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Knowledge transformation from climate change science in Finnish school geography from 1985 to 2024. How are the impacts of climate change presented?

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Abstract

Climate change has been a well-known phenomenon in science and the public press since the 1950s even if controversial positions were present about that period. The press and some publications wrote that the Earth was in a cool period and that a new ice age might emerge, but on the other hand, several publications were writing about temperature rise. In 1979, the WMO conference presented the causes and impacts of climate change almost as we know it today. Despite this, previous research has shown that climate change has only slowly transformed Finnish school geography. This article aims to interpret how the impacts of climate change have been presented from 1985 to the present. This study analyses Finnish National Core Curricula and textbooks for upper secondary school geography. The analysis is based on the conceptualisations of knowledge transformation and powerful geographical knowledge. Climate change was first time mentioned in the core curriculum of 2003. Textbooks in the 1980s and 1990s to some extent still presented climate change discourse from the 1970s. Textbooks based on the curricula of 2015 and 2019 give their readers a holistic perspective on the impacts of climate change, providing powerful geographical knowledge. According to our results, disciplinary knowledge can be found first at the classroom level in textbooks by the work of textbook authors and only later in institutional curricula.

Keywords: Climate Change, Curriculum, Geography, Textbooks, Transformation, Powerful Knowledge, Upper Secondary School

1. Introduction

"For students of global change, history can serve as an inspirational story of how far we have come. It can also serve as a humbling reminder that change is indeed investable in our lives, in the Earth system, and in our ideas and institutions" (Fleming, 2008, p. 130).

Climate change has been a well-known phenomenon at least since the 1950s, when some scientific articles and the public press started to show concern about the cooling of the

Earth (Fleming, 2008, pp. 107, 133). The IPCC published its first report in 1990, introducing the impacts of climate change on ecosystems and societies (Climate Change, 1990). Despite this, knowledge of climate change has transformed slowly to geography classrooms: for example, in Finland, it was first mentioned in upper secondary school geography textbooks in the 1980s (Ikonen, 2009), and in the Finnish upper secondary geography curriculum only in 2003 (Ikonen and Tani, 2024).

We are aware that climate change is one of the many complex issues that can be taught and studied in many school subjects, not just geography. Geography is, however, a subject that includes both natural and human/social scientific elements and can thus look at climate change as a multidisciplinary phenomenon. Therefore, geography can be argued to be in an excellent position to explore and understand today's climate crisis (Taylor and O'Keefe, 2021). In this article, we will analyse how climate change has been represented in Finnish geography curricula and textbooks from its first mentions to the present moment. The analysis timeline starts from 1985 when climate change was first mentioned in Finnish upper secondary school textbooks (Ikonen, 2009). This article is part of a larger research project analysing the causes, impacts, ways of adaptation and limiting climate change in geography textbooks. In this article, we will concentrate on the analysis of the impacts of climate change. The theoretical background of the research is constructed on the concepts of *powerful knowledge* and knowledge *transformation*. These concepts and their main ideas will be described in the next section.

2. Theoretical background

2.1 Powerful knowledge

The English sociologist and education researcher Michael Young introduced his idea of *powerful knowledge* in 2008. He argued that to explore the differentiation of knowledge in a curriculum, there has to be a new way of thinking about the role of knowledge (Young, 2008). Young argues that powerful knowledge differs from everyday knowledge in that it is systematic and abstract, and developed by experts in disciplines (Young and Muller, 2010, 2016, p. 110). Overall, the concept of powerful knowledge highlights the importance of education in providing the intellectual tools for individuals to navigate an increasingly complex world. It addresses the importance of education in promoting social justice and equality by ensuring that all students have access to powerful knowledge. Numerous researchers have applied the concept of powerful knowledge to the context of geography education. In many of these studies, powerful geographical knowledge has been used by referring to the definitions of David Lambert (2017; Lambert et al., 2015), Alaric Maude (2015, 2016, 2017), and Tine Béneker (2018). The main elements of these definitions are shown in Table 1.

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Table 1. Definitions of powerful geographical knowledge (Béneker, 2018; Lambert et al., 2015; Maude, 2016, 2017). Authors' elaboration.

Lambert et al. (2015), Maude (2015, 2016, 2017) and Béneker (2018) all argue that powerful geographical knowledge can provide students with new perspectives, analytical skills and the ability to engage with significant global issues. They suggest that powerful geographical knowledge enables students to think critically about the world around them and to consider alternative futures. There are also some differences in their definitions. Lambert et al. (2015) emphasise the importance of geographical thinking and critical understanding, while Maude (2015, 2016, 2017) emphasises students' empowerment and ability to participate in global issues; he also gives concrete examples for teachers. Béneker (2018) emphasises the systematic acquisition of knowledge, including understanding its sources and limitations and the ability to use, collect and evaluate knowledge. This study applies Béneker's (2018) definition of powerful geographical knowledge because we found it the most suitable for analysing complex issues like climate change.

