweden" (translation by author), and Johnsson Harrie (2011, 5–7) presented a similar description in her review of the research field.

Discussions in Sweden regarding the practices of geography education had been occurring long before 2011, both by teachers and in academia, particularly after the journal *Geografiska notiser* began publication in 1943 by the Swedish Association of Geography Teachers.

In addition, research regarding geography education had been conducted in Sweden prior to 2011, and both licentiate and doctoral dissertations had been written in the field (e.g., Peterson 1971; Olsson 1986; Wennberg 1990; Blom Mondlane & Jansund 2003; Molin 2006). Ottosson (1987) also wrote a dissertation on map reading in an educational context but outside the field of geography education.

Since 2011, an increasing number of licentiate and doctoral dissertations in Sweden have contributed to the research-based knowledge regarding geography education (e.g., Grahn 2011; Torbjörnsson 2011; Arrhenius 2013; Nerdal 2014; Pettersson 2014; Torbjörnsson 2014). Even considering those publications, the Swedish Research Council (2015, 36) concluded in 2015 that only a few research-based studies in the field of geography didactics existed in Sweden and that senior researchers were scarce.

One of the most dominating themes in the field of geography educational research in recent years concerns teaching and learning with regard to environmental issues and sustainable development (e.g., Grahn 2011; Torbjörnsson 2011, Nerdal 2014; Pettersson 2014; Torbjörnsson 2014).

These studies are linked to a broader multidisciplinary field because these issues are not only taught in geography. These issues are also frequently associated with developing attitudes and with the academic field of geography rather than with an image of the world.

Other themes of studies conducted on geography education in Sweden include curriculum reforms in which a major theme is to increase the inclusion of the academic field of geography into geography education (Wennberg 1990; Molin & Grubbström 2013), the view of culture in textbooks (Olsson 1986), the development of a method so that student projects move geography education closer to geographical research (Blom Mondlane & Jansund 2003), teachers' choices in filling the curriculum space (Molin 2006), and manners of learning whilst using computer-based animations in geography education (Arrhenius 2013).

If one looks behind the general shortage of research regarding geography education in Sweden, we can see that amongst the available studies, research regarding developing the image of the world in geography education is even scarcer. The studies that exist are Olsson's (1986) dissertation in which she identifies what may be perceived as different images of the world and attitudes in geography textbooks and the dissertation by Peterson (1971), who studied place location knowledge and map-reading abilities amongst school children. Studies such as Ehrlén's (2007) may be perceived as a component of this field although her study of how children age six to nine view the earth is outside the context of geography education.

1.2 Aim

> *The overall aim of this thesis is to study, in relation to geography education and with a historical perspective, the challenges of knowing and understanding the world.*

The cases in this study are all from Sweden. The need to develop a geographical frame of reference to which we can add the locations we learn about and spatially relate the objects and events we think about—to enable geographical reasoning—is often expressed when discussing geography education (e.g., Skolverket 2011, 159). The level of detail of geographical locations required for such an impression of the world is, however, disputed and has been a source of debate for many years. Some experts argue, for example, that there is only a need to have a general image of the world whilst others argue for more extensive place location knowledge (see examples in Paper I).

What renders one's image of the world can be used as a geographical frame of reference enabling geographical reasoning. For example,

chronological closeness and relative order are essential when thinking about history—to be able to think geographically, perceiving the spatial closeness of things is essential. Therefore, an image of the world comprising geographical localisations as separate entities rather than a spatial map can be perceived as defective. There has been extensive criticism of geography education in the nineteenth and early twentieth centuries in Sweden because such education communicated an image of the world comprising separate regional containers (see examples in Paper I). This criticism was based on the textbooks used in geography education during that time because the books do contain many text-based descriptions of regions. In previous studies of that time, the role of maps and visual pedagogy in relation to the textbooks has been largely absent when describing geography education. Therefore, the first paper has the following aim:

> *Describe the educational ideas of geography education during the nineteenth and early twentieth centuries in Sweden with respect to the relationship between maps and textbooks.*

Utilising text analysis, the first paper examines educational ideas regarding the types of images of the world that educators communicated during the nineteenth and early twentieth centuries.

The second and third papers measure two different aspects of students' images of the world. Previous Swedish studies of geography education have focused on measurements, e.g., national tests in geography that measure student achievement (Molin & Grubbström 2013), the article by Torbjörnsson, Molin, and Karlberg (2011) in which measurements are developed to measure students' attitudes towards environmental issues, and the previously mentioned study by Peterson (1971), in which there is also a clear focus on measurements. That second study includes measurements of map reading skills and children's images of the world in the form of place location knowledge. Place location knowledge is the focus of the second paper in this thesis, whose purpose is to

> *Analyse how children's place location knowledge evolves with societal change.*

In the study, outline maps are used to determine school children's ability to locate geographical names on maps. The term "place location knowledge" refers here to the ability to identify a correct location on a map associated with a geographical name. The contribution of the paper is that it not only describes school children's current ability to locate specific countries, oceans, regions, and continents on maps but also contrasts these results with the above mentioned study conducted 45 years earlier by Peterson (1971). As a component of the societal change in Sweden since the 1960s, contact

with the surrounding world has increased. This increased contact has resulted from the extensive flow of news worldwide and the increasing amount of travel abroad. Therefore, covariance between the ability to locate place names and variables such as travel experiences, media consumption, and map-reading habits are examined in the present study, which was conducted in 2013.

In addition to the ability to locate geographical locations on a flat map, which is relevant to a person's image of the world as a geographical frame of reference, one should be able to extract geographical closeness from that ability. An image or a map is spatial in essence and resembles the geography it depicts. A greater distance on the image or map often represents a greater distance in reality. Although this is generally true, it is not true for the sections of the world map that lie close to the periphery of the map, which could cause trouble. The aim of the third paper is therefore to

> *Analyse how map readers understand the peripheral continuity of world maps.*

In this paper, I attempt to determine whether there is a naïve understanding of the peripheral continuity of world maps that differs from the actual peripheral continuity. Here naïve understanding indicates that the understanding or reasoning necessary to resolve a task is not sufficiently developed to reach a correct solution; the term applies only to the specific task and implies nothing about the respondent in general. Geometry and map projections are central in this third paper, and Chapter 3 will present a background of these topics. First, however, a background of topics such as geography education in Sweden and regional geography are presented in Chapter 2.

2. Background

2.1 Objectives in Swedish National Curricula to Help Students Develop their Image of the World

Because of the Swedish focus on geography education in this thesis, it is necessary to understand the national curricula in Sweden with regard to helping students develop their image of the world. The focus of this short review of the national curricula is only on the development of the image of the world and does not therefore claim to exhaustively examine all aspects of the teaching of geography. Additional aspects of geography education are also described in the curricula but not presented in this review.

Elementary education became compulsory in Sweden in 1842. In the Swedish education system, the topic of geography was only taught to older students to contribute to the students' image of the world (in Swedish, *världsbild*). The younger students were exposed to visual experience-based teaching (in Swedish, *åskådningsövningar* and in German, *Anschauungs-pädagogik*), aimed, according to the national curricula of the late nineteenth century, to contribute with

> […] depictions of the home area, of which the most common geographic objects, such as height, plain, lake, river, island, strait, etc., are presented for the children's viewing [and shown on the map]. (Normalplan 1878, 11; Normalplan 1889, 11; Normalplan 1900, 13, translation by author. The section in square brackets regarding the map was not in the source from 1878).

In 1919, visual, experience-based teaching was removed from the national curriculum. However, the new topic, *hembygdsundervisning* (similar to the topic local history teaching or home region instruction), was introduced to teach the children to make observations regarding their surroundings, connect those observations to descriptions and narratives, and broaden their awareness of the local community. Other goals were to provide basic education in geography, nature studies and even history (kungl. Folkskolöverstyrelsen 1919, 77–78). The national curriculum from 1955 contains nearly the same goal:

> Help the students to orient themselves in their surroundings and give them knowledge regarding things and circumstances that interest them during their first school years. Lessons also aim to develop the ability of observation,

> organise and expand their awareness of their surroundings, promote their knowledge of the local community and provide a basic education in geography, nature studies, history and civics (kungl. Skolöverstyrelsen 1955, 90–91, translation by author).

Although there was mention of the globe in the third grade, the teaching of geography in *hembygdsundervisning* up to 1955 was quite local (kungl. Skolöverstyrelsen 1955, 94). In the curricula from the 1960s, however, events from other portions of the world were included (kungl. Skolöverstyrelsen 1962, 231; Skolöverstyrelsen 1969b, 14–22). By 1980, the topic had become merged with other subjects to become a new subject: *samhällsorienterande ämnen* (civic orientation). And amongst the core contents were "locations and distances in the local area and home region, map concepts" and "regional geography: the local area, the home region, Sweden and the world. To find on the map" (Skolöverstyrelsen 1980, 123, translation by author). In the curriculum from 1994, one of the goals in geography for the fifth grade was to have relevant place location knowledge (Utbildningsdepartementet 1994, 20); and in the present national curriculum, elements such as the globe, the locations of continents and oceans, and names and locations of countries and places important for the students to know are components of the core content for the three first years (Skolverket 2011, 160).

Thus, the national curriculum in Sweden concerns helping students develop their image of the world during the first years of elementary education. Since elementary education became compulsory in the nineteenth century, there has always been a curriculum seeking to help students develop an image of their surroundings. This topic originates in visual, experience-based teaching (see section 2.2 Visual Pedagogy). Since the end of the 1960s, the definition of the students' surroundings has broadened from the local to include the rest of the world.

For older children that have studied at least around three years in elementary school, geography has, according to all national curricula (except from 1980), been the topic meant to contribute to the students' image of the world. In the national curriculum in the nineteenth century and the beginning of the twentieth century, the following was mandated to be included in geography education:

> The main features of physical geography, the geography of the native country in more detail, the rest of the civilised countries in a briefer overview (Normalplan 1878, 23; Normalplan 1889, 29; Normalplan 1900, 34, translation by author).

The national curricula in geography education from 1919, 1955, 1962, and 1969 consistently seeks to give students knowledge and an orientation of geographical features regarding both nature and society for Sweden and the

Nordic countries and also an orientation of the earth in general (kungl. Folkskolöverstyrelsen 1919, 87; kungl. Skolöverstyrelsen 1955, 108; kungl. Skolöverstyrelsen 1962, 263; Skolöverstyrelsen 1969a, 186). In the curriculum from 1980, geography is not a discrete subject; instead, geographical content is a component of civic orientation. The core contents associated with helping students develop their image of the world are here labelled "regional geography" and include "the image of the world, continents and oceans. A selection of areas in Sweden, Scandinavia and Europe and areas of other continents" (Skolöverstyrelsen 1980, 123, translation by author).

A goal of geography education in the curricula from 1994 and 2011 was to develop a frame of reference regarding different places and areas and their locations (Utbildningsdepartementet 1994, 19; Skolverket 2011, 159).

Thus, geography education is clearly more than helping the students develop an image of the world. Other aspects of geography education are also expressed in the curricula. However, when studying what the curricula includes regarding helping students develop their image of the world, we can see that this component of geography education has been promoted in every national curriculum since elementary school became compulsory in the nineteenth century. In addition, we can see that the focus on Sweden diminishes with time and moves towards helping students develop a more global geographical frame of reference.

2.2 Visual Pedagogy

It is sometimes argued that we must recognise the role of images and not always see text as superior (e.g., Mörner 2003). A term used in educational research when recognising the role of images and other modes of communication to expand the concept of literacy into more than simply reading text is *multimodality* (e.g., Selander & Kress 2010). Although the term is quite new, images in educational settings have been utilised for a long time, and the status of images in relation to text has changed throughout the history of Swedish pedagogy (Jonsson 2010).

Famous early contributors to the field of visual pedagogy are Comenius (1592–1670), who published *Orbis Pictus*, one of the earliest illustrated books for children, and Pestalozzi (1746–1827), who developed principles of education based on visualisation and experiences. Pestalozzi believed that all education should stem from the visual[1] and was referenced in Swedish pedagogical texts around the turn of the century (Jonsson 2006, 56).

[1] The word "visual" refers here to the Swedish word *åskådning* (German: *Anschauung*) and indicates more than that can be seen with one's eyes (Swedish: *skåda*). The term can also indicate rendering something understandable (i.e., "I see!") (Ekström 2000, 140).

In the nineteenth century, visual, experience-based teaching (in Swedish, *åskådningsundervisning* or *åskådningsövningar*) was introduced as a discrete subject in Swedish schools and in 1919 was replaced with the new subject, home region instruction (in Swedish, *hembygdsundervisning*), which contained essentially identical contents as visual, experience-based teaching. In the national curriculum from 1919, visual pedagogy was also emphasised in geography education (Jonsson 2006, 97 & 109–110).

When describing the history of geography education in Sweden, the influences from visual pedagogy are seldom the focus, and when influences from persons such as Comenius and Pestalozzi are mentioned, it is not in relation to visual pedagogy but on the order of geographical teaching. In other words, the question is whether the teaching should begin with the neighbourhood and expand from there to the rest of the world or the inverse (Wennberg 1990, 87–88).

2.3 Regional Geography

Ptolemy's classical work *Geographia* ("earth description") from the second century included a book with instructions regarding how to measure coordinates and project them onto a map. The subsequent books of this work were mostly descriptions of different known locations. Originally, there were also maps; however, they have disappeared (Berggren & Jones 2001).

For a long period of time, the field of geography primarily involved those elements: to map, navigate, and describe locations. Early geography included the work of explorers who travelled the globe, drew maps, and wrote descriptions of the places they visited (Johnston & Sidaway 2004, 41). The work of Humboldt and Ritter in nineteenth century Germany is often considered a turning point in the geographic tradition. Those authors rendered geography more scientific by identifying spatial regularities in their findings. This type of geography has been called regional geography and is referred to as nature deterministic because the causal relations between nature and human activities in a region were central to this philosophy (Livingstone 1992, 6).

A French version of regional geography was also introduced that was slightly less nature-deterministic and that recognised the possibility that society could modify nature (Livingstone 1992, 267). The region was the unit of study in regional geography, and both nature and society were included. Although encyclopaedia-like descriptions of places, including both nature and society, had been produced earlier, in regional geography, Hettner created a more systematic approach with his *Länderkunde Schema*, in which causal conclusions were drawn from the relation between nature and society within a given region (Livingstone 1992, 263–264).

2.4 Spatial Abilities

One's image of the world is associated with that person's spatial abilities. Studies have shown how conceptual knowledge regarding the earth develops during childhood (e.g., Nussbaum & Novak 1976; Vosniadou & Brewer 1992; Ehrlén 2007). Those studies investigated the difficulty many children have in mentally combining the concepts of a round earth in space and the flat surroundings they experience.

The cognitive development in childhood that affects spatial abilities has also been examined by Piaget and Inhelder (1956) in *The Child's Conception of Space*. In this book, the authors present three stages of spatial conception the child experiences during childhood. The three stages are topological, projective, and Euclidean space. The Piagetian idea regarding stages of spatial understanding has, however, been questioned by many scholars, specifically regarding the ages at which the different stages occur, whether the stages of spatial understanding can be clearly separated, and whether understanding is inherent or developed by interactions between people and the environment (Blaut 1997, 172).

In addition to changes in how the conceptual knowledge about the earth tends to develop with age, there are also individual differences regarding the ability to grasp geographical patterns and think spatially.

In the third paper of this thesis, the primary focus is to model how map readers *generally* respond to the periphery of world maps; individual factors are therefore not examined. However, a common manner of testing individual spatial abilities is to observe how well subjects solve mental transformation tasks such as mental rotation and mental folding (see Figure 1).

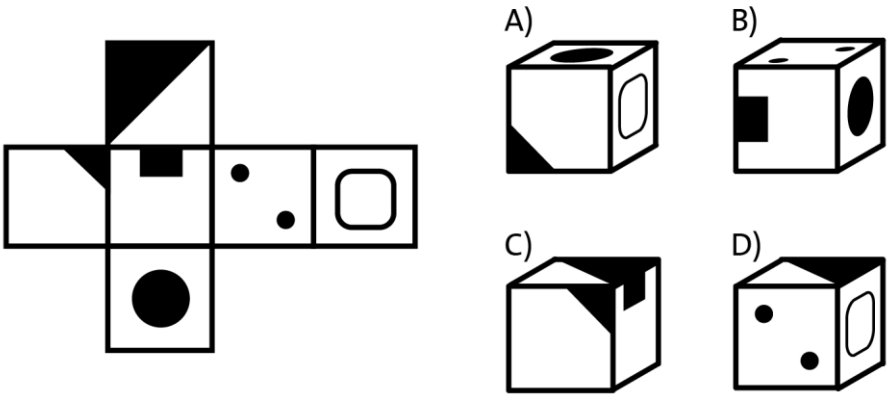


Figure 1. A mental (paper) folding exercise in which the respondent is requested to pick the cube that cannot represent the unfolded cube when folded together.

3. Geometry and Map Projections

Maps are representations of geographical spaces. Geometry is a manner of describing and measuring spaces and is used for mapping geographical spaces. A map projection is useful when creating a map and refers to the manner in which a spherical surface is represented on a plane. This chapter presents an introduction to map projections, the field of geometry, and its relation to geography. The chapter also presents explanations of the terms Euclidean and non-Euclidean geometry that are used in this thesis.

3.1 Geometry

3.1.1 The ancient origin of geometry and its relation to geography

Both geometry (from the Greek γεωμετρία, "earth measurement") and geography (from the Greek γεωγραφία, "earth description") have developed from practices that involved mapping (and navigating) the spatial relations of features on the earth's surface.

Ptolemy (ca. A.D. 90–168) described in *Geographia* how to map distant spatial locations using a global spherical coordinate system. Maps of the known world had also been constructed previously by Eratosthenes (ca. 275–194 B.C.), using a global system of parallels and meridians (latitudes and longitudes). However, Ptolemy developed the map projection further in his book collection (Snyder 1993, 1–5).

Geometry also originates from the practice of mapping spatial relations—but often for closer distances than were used in ancient geography. Geometry was developed much earlier than geography and comprised a set of rules to describe relations between, for example, distances, areas, and volumes of geometrical objects such as triangles and pyramids. Those rules were early used in Egypt and Mesopotamia by architects and land surveyors (Katz 2004, 1–16).

In ancient Greece, pure mathematical geometry was separated from the more practical uses of the subject. The distinct subject covering practical measurements was called geodesy (Heath 1981, 16).

3.1.2 Euclidean geometry and Cartesian coordinates

In *Elements* (ca. 300 B. C.), the mathematician Euclid summarised many of the known geometrical rules. In addition to creating a comprehensive summary of previously known geometrical rules, Euclid introduced a new level of mathematical rigour by beginning his books with definitions and postulates (axioms). The geometrical rules of his 13 books were mathematically proven using those definitions and postulates. Five of his postulates remain quite well known (Heath 1956, 154–155):

1. [One can] draw a straight line from any point to any point.
2. [One can] produce a finite straight line continuously in a straight line.
3. [One can] describe a circle with any centre and distance.
4. [A]ll right angles are equal to one another.
5. [I]f a straight line falling on two straight lines make the interior angles on the same less than two right angles, the two straight lines, if produced indefinitely, meet on that side on which are the angles less than the two right angles.