In her inaugural lecture, Béneker (2018) highlighted the importance of a knowledge-based curriculum, which she sees has been threatened by the focus on 21st-century skills and competences. Studying and learning have been emphasised, while discipline-based teaching has been regarded as out-of-date. Béneker continues that reliable education is based on knowledge, "and that you have to enable pupils and students to see and discover how that knowledge comes about, and how it is developed and used but also misused in various ways". Powerful geographical knowledge can help in thinking about complex issues like migration and climate change (Béneker, 2018, p. 3).

Béneker (2018) has presented a model of four overlapping fields that together form powerful geographical knowledge. The first field is "conceptual and theoretical knowledge", which includes key concepts of geography and relational thinking. Béneker (2018) argues that this "grammar" of geography enables us to look at the world in new ways. The second field, the "vocabulary" of the discipline, is "concrete geographical knowledge", which can help us understand the world better to create a geographical world view. The third field consists of "knowledge of societal debates", which enables us to participate in major societal debates and to imagine desirable futures. The fourth field is "knowledge of knowledge", which Béneker (2018) sees as powerful when a person knows where knowledge comes from and understands its limitations. In geography, students must know how to use, collect and evaluate knowledge. Béneker (2018) sees an overlapping element between conceptual and concrete knowledge, which she has named as "systematic knowledge", which can be acquired through conceptual knowledge of concrete phenomena and places (Béneker, 2018, pp. 10-11). Powerful knowledge is dynamic and subject to change, but at the same time it is based on scientific proof. Powerful knowledge exists outside of a student's experience and is conceptual and sometimes counterintuitive (Béneker, 2018, p. 9).

2.2 Transformation

Between academic knowledge and school knowledge, there is a process in which disciplinary knowledge is transformed into teachable knowledge. There are different definitions of this process by various scholars: Bernstein (1990, 2000) calls this process *recontextualization*, Chevallard (2007; Chevallard and Bosch, 2014*) didactic transposition*, while, for example, Gericke et al. (2018; see also Hudson et al., 2023) write about *transformation*. All these deal with the relationships between academic and school knowledge but their initial concerns differ slightly. Bernstein is concerned with social and political issues like power relations, whereas Chevallard writes about epistemological and cultural constraints. In their work, Gericke et al. (2018) and Hudson et al. (2023) are more concerned with the meaning of powerful knowledge at different levels (society, institutions, classrooms). In this article, we apply Gericke et al.'s (2018) ideas of knowledge transformation and, therefore, describe it in more detail in the following.

Gericke et al. (2018, p. 432) describe knowledge transformation as "an integrative process in which content knowledge is transformed into knowledge that is taught and

learned through various transformation processes that take place outside and within the educational system at the individual, institutional, and societal levels". At the societal level, there is discussion about what should be taught in schools; at the institutional level, choices are made about what is taught, and in the classrooms, things presented in the curriculum should be taught (Gericke et al., 2018, pp. 433-437; see also Deng, 2021, p. 1657; Hudson et al., 2023, p. 122).

The transformation process of knowledge from scientific to institutional knowledge takes place, among other ways, through curricula, textbooks and other learning materials. In the curricula and learning materials, interpretations are made of what kind of scientific knowledge is considered important from the point of view of the subject's goals, contents and teaching methods. In this way, choices are inevitably made about which elements of scientific knowledge are perceived to be so important that they should be passed on to school education. A second round of the transformation process occurs in the teacher's work: the teachers make their own choices about what things are emphasised and what kind of interpretations are made of the things being taught.

The transformation at the classroom level is the most meaningful from the student's point of view (Gericke et al., 2018). By our interpretation, textbooks are links between the institutional and the classroom level. In the Finnish case, they are based on national core curricula, which textbook authors then interpret. The role of textbooks has traditionally been very strong in Finland, and they are still the most commonly used learning materials (see Karvonen, 2018). Thus, textbooks can operate at the classroom level in knowledge transformation.

As described above, via transformation, disciplinary knowledge goes through several processes influenced by different power actors and stakeholders before being finally taught in schools. This article analyses knowledge transformation from climate change science into Finnish upper secondary geography curricula and textbooks. We start by briefly examining how climate change has been seen in climate science from the end of the 1800s to the present. Since the 1980s, scientific publications concerning climate change have grown exponentially. This article uses the meta-analyses of the IPCC created for climate change research since 1990.

3. What climate science knew and knows about the impacts of climate change

In 1896, Svante Arrhenius demonstrated that variations in atmospheric CO_2 concentration could greatly affect the overall heat budget and the surface of the planet Earth. He suggested that carbon dioxide might trigger feedback phenomena that could account for glacial retreats and growths (Arrhenius, 1896, p. 268). Even though Arrhenius is widely regarded as a pioneer in the studies of the greenhouse effect and climate change, Fleming (1998, pp. 65, 75) has pointed out that the assumptions that Arrhenius made were no longer contiguous the climate research of the 1990s. By 1904, Arrhenius had suggested that increasing CO_2 content in the atmosphere by burning fossil fuels might be beneficial in making the Earth's climate warmer and more suitable for plant growth, thus providing more food for the growing population (Fleming, 1998, p. 82).