Those five postulates define what we call Euclidean geometry, to which we are referring when discussing how different distances, angles, and areas relate to one another on a plane. In Euclidean geometry, the sum of the angles of a triangle is, for example, always 180°, and two parallel lines never meet.

Many mathematicians have contributed to geometry since Euclid. Descartes (1596–1650) developed analytical geometry and introduced the term real number ($\mathbb{R}$) for numbers that compose the continuous number line (see Figure 2).

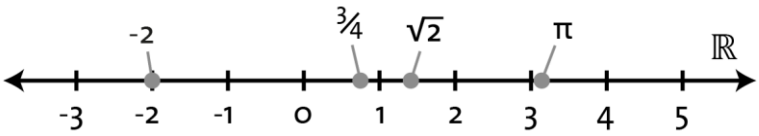


Figure 2. The real numbers compose the number line. Examples of rational and irrational numbers along the number line.

Those real numbers can be used as coordinates that describe positions along a line. However, Descartes also introduced a second dimension ($\mathbb{R}^2$), in which pairs of real numbers may be used as coordinates to describe a position on a plane. This manner of describing locations on a plane as distances along orthogonal directions from an origin is called a Cartesian coordinate system (see Figure 3).

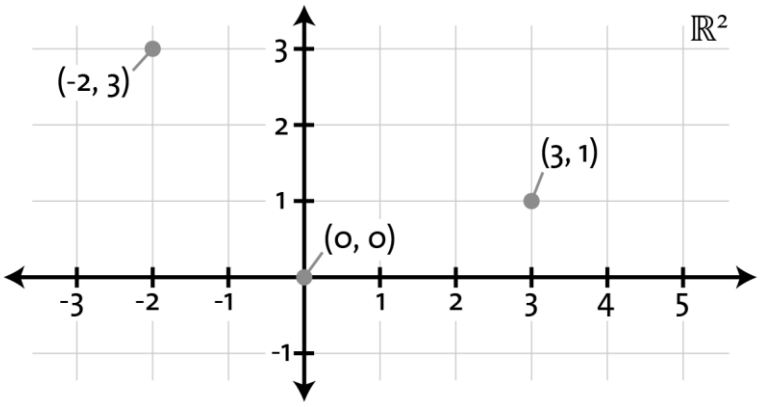


Figure 3. Two-dimensional Cartesian coordinate system.

One more real number can be added to the coordinate to create a three-dimensional space ($\mathbb{R}^3$), and more dimensions can be created in the same manner. However, dimensions greater than the third are often considered difficult to visualise. All possible spaces created in this manner ($\mathbb{R}^n$) are called Euclidean spaces. The Euclidean spaces $\mathbb{R}^2$ and $\mathbb{R}^3$ largely correspond to how we experience the world around us in our everyday lives. Therefore[2], we tend to develop a spatial understanding based on Euclidean geometry (see section 2.4 Spatial Abilities). Descartes' Cartesian coordinate system enables the plotting of graphs that represent mathematical functions, which creates the foundation for constructing map projections using analytical mathematics. Descartes also introduced the use of algebra to describe geometry (analytical geometry) (van Maanen 2003, 42).

3.1.3 Non-Euclidean and spherical geometry

The fifth of Euclid's postulates (also known as the parallel postulate) has received a great deal of attention. Discussion of the fifth postulate resulted in some nineteenth century scholars beginning to investigate what would occur in geometry if the fifth postulate were false (e.g., Lobachevski 1829; Bolyai 1832). This assumption led to the creation of something known as non-Euclidean geometry. There are two types of non-Euclidean geometry. Elliptic geometry follows the assumption that all possible lines meet (in Euclidean geometry, parallel lines do not), and in hyperbolic geometry, there are at least two possible lines passing each point that never meet a specific line (see Figure 4).

[2] The reason is disputed. Some scholars argue that Euclidean understanding does not develop from experiences but is something inherent (Blaut 1997, 172). This is further discussed in section 2.4 Spatial Abilities.

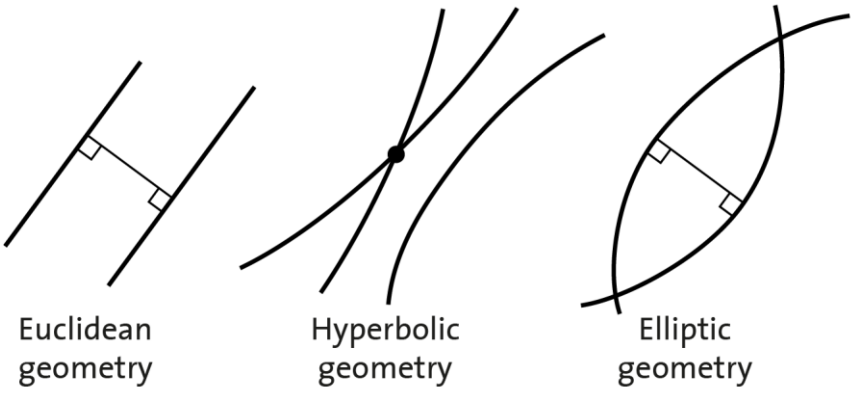


Figure 4. Visualisations of the parallel postulate for Euclidean geometry and the variations for hyperbolic and elliptic geometry.

When introduced, non-Euclidean geometry was sometimes considered difficult or impossible to understand, an opinion that has also been expressed in literature. For example in Dostoevsky's *The Brothers Karamazov* (1880), Ivan explains his thoughts regarding non-Euclidian geometry.

> But you must note this: if God exists and if He really did create the world, then, as we all know, He created it according to the geometry of Euclid and the human mind with the conception of only three dimensions in space. Yet there have been and still are geometricians and philosophers, and even some of the most distinguished, who doubt whether the whole universe, or to speak more widely, the whole of being, was only created in Euclid's geometry; they even dare to dream that two parallel lines, which according to Euclid can never meet on earth, may meet somewhere in infinity. I have come to the conclusion that, since I can't understand even that, I can't expect to understand about God. I acknowledge humbly that I have no faculty for settling such questions, I have a Euclidian earthly mind, and how could I solve problems that are not of this world? (Dostoevsky, Book V, Chapter 3).

It is, however, possible to understand non-Euclidean geometry. In fact, elliptic geometry could perhaps be considered even more earthly than Euclidean geometry because spherical geometry (which describes the geometry of the earth's surface if the earth is considered spherical) is one type of elliptic geometry.

Spherical geometry had been around for approximately two thousand years before it was categorised as non-Euclidean. In applications for astronomy, mapping, and navigation, spherical geometry has existed since ancient times, and one of the early contributors to this field was Hipparchus (ca. 190–120 B.C.) (Snyder 1993, 4–5).

In Euclidean geometry, the shortest distance between two points is along the line that intersects those points. In spherical geometry, however, the shortest distance between points on a spherical surface is along the great

circle that intersects both points. A great circle is the intersection of the surface of a sphere and a plane that intersects the centre of the sphere. Great circles are the lines of spherical geometry, and because two different great circles always meet, spherical geometry is considered a type of elliptic geometry. In Figure 5, we can see how three great circles compose a spherical triangle. In elliptical geometry, the triangular sum is always greater than 180°. In hyperbolic geometry, conversely, the triangular sum is always less than 180°. And in Euclidean geometry, which we know from flat surfaces, the triangular sum is always exactly 180°.

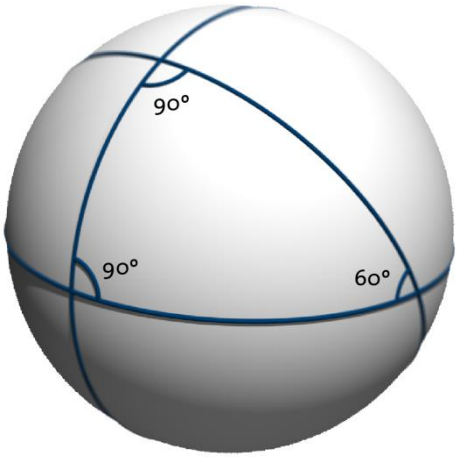


Figure 5. In spherical geometry (a non-Euclidean geometry categorised as elliptic geometry), great circles are the shortest distances between points on the spherical surface, and the triangular sum of a spherical triangle is always larger than 180°.

3.2 Map Projections

We can assume the earth to be a perfect sphere. In reality, the shape of the earth is more uneven, which should be considered when projecting the earth for a regional map. However, to think of the earth as a sphere works quite well in this thesis, in which only world maps are discussed (Fisher & Miller 1944, 5; Snyder 1987, 11). Locations on the spherical earth can be described with a spherical coordinate system indicating the longitude and latitude of the location. A grid of longitudes and latitudes with even intervals is called a graticule. Figure 6 shows a graticule with an interval of 10° between the shown longitudes and latitudes, respectively.

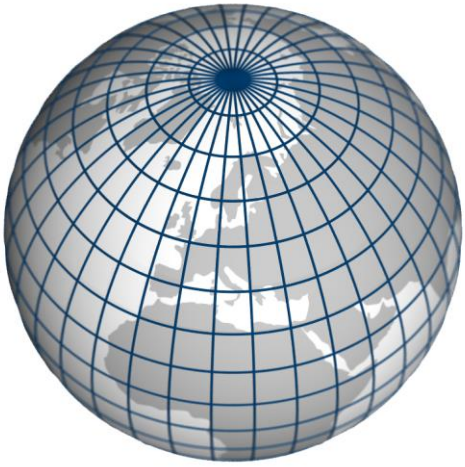


Figure 6. The grid of longitudes and latitudes form the graticule.

A map projection transforms locations on the spherical earth into a flat map. A classical method of describing map projections is to describe the map as the shadow of the round globe on a developable surface. By moving the light source to different locations and changing the configuration and location of the developable surface, projections such as the planar Gnomic projection and the cylindrical Mercator projection can be constructed. Figure 7 illustrates the three projection principles: conic, cylindrical, and planar. When constructing a projection according to these principles, the intersection of the surface of the spherical Earth and the undeveloped surface (a cone, cylinder, or plane) are defined by the tangent or the secants.

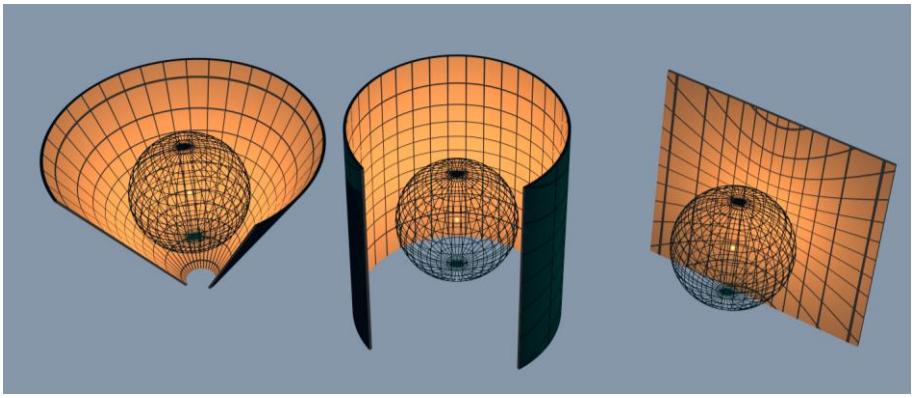


Figure 7. The three map projection principles: conic, cylindrical, and planar.

An infinite number of possible projections for each construction principle exist, and different projections can be selected for different purposes. The central meridian (the longitude that defines the centre of a projected

coordinate system) can, for example, be changed to place another portion of the world in the centre of the world map.

Many map projections do not fit into one of the three different construction principles. The manner of describing the construction of map projections is hence not limited to how to relatively place the globe, light source, and developable surface to arrive at the correct method of projecting the earth onto a surface. A map projection can also be described with a mathematical formula. In that manner, for example, pseudo-cylindrical projections can be constructed.

A flat world map cannot contain all of the qualities of a globe, and when portions of the map do not represent areas with the correct relative sizes or misrepresent shapes, this is referred to as distortions created by the map projection.

There are various manners of communicating the distortion of a map projection. One of the most well-known methods is to use Tissot's indicatrix (Tissot 1881), in which infinitesimal circles of identical size are distorted with the map and then rescaled to render the differences in size and shape visible to the map reader (see Figure 8). Another manner of visualising the distortion is to draw the edges of an icosahedron, a geometrical solid comprising 20 regular triangles (see Figure 9). This manner of visualising the distortion was proposed by Fischer and Miller (1944, 10–11).

Qualities of map projections have occasionally been the source of debates, and the most heated debates have most likely centred on the Mercator projection and the projection proposed by Peters (1983).

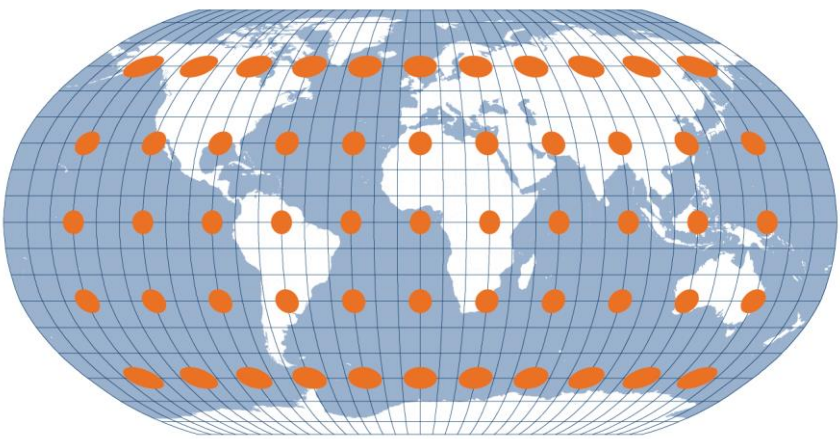


Figure 8. Tissot's indicatrix indicates distortion on a world map based on the pseudo-cylindrical Robinson projection. All the ellipses are circles of identical size and shape at a spherical earth. The differences on the map are because of the projection (in this case the pseudo-cylindrical Robinson projection).

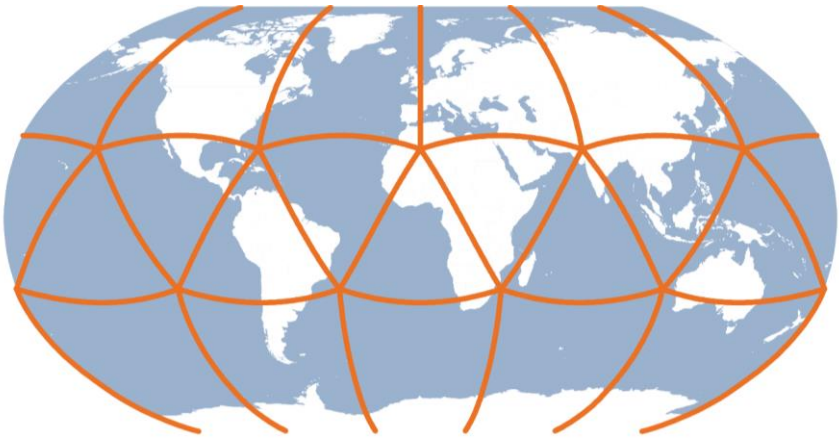


Figure 9. Icosahedron net, inspired by Fisher and Miller (1944). All the triangles are of identical size and shape at a spherical earth, and the differences on this map are because of the projection (in this case, the Robinson projection).

The Mercator projection presents the world without angular distortion but with an extreme areal distortion, whereas the projection presented by Peters has no areal distortion but an extreme angular distortion. Those two projections have been used as dichotomies that have polarised public debate although the cartographic community have chosen to distance themselves from both of these extremes for ordinary world maps (The American Cartographer 1989). The globe is sometimes presented as the only correct map because it does not distort relative sizes or shapes (Fisher & Miller 1944, 13). However, it is important to note that some of the qualities of map projections are not qualities that are preserved from the sphere. Instead they are qualities that are created because of the projection. For example, the shortest distances are represented as straight lines with the Gnomic projection, rhumb lines are represented as straight lines with the Mercator projection, and the bearing to Mecca can be calculated with a Qibla map. Monmomier commented on the distortion in the following:

> If 'to distort' is 'to lie,' then maps must lie. Their lies, however, are usually white lies, not deliberate fabrications. Making a road relatively wider than it is on the Earth makes it visible; distorting distances on a projection enables the map user to see the whole Earth at once; separating features by greater than Earth distances allows representation of relative positions. Distortion is necessary in order that the map reader be permitted to comprehend the meaning of the map (Monmonier 1977, 7).

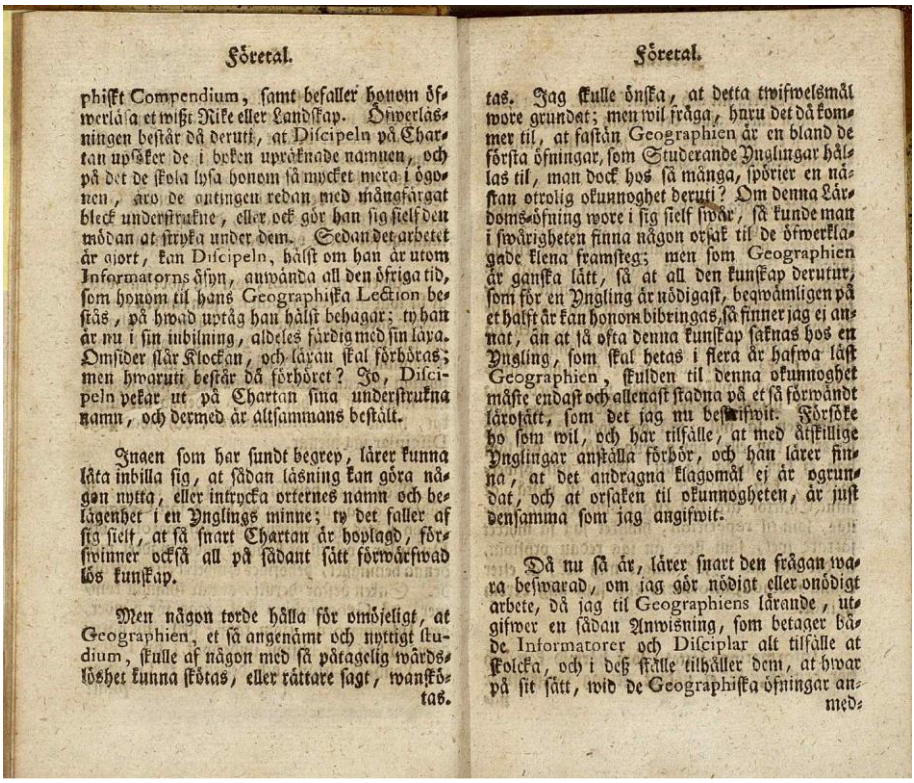
There are scholars who argue that map readers can learn to cope with distortion in world maps (Langer 1951, 79–80; Vinge 1951) and that novices can use visual cues to understand map projections (Battersby & Kessler 2012). Visual indications for more formal map projection detection have also been described (Olson 2006).