At the beginning of the twentieth century, most scientists did not believe that increasing CO_2 emissions would lead to global warming. By the 1940s, temperatures decreased, and climate change became a public agenda; the press began publishing articles on climate cooling. The public press was writing about a possible food crisis for the growing population, and even at the end of the century, temperatures might fall two to three degrees Celsius. This cooling trend was observable but relatively local, modest and short-lived in the Northern Hemisphere (Fleming, 2008, pp. 131, 134).

Research on global cooling from the 1940s to the mid-1970s presents a complex picture. While some studies indicate cooling trends (Lebassi et al., 2008; Coops and Waring, 2011; Pinna, 1996), others suggest regional variations and the influence of human activities like aerosols. Peterson et al. (2008) even argue that global cooling was a myth created by the public press and previously various works already gave

emphasis to greenhouse warming (Keeling, 1960; Suess and Revelle, 1957).

Some researchers during the 1960s considered climate change primarily a local phenomenon. For example, *The National Academy of Science* predicted in 1966 that climate change could have local influences (Miller, 2004, pp. 52–53).

In the 1970s, climate change started to be seen as a global issue. The climate issue was a concern at the United Nations conference organised in 1972 in Stockholm. It was stated that a solution could be achieved only by collaboration among nations (Sohn, 1973). According to Peterson et al. (2008), in the 1970s, there was still no consensus about the impacts of climate change: some researchers predicted warming, while others predicted cooling. Some scholars argued that climate change was human-caused, while other scholars believed it to be a natural phenomenon (Peterson et al., 2008, p. 1332; see also Barret, 1971; Bryson and Dittberner, 1976; Fohl, 1977; Machta, 1972).

In 1979, the World Climate Conference was held In Geneva. By then, it was clear that human-caused climate change would have a major impact on ecosystems and societies. In the keynote speech of the Genova conference, White (1979) summarised that science predicts a significant global surface temperature increase that would have a central role in food production, water supplies, economic and environmental welfare, political stability, and even world peace. According to him, governments needed to understand the influence of climate change on society (White, 1979, pp. 4-8).

In the early 1980s, climate change and increasing temperatures based on carbon dioxide were seen as real in the scientific community (Fleming, 2008, p. 133). Climate science still had, at some point, a strong belief that the climate was a local or regional phenomenon (National Research Council, 1983, p. 3). Other perspectives began to appear, and climate was seen in the atmosphere as a single entity linked to oceans, vegetation and glaciers. At the end of the 1980s, climate change was seen as a global environmental issue that could only be addressed through global political cooperation. This paradigm change led to the formation of a political institution, *The Intergovernmental Panel on Climate Change* (IPCC), in 1988 (Miller, 2004, p. 54), which released its first report in 1990 (Climate Change, 1990).

In 1992, the IPCC established some future scenarios, predicting that the doubling of CO_2 would happen between 2025 and 2050, increasing the global mean temperature from 1.5 °C to 4.5°C (IPCC, 1992, pp. 87-88). Since then, the IPCC has published several reports about the impacts of climate change and admitted that knowledge about some details is limited and needs to be researched more (IPCC, 1995, 2001, 2007, 2014, 2018, 2021).

4. Research question and the research data

This research aims to answer the following question: How has the knowledge of the impacts of climate change been transformed from disciplinary knowledge (climate science) to the Finnish upper secondary school curricula for geography and geography textbooks between 1985 and 2024? Based on our results, we will discuss whether curricula and textbooks offer students powerful geographical knowledge for understanding the impacts of climate change.

Teaching in Finnish upper secondary schools is regulated by the National Core Curriculum. Local education providers (municipalities and schools) create their specified curricula based on the national framework. This gives schools some freedom to design special courses, which can be offered to students in addition to the compulsory and optional courses mentioned in the core curriculum (Ropo and Valijarvi, 2010).

In the Finnish school system, teachers have considerable autonomy in choosing pedagogical and didactical methods. However, Karvonen et al. (2018) argue that most teachers in Finland generally use curriculum materials, particularly textbooks, in their planning and teaching activities. According to Tani et al. (2020a), textbooks also play a major role in Finnish geography teaching. Moate (2021) argues that the Finnish school system is textbook-based, and Puustinen et al. (2024) argue that textbooks are

often more important for teachers than curriculum in Finland.

For these reasons, the research data comprises five Finnish national core curricula, eight compulsory geography courses, and thirteen textbooks in upper secondary geography (Table 2). The 2019 curriculum is still in use in 2024. Some textbooks combine two courses (Aartolahti et al., 1986, 1996; Ervasti et al., 1999, 2001, 2005). The first author collected all the data from the textbooks and curricula dealing with climate change (totalling 20374 words). From the data corpus, we selected all text paragraphs dealing with the impacts of climate change. These paragraphs form the data for this article (totalling 8223 words).

Curricula	Textbooks and compulsory geography courses
1985	3 textbooks, 4 courses
1994	3 textbooks, 6 courses
2003	3 textbooks, 4 courses
2015	2 textbooks, 2 courses
2019	2 textbooks, 2 courses

Table 2. Finnish national framework curricula and textbooks, and