4. Methodology

4.1 Empirical Material

The sources used for the first paper are pedagogical and methodological texts written for teachers. The oldest text used as a source is from 1726 and the newest from 1969. The goal of the paper is to describe the educational ideas of geography education during the nineteenth and early twentieth centuries in Sweden with respect to the relationship between maps and textbooks. Often, materials from this time period have been used only to compare with more contemporary educational ideas. However, by including sources from this time period and also from before the nineteenth century, the nineteenth

Figure 10. Map engraved by Åkerman in the Memory and School Atlas by Ziervogel (1758a). Reproduction: National Library of Sweden.



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phiſkt Compendium, ſamt befaller honom öfwerläſa et wiſſt Rike eller Landſkap. Öfwerläſningen beſtår då deruti, at Diſcipeln på Chartan upſöker de i boken upräknade namnen, och på det de ſkola lyſa honom ſå mycket mera i ögonen, äro de antingen redan med mångfärgat bleck underſtrukne, eller ock gör han ſig ſielf den mödan at ſtryka under dem. Sedan det arbetet är ajort, kan Diſcipeln, hälſt om han är utom Informatorns åſyn, anwända all den öfriga tid, ſom honom til hans Geographiſka Lection beſtås, på hwad uptåg han hälſt behagar; ty han är nu i ſin inbilning, aldeles färdig med ſin läxa. Omſider ſlår Klockan, och läxan ſkal förhöras; men hwaruti beſtår då förhöret? Jo, Diſcipeln pekar ut på Chartan ſina underſtrukna namn, och dermed är altſammans beſtält.

Ingen ſom har ſundt begrep, lärer kunna låta inbilla ſig, at ſådan läsning kan göra någon nytta, eller intrycka orternes namn och belägenhet i en Ynglings minne; ty det faller af ſig ſielf, at ſå ſnart Chartan är hoplagd, förſwinner också all på ſådant ſätt förwärfwad lös kunſkap.

Men någon torde hålla för omöjeligt, at Geographien, et ſå angenämt och nyttigt ſtudium, ſkulle af någon med ſå påtagelig wårdslöshet kunna ſköras, eller rättare ſagt, wanſköras.

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tas. Jag ſkulle önſka, at detta twifwelsmål wore grundat; men wil fråga, huru det då kommer til, at faſtän Geographien är en bland de förſta öfningar, ſom Studerande Ynglingar hålas til, man dock hos ſå många, ſpörier en näſtan otrolig okunnoghet deruti? Om denna Lärdoms-öfning wore i ſig ſielf ſwår, ſå kunde man i ſwårigheten finna någon orſak til de öfwerklagade klena framſteg; men ſom Geographien är ganſka lätt, ſå at all den kunſkap derutur, ſom för en Yngling är nödigaſt, beqwämligen på et halft år kan honom bibringas, ſå finner jag ej annat, än at ſå ofta denna kunſkap ſaknas hos en Yngling, ſom ſkal betas i flera år hafwa läſt Geographien, ſkulden til denna okunnoghet mäſte endaſt och allenaſt ſtadna på et ſå förwändt läroſätt, ſom det jag nu beſkrifwit. Förſöke ho ſom wil, och har tilfälle, at med åtſkillige Ynglingar anſtälla förhör, och han lärer finna, at det andragna klagomål ej är ogrundat, och at orſaken til okunnogheten, är juſt denſamma ſom jag angifwit.

Då nu ſå är, lärer ſnart den frågan wara beſwarad, om jag gör nödigt eller onödigt arbete, då jag til Geographiens läraude, utgifwer en ſådan Anwisning, ſom betager både Informatorer och Diſciplar alt tilfälle at ſkolcka, och i deß ſtälle tilhåller dem, at hwar på ſit ſätt, wid de Geographiſka öfningar anmed-

Figure 11. Pages from the explanations and remarks accompanying seventeen engraved and coloured maps that compose the Memory and School Atlas (Ziervogel 1758b). Reproduction: National Library of Sweden.

and early twentieth centuries become more diversified, and discussions from this time period are shown to have much more in common with contemporary discussions than previously believed. Figure 11 shows one of the sources from the eighteenth century, and Figure 10 shows one of the maps in the school atlas with which it was publicised.

There is a large variation in methodology used in the three papers constituting this compilation thesis. Whereas the empirical material for the first paper is based on an analysis of texts, the second and third papers are based on responses from 1,206 respondents. Of those, 670 respondents participated in both of those studies. All of the respondents in Paper II and a majority of the respondents in Paper III were school children in the Swedish town of Arvika. The reason for choosing Arvika was because Paper II is based on a comparison with a previous study of place location knowledge (Peterson 1971) conducted in Arvika. The construction of data for the second paper was designed to be as similar as possible to the previous study. Peterson's clear and detailed thesis rendered this possible. A difference in the manner of administering the questionnaires to the respondents was that I as the researcher was not present in the classroom when the children in

Arvika completed the questionnaire. When Peterson conducted her study in 1968, she was present in all of the classes that participated. This may have affected the degree of commitment from the children because the presence of the researcher shows a greater commitment from the researcher. However, it is possible that my presence also could have negatively affected the children's commitment to filling out the questionnaire. The third paper has a clear hypothesis that is tested using empirical data based on responses from respondents. The hypothesis follows from the assumption that people often conform to a Euclidean understanding when reading maps. Hints that the hypothesis could be true were presented in my bachelor's thesis; however, this hypothesis was not thoroughly tested at that time. Respondents in the study were requested to propose the location and direction for the continuation of three aircraft en route to crossing the edge of a world map.

4.2 Measurements

In the three papers, I categorised or quantified the empirical material in accordance with different types of measurements. In the first paper, the categories were developed while reading the texts to be analysed in a fashion similar to the grounded theory approach. In the second paper, the measurements had to be identical to the measurements of a previous study to render the results comparable. In the third paper, I developed measurements that in different manners indicated the distance between the respondents' responses to specific types of answers.

4.2.1 Measurements used in Paper I

The method used for Paper I is a text analysis. The measurements used to analyse the texts were constructed in a manner similar to the grounded theory approach (Glaser & Strauss 1967). The first step may be characterised as inductive because the texts were read in an attempt to identify conceptual themes related to maps and the relationship between texts and maps. Based on certain themes, different potential standpoints that a text could take were delineated. The next step was rereading the texts and relating the texts to the different standpoints. When a theme could not easily be divided into standpoints, a more narrative approach was used for that theme. To draw conclusions, the standpoints of those themes during the nineteenth and early twentieth centuries were compared with the standpoints before and after the study period. The reason for using this process was the difficulty of developing a theory to be tested before reading the texts—because the character of the texts and therefore the type of information that could be extracted from the previously unstudied texts was unknown before reading the texts.

4.2.2 Measurements used in Paper II

One's image of the world is quite complex and cannot be exhaustively described. However, in educational contexts and in research, methods that attempt to capture fragments of someone's image have been developed. Two important methods have often been used to measure place location knowledge. Both methods compare a map constructed from memory with a map considered to be a correct representation. The first of these methods allows respondents to draw a map (sometimes referred to as a mental map) from memory on blank paper or another surface (e.g., Chiodo 1993; Kong, Savage, Saarinen, & MacCabe 1994; Saarinen & MacCabe 1995; Wiegand 1995; Axia, Bremner, Deluca, & Andreasen 1998; Pinheiro 1998; Wiegand 1998; Harwood & Rawlings 2001; Chokor 2003; Schmeinck 2009). Another quite common method that is easier to quantify is to measure place location knowledge by allowing the respondents to locate geographical locations on an outline map (also referred to as a blank map). This method, which is widely used to evaluate students' place location knowledge in educational contexts has been used in research for more than 100 years (e.g., Ridgley 1912; Journal of Geography 1912; Journal of Geography 1917; Hutter 1944; Fine 1951; Williams 1952; Johnson 1970; Wise 1975; Griffin & Fredrich 1976; Herman, Hawkins, & Berryman 1985; Beatty & Tröster 1987; Gallup Organization 1988; Beatty 1989; Bein 1990; Barrett & Farroni 1996; Gregg, Stainton, & Leinhardt 1997; Torrens 2001; RoperASW 2002; Poria, Atzaba-Poria, & Barrett 2005; Raento & Hottola 2005; Roper Public Affairs 2006; Bein, Hayes, & Jones 2009; Dunn 2011; Misheck, Ezra, & Mandoga 2013).

Paper II compares Peterson's (1971) results from 1968 with my results from 2013. It was therefore natural to use the same measurements for my results as Peterson used in her study. The measurements used were therefore whether the respondents answered correctly when requested to connect a geographical name with the correct location on an outline map. The respondents were also requested to answer some introductory questions about themselves to determine whether media or travel habits were covariates with the place location knowledge.

4.2.3 Measurements used in Paper III

The primary input from the respondents for the third paper was the location and direction of arrows the respondents drew on world maps. The responses representing proposed continuations were visualised by arrows with different widths representing the frequency of proposed continuation for each combination of location and direction. This suggests the tendency of the proposed continuations. To be able to test the hypothesis of the paper statistically, those proposed continuations also needed to be quantified.

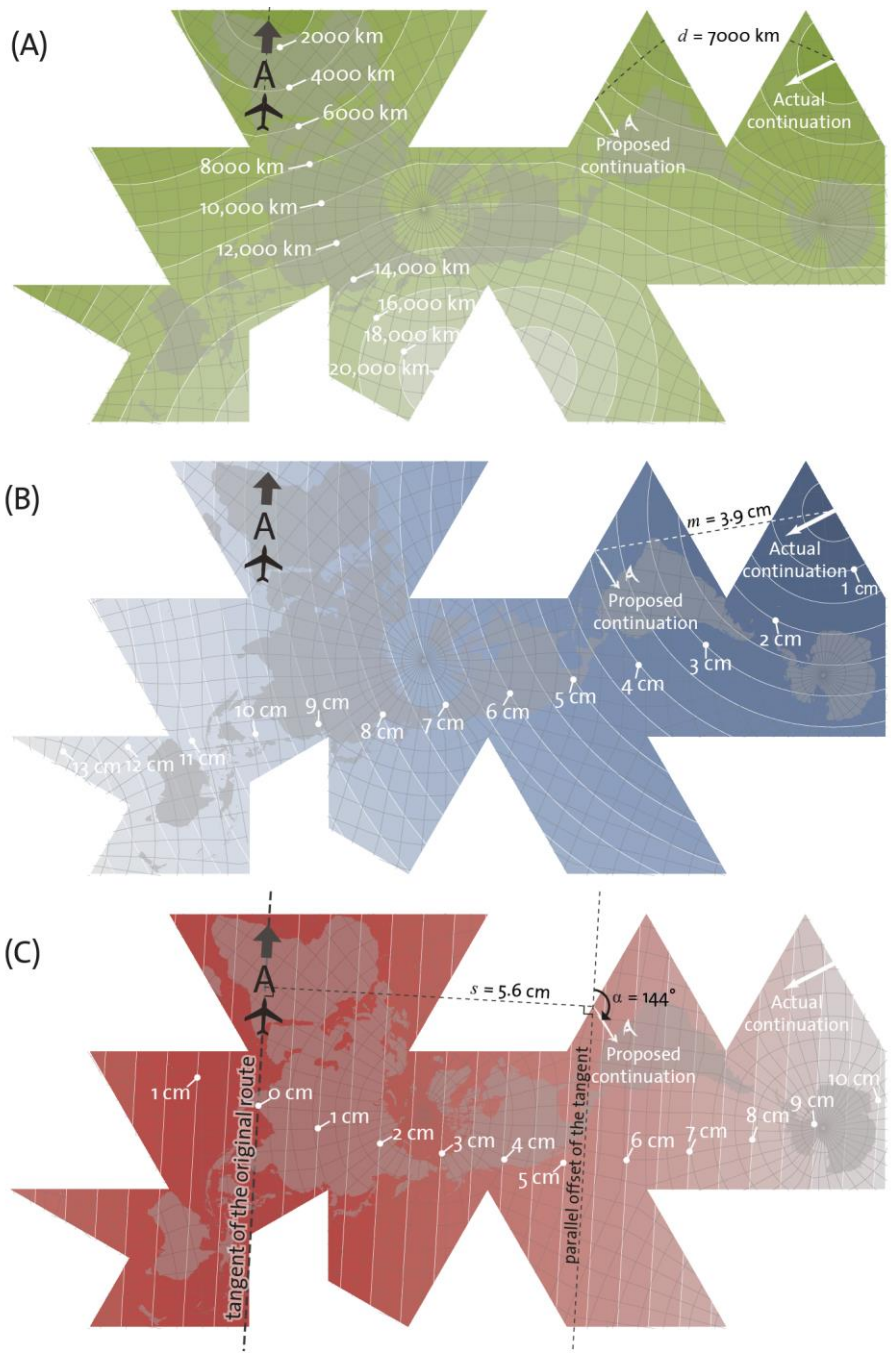

Figure 12. Measurements for proposed continuations. (A) The geographical difference d between the proposed and actual continuation. (B) The map difference m between the proposed and actual continuation. (C) The degree of the proposed continuation is linear, measured as the distance s to the tangent of the original route and the angle α on the map related to the parallel offset of the tangent.

Two categories of measurements were developed: closeness to the actual continuation and closeness to the continuation if one follows the hypothesis (linear peripheral continuation). Closeness to the actual continuation was measured by the geographical distance *d* (see Figure 12A) and by the distance *m* that measures distance on the map (see Figure 12B). Closeness to the linear peripheral continuation was measured by the distance *s* on the map to the tangent of the original route and as the angle α between the proposed direction and the direction of the tangent of the original route (see Figure 12C).

Except for measurements derived from the location and direction of the proposed continuation drawn on the map by the respondent, a fifth measurement *c* was used. The measurement *c* is the self-rated certainty of the respondent's answer, ranging from 0 per cent (complete guess) to 100 per cent (completely certain) for each of the proposed continuations.

4.3 Statistical Methods

The hypotheses in Papers II and III were tested using statistical methods. All of the quantitative data constructed in these studies were at least of ordinal scale: one number is larger or smaller than another. In accordance with Cliff and Keats (2003, ix), who stated that the majority of the data in behavioural measurements cannot be considered more than ordinal, I have avoided statistical methods that require empirical data of an interval scale. In one case, however, I relied on assumptions of interval data. The statistical methods are discussed below.

4.3.1 Statistical methods used in Paper II

Certainly, a greater number of correctly located continents correspond to a greater ability to locate continents on a map. The score on the test could also be perceived as an interval scale because the ability to locate one instead of zero continents could be perceived as the same amount of improvement as being able to locate six instead of five continents. This perception can, however, be disputed because one could argue that the ability to locate one instead of zero continents appears to be a much larger improvement than to learn only one more continent when one already has the ability to locate five. The statistical method for testing changes in the results between the two years was selected to depend only on the idea that the number of correctly located geographical areas is of ordinal and not interval scale. Therefore, these results cannot be contested by arguing that the data are not of interval scale.

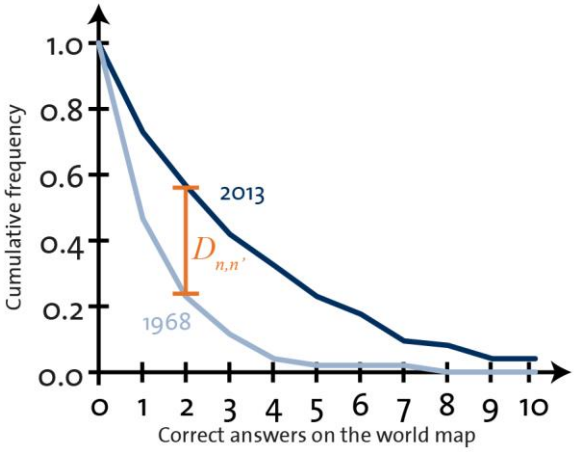

Figure 13. The Kolmogorov-Smirnov statistics $D_{n,n'}$ shows the largest difference between two cumulative frequencies. In this case, $D_{n,n'}$ is 0.335, the difference between the proportion of girls in the 3rd grade who have at least two correctly located continents and oceans.

The statistical method used for the comparison in the Arvika study is the two-sample Kolmogorov-Smirnov test (two-sided), which compares two samples of cumulative frequencies (see Figure 13).

The regression analysis used to test whether the ability to locate geographical names on a map is a covariate with individual factors is, however, dependent on an interval scale and could therefore be contested on these grounds. I would argue, however, that the numbers could be perceived as an interval scale and that it therefore makes sense to calculate items such as arithmetic means and standard deviations and also use the empirical data in a regression analysis. The regression analysis in Paper II is based on a multilevel model because the study includes respondents from school classes. This indicates that when we are searching for covariation, group factors such as the teacher or the atmosphere in the classroom whilst taking the test can interfere with individual variables. If the students *i* were randomly picked from schools from all over the world, this would be addressed with the error term e_i in the regression model (see Equation 1). Now, however, when we have many respondents *i* from the same school classes *j*, we must address this with a multilevel model (see Equations 2a and 2b) (Hox 2010, 4–5).

$$y_i = \beta_0 x_{0i} + \ldots + \beta_n x_{ni} + e_i \qquad \text{(Equation 1)}$$

$$y_{ij} = \beta_{0j} + \beta_1 x_{1j} + \beta_2 x_{2ij} + \ldots + \beta_n x_{nij} + e_{ij} \qquad \text{(Equation 2a)}$$

$$\beta_{0j} = \beta_0 + u_{0j} \qquad \text{(Equation 2b)}$$

4.3.2 Statistical methods used in Paper III

The measurements used in Paper III are at least of ordinal scale because a lower number indicates that the answer is closer to either the actual or the linear continuation. Cumulative frequencies and a Kolmogorov-Smirnov test could therefore be relevant in this paper. However, because the low values of the measurements are of the greatest interest when testing the hypothesis, the statistical test was constructed to not consider differences amongst the large values but instead determine whether the answer is larger or smaller then a chosen limit. So that the result does not depend too heavily upon this limit, an extra limit was used for each measurement to determine whether the results were stable. This division of cumulative frequencies resulted in frequencies of dichotomous data. A binomial distribution test was used to calculate p-values whilst testing the different null hypotheses (Welkowitz, Cohen & Lea 2011, 438). The statistical testing did not assume that the data represent an interval scale or do not, and the paper is therefore independent of whether the quantifications of the proposed continuations do represent interval scales or do not.

4.4 Ethical Considerations

The involvement of school children as respondents in Papers II and III was not addressed directly by me as a researcher; rather, the questionnaires were administered to the children with the help of the director of education at the municipality, head teachers, and classroom teachers. The questionnaires were anonymous, which was explained to the respondents on the first page of the questionnaire: "You can contribute to research by answering these questions. Nobody will know which answers are yours" (translation by the author). Because the questionnaires were anonymous and no sensitive personal data were asked for, I decided in consultation with the director of education of the municipality that consents were not required from the guardians of the children. The answers by the adult respondents for Paper III were also anonymous, and those respondents were also informed that their participation would contribute to research. When including respondents in the studies, one must endeavour to conduct research that is interesting and relevant to the public, something I have tried to achieve. All respondents were given an address for a web page with more information regarding the research. Paper II relies heavily on data published by Sonja Peterson in 1971. I have clearly stated which portions of the data were constructed by Peterson and which portions were constructed by me, being careful not to take credit for the work of others.

5. Summary of Papers

In this section the three papers of my thesis are summarised. The papers are presented in chronological order. The first paper focuses on the nineteenth and early twentieth centuries, the second paper focuses on differences between 1968 and 2013, and the third and final paper focuses on previously unknown difficulties regarding map reading that may help improve map reading in the future. All three papers were single-authored.

5.1 Summary of Paper I

Educational ideas in geography education in Sweden during the nineteenth and early twentieth centuries: The relationship between maps and texts

International Research in Geographical and Environmental Education

The first paper is based on an analysis of pedagogical and methodological texts intended for geography teachers and written between 1726 and 1969. The paper describes educational ideas on the relation between maps and textbooks in Swedish geography education from the nineteenth and early twentieth centuries. This time period has previously only been compared with succeeding time periods, and those comparisons have sometimes lumped together educational practices considered old-fashioned (e.g., rote learning) as educational ideas from the nineteenth and early twentieth centuries, often connected with the tradition of regional geography. The findings of the first paper showed that although the old-fashioned practices existed during this time, the educational ideas of the nineteenth century in Sweden, regional geography together with visual pedagogy incorporated understanding rather than simple rote learning. The findings in this paper differ from the findings in previous literature because the sources and the time periods that were used for comparison were different. The sources for Paper I were pedagogical and methodological texts intended for geography teachers, and comparisons were also made with (not previously studied) texts written during the eighteenth century. Based on the descriptions of the educational ideas of the nineteenth and early twentieth centuries and their relation to ideas observed in texts from the eighteenth century, the map is clearly considered an essential component of Swedish geography education. Some of the texts also emphasised the map as the most important tool in

geography, even compared with textbooks. Consistent with this idea, textbooks are criticised for describing, in an encyclopaedia-like manner, concepts that were better illustrated by maps instead of complementing the maps by providing context and vivid vignettes of different types of areas. Compared with the discussions of the mid-twentieth century, it can be argued that this discussion continues with identical types of examples regarding poor educational practices in geography education, particularly in textbooks. When the debates over geography education began in 1943 in the journal *Geografiska Notiser*, as tensions rose in the Swedish academic field of geography over regional geography, the arguments changed the notation from the importance of reading maps instead of map descriptions to the discussion regarding regional geography in geography education. The term *regional geography* and the geography education of the nineteenth century became associated with the eighteenth century tradition of learning encyclopaedia-like descriptions of regions by heart. In this manner, a discussion of geography textbooks older than regional geography becomes a "modern" critique of the use of regional geography in geography education. The conclusion that can be drawn is that although rote learning was used as a teaching method in Swedish geography education during the nineteenth and early twentieth centuries when the then prevailing geographical research focus was regional geography, textbooks with regional descriptions and the teaching method of learning geographical names and information by heart should not be thought to originate from regional geography and from that time period. The ideas behind this method and also the critique of the practice of rote learning in geography education existed before the introduction of regional geography to Sweden, and the use of maps to bring context and understanding to names and information was further emphasised during the period when regional geography was the dominant form of geography in the academic field of geography in Sweden.

5.2 Summary of Paper II

Changes in place location knowledge:
A follow-up study in Arvika, Sweden, 1968 and 2013

International Research in Geographical and Environmental Education

The second paper is based on a comparison of place location knowledge amongst the school children in a Swedish town in 2013 and the place location knowledge in the same town 45 years earlier. The paper challenges the idea of widespread place name ignorance amongst current youth. The study showed that in the results from 2013, a higher percentage of correct answers were given by children who followed the news every week and by children who had travelled outside Scandinavia. The effect of both variables

can be observed in previous studies and is likely linked to socioeconomic class. Because of this link, these variables should not be considered independent explanatory variables. An interesting difference between the findings of the present study and those of previous studies is that the pattern from 1968, in which boys tended to score better than girls, was not observed in the 2013 study. In the results from 2013, no significant differences were observed by gender. Perhaps the most interesting result of this study and the result that renders this study unique is the comparison between the two decades. The results indicate that the children in Arvika in 2013 were better at identifying continents and oceans on a world map but worse at identifying countries, regions, islands, seas, and oceans on a map of Europe. For both maps, since 1968, the ability to locate areas such as continents and countries was better than for natural areas such as oceans and islands. These changes do not indicate a general improvement or worsening of place location knowledge. Instead, this change may be an adaption to today's society, in which children in Sweden receive news from and travel to all parts of the world; in addition, detailed geographic information can easily be researched. In this type of society, it becomes increasingly important to understand the broader context of geographical locations. This situation casts doubt on the picture of the continuous worsening of children's school results and the focus on restoring an "old-fashioned" geography education or a return to excellence. Children today have neither increased nor decreased knowledge compared to children of past generations; rather, today's children know different things, and their society is not the same as the society of earlier generations. This is apparently also true for place location knowledge. A far more pressing issue than whether the children of today know more than previous generations should be the realisation of the differences amongst children today. When children from families who travel abroad and frequently follow the news perform better, the school has an important role in ensuring a balanced level of place location knowledge amongst children.

5.3 Summary of Paper III

Beyond the periphery:
Child and adult understanding of world map continuity

Annals of the Association of American Geographers

The third paper is based on questionnaires administered to 670 children aged 9–15 and 82 adults. This paper demonstrates the existence of a previously unknown difficulty in world-map reading: the difficulty of determining how the edges of the world map fit together. This paper shows that the naïve understanding of this problem is linear, that the proposed continuation is along a straight line that is tangential to the original route when the route crosses the edge. This tendency to propose a linear continuation in cases without actual linear peripheral continuation was identified as entirely dominant amongst children, regardless of the projection. This tendency was also clearly visible amongst the adults for a projection that was rectangular (cylindrical with a normal aspect). Downs and Liben (1991) emphasised that Euclidean understanding is necessary to understand map projections. Based on the results of the paper, I argue that Euclidean understanding is not sufficient to understand the peripheral continuation of the mapped world. A non-Euclidean understanding based on spherical geometry is also required. These results reveal a previously unknown problem regarding the understanding of world map projections, i.e., an understanding in which many children and adults make the mistake of thinking that they will end up at the North Pole if they pass the southern edge of a rectangular world map. This new knowledge should be useful in improving the design of world maps. One manner in which to help a map reader determine the actual peripheral continuation may be to provide guidance in the identification of the paths of great circles. This assistance could be provided, for example, by drawing a network of great-circle arcs on the world map, such as those proposed by Fisher and Miller (1944, 11) or by avoiding rectangular projections, which because of their straight lines and right angles, can give the impression that the movements between two points on the globe occur along a straight line on the map. In this manner, the results of Paper III—in which the rectangular projection resulted in a tendency towards a naïve linear understanding, even amongst the adults—contribute to the recommendation to avoid rectangular projections when designing world maps (The American Cartographer 1989). According to the results of Paper III, another method for helping a map reader determine the correct continuation is to split recognisable shapes (preferably cosmetically although this split could also be through geographical objects) when interrupting the world map. Now that this naïve understanding has been elucidated, peripheral continuation of world maps can be addressed by researchers, educators, and mapmakers to improve our understanding of our world.

6. Concluding Discussion

Empirically based research in the field of geography education can contribute to geography education in different manners. In the previously mentioned quote, Downs (1994, 57) mentioned contributions such as "inform and underpin decisions about standard setting, curriculum design, materials development, teaching strategies, and assessment procedures". In Sweden, there are an increasing number of studies in geography education on important topics such as how to teach sustainability and environmental issues (e.g., Grahn 2011; Torbjörnsson 2011, Nerdal 2014; Pettersson 2014; Torbjörnsson 2014). However, regarding the component of geography education designed to help students develop an image of the world—to have as a reference when discussing geographical locations or processes—scant research has been conducted in Sweden recently, although the role and amount of place location knowledge in the national curriculum have been debated (e.g., Destouni et al. [2010]). Outside Sweden, long-lasting debates have occurred regarding the types of knowledge, skills and values that should be taught in geography education (Lidstone 2003). This thesis studies different challenges of knowing and understanding the world based on cases from Sweden. The empirically based findings of the three papers can inform and underpin discussions regarding geography education but also contribute new insights to neighbouring fields such as cartography.

An essential component of knowing and understanding the world is to render the image of the world a relevant geographical frame of reference. In this sense, distances and relative positions between locations can be drawn from one's world image to enable geographical reasoning. The world image can be perceived as a mental *image* or *map* of the world, not as *disconnected* descriptions of regions from which relative distances and relative positions cannot be generated.

- The first paper of the thesis describes educational ideas in Sweden during the nineteenth and the beginning of the twentieth centuries. The findings show that this idea of the map being essential when helping students develop their image of the world has been around for an extremely long time. This idea does not contradict the idea that the actual teaching practices in many schools during many different periods of time could have been focusing more on learning regional text-based descriptions rather than using maps when trying

to help students develop their images of the world. However, the findings show the existence of an early critique of this type of teaching practice, focusing more on maps.

- The second paper renders it clear that the knowledge constituting the geographical frame of reference amongst school children has not decreased during the past 45 years. Place location knowledge has neither significantly increased nor decreased overall, but rather shifted to a more global frame of reference.
- The third paper indicates a new aspect of global geographical frames of reference, showing that both children and adults have difficulty deducing relative distances and relative positions between locations close to the periphery of world maps. This difficulty appears to come from an understanding based on Euclidean geometry although non-Euclidean spherical geometry is instead required in this circumstance.

What are the challenges regarding knowing and understanding the world in geography education?

- It is a challenge to view the component of geography education aiming to help a person develop an image of the world as something more than simply an old-fashioned remnant of geography from the past. However, this thesis could influence the discussion and practice of geography education by emphasising that this component of geography education is not a remnant of the academic field of regional geography from the nineteenth century. Instead, the thesis shows that the component of geography education aiming to help a person develop an image of the world has an older origin than academic geography and had from long ago a close relation to visual pedagogy. This knowledge can contribute to a better understanding of an topic originating in the body of knowledge that is associated with one's worldview (one's image of the world and one's attitudes) and not in the academic field of geography. In a way, it is this body of knowledge, not the academic field, that entitles geography to be a subject of its own in elementary schools.
- The thesis can also be perceived as encouraging in a society in which many discussions occur regarding declining achievement in today's school children. Such discussions have often been related to results of the PISA (Programme for International Student Assessment) tests (Skolverket 2013). The results of the study indicate the problems with assuming a continuous decline in children's test results and show, for example, that children today are better at localising continents on a world map than were students from 1968.

The children's place location knowledge has, according to the study, become more global and less focused on their own region since the end of the 1960s. We know that the national curricula in Sweden shifted to a more global focus in geography education in the 1960s and that society at large has continued in the same direction. It is clear from that study that place location knowledge has followed this change in society and become more global. This appears to be both natural and right; however, the results also show that the level of place location knowledge follows society because children involved in activities such as travelling outside Scandinavia and frequently following the news (activities often linked to socio-economic class) tend to be better at correctly locating continents and oceans on a world map. Schools face a challenge in ensuring a balanced level of place location knowledge amongst children despite socioeconomic differences.

- From the third paper, we can learn that an image of the world that can be used as a geographical frame of reference is not "just" knowledge of place names and their locations on a map. When the frame of reference covers the entire world, it takes a high level of spatial understanding to understand how the flat image of the world is connected along the edges. This paper is a testimony that the component of geography education aiming to help students in developing their image of the world is complex and remains full of interesting challenges to study.

The findings in this thesis raise questions that could be interesting starting points for future research. With regard to the first paper, in which the focus is the educational ideas observed in texts written for teachers, it would be interesting to study sources regarding actual teaching practices and contrast those practices with the educational ideas included in this study. Another method of furthering progress in this discipline could be to make comparisons with other countries regarding the history of the teaching of geography. It would, for example, be of interest to compare Sweden with the history of geography education in Norway, a history that has previously been studied by Sætre (2013). It would also be possible to go even further back in time (using sources studied by, e.g., Forss 2013), although the proportion of children engaged by the teaching process would decrease whilst doing so. Possible future studies related to the second paper could be to search for more previously conducted studies that reveal how well students performed in different school subjects to compare with more recent results. From the third and final paper constituting this thesis, there are many possible directions of investigating how map readers understand peripheral continuity. Individual differences would be one interesting direction, to see whether, for example, the spatial ability of the map reader correlates with the ability to

propose locations and directions of continuity in accordance with actual peripheral continuity. Additionally, it would be interesting to study different methods of helping map readers identify the actual peripheral continuity either by map design or by teaching the map readers to understand the spherical non-Euclidean geometry underlying the map projection. Teaching map readers to understand the spherical geometry behind a flat representation of the world raises many new and interesting questions. What we see as qualities of map projections today would, for example, most likely change if we abandoned Euclidean thinking and learned to develop a spherical image of the world.

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Sammanfattning (Swedish Summary)

Avhandlingen avser att bidra med empiriskt grundad kunskap om den del av geografiundervisningen som syftar till att hjälpa elever att utveckla en geografisk referensram, en världsbild. Avhandlingens exempel är från ett svenskt sammanhang och förändringar över tid är ett återkommande tema i studierna.

I den första artikeln nyanserar jag dagens syn på idéer för hur geografiundervisning skulle bedrivas på 1800-talet och runt sekelskiftet genom att i en textanalys inkludera källmaterial som vänder sig till läraren, samt genom att inkludera även äldre källor från 1700-talet. På så vis sätts influenserna som kom under 1800-talet och runt sekelskiftet i relation till både tidigare och senare pedagogiska idéer. I tidigare jämförelser har 1800-talet och sekelskiftet endast jämförts med geografiundervisning i senare tider, vilket medfört att idéer från den tiden framställts som de traditionella undervisningsidéerna som i senare tider behövts göras upp med. Vidare har det källmaterial som använts för att beskriva geografiundervisningen under den tiden ofta varit textbaserade läroböcker med regionala beskrivningar, vilket har resulterat i att bilden av de idéer som framkommit från den tiden är att den världsbild som skulle förmedlas är textbaserade beskrivningar av tydligt avgränsade geografiska områden. I den aktuella studien visade texterna som vände sig till lärarna att kartans roll som oumbärlig i geografiundervisningen framhölls och kritik framfördes mot hur läroböckerna med sina lexikonlika regionala beskrivningar var utformade. Dessa idéer visade på stora likheter med diskussionerna som fördes i Sverige under 1900-talet, men den kritiken mot läroböckernas utformning och åsikten att kartan skulle ha en central roll benämns då ofta i termer av att den gamla regionalgeografin skulle tonas ner och ersättas med geografi som låg närmare den tidens geografiska forskning.

I den andra artikeln problematiserar jag idén om att elever kunde så mycket mer namngeografi förr i tiden. I studien, där en jämförelse görs med en studie som gjordes 1968, visas istället att 45 år senare har grundskoleeleverna blivit bättre på att peka ut världsdelar på en världskarta. Däremot visas eleverna i studien vara sämre på att peka ut geografiska områden som vatten och öar på en karta över Europa. Angående länder i Europa och världshav finns ingen enhetlig trend. Men för samtliga kategorier av geografiska företeelser som eleverna fick peka ut har skillnaden mellan pojkar och flickor försvunnit 2013, medan pojkarna var generellt bättre på namngeografi enligt studien från 1968.

I båda dessa första artiklar stöder jag mig på empiriskt material som ligger till grund för jämförelser över tid och i båda dessa artiklar relaterar jag mina resultat till internationell (främst amerikansk) forskning. I den tredje artikeln ger jag mig in i diskussionen kring kartprojektioner av världskartor och identifierar där helt nya kartläsningssvårigheter rörande förståelsen för världskartors kant som skulle behöva uppmärksammas i undervisnings- och kartutformningssammanhang. Studien visar bland annat att både barn och vuxna ofta felaktigt tror att ett flygplan som passerar ut över den södra kanten av en rektangulär världskarta kommer tillbaka till kartan från den norra kanten. Detta missförstånd, att tro att nordpolen (den plats som på jorden ligger allra längst från sydpolen) är dit någon anländer precis efter att ha passerat sydpolen är klart problematisk för dessa personers världsbild. Missförståndet följer enligt studien idén om linjär perifer kontinuitet, alltså idén att man dyker upp längs den linje som bildar en på kartan rak svans efter flygplanet då det åker ut över kartkanten. Intressant är också att samma idé som missleder kartläsaren när det gäller hur kanten av världskartan sitter ihop i nord-sydlig riktning istället hjälper kartläsaren att mentalt foga samman kartkanterna korrekt i öst-västlig riktning. Att denna svårighet nu upptäckts möjliggör att undervisning kan utformas för att bidra till att förbättra även den delen av elevers världsbild.

Tillsammans visar dessa tre studier på en komplexitet vad gäller den delen av geografiundervisningen som syftar till att hjälpa elever att utveckla en geografisk referensram. Inledningsvis har alltså visats att idéerna kring denna del av geografiundervisningen redan under 1800-talet var mycket mer inriktade på att ge eleverna en förståelse och uppfattning om deras omvärld; då inte bara som en textbaserad utantillkunskap utan nära kopplad till kartan och åskådningsundervisningen. Därefter visades att tidigare generationer av skolbarn inte självklart var bättre på namngeografi i jämförelse med dagens generation, då dagens skolbarn visats ha en i större utsträckning global geografisk referensram. Slutligen har det i denna avhandling visats att en världskarta inte alltid lätt överförs till en förståelse av hur platser förhåller sig till varandra, eftersom passage av världskartans kant ställer till det för många kartläsare.

Nyckelord: kartografi, geografiundervisning, kartor, kartprojektioner, namngeografi, världskartor, Sverige

Errata of Attached Papers

Paper I. In list of references, the English translation of the book by Ziervogel (1758a) should read “Memory and school atlas”.

Paper III. In Appendix, “*c*” should read “Mean *c*” to indicate that it is the mean values of *c* (certainty) of children and adults, respectively, that are shown in the table for each of the fifteen cases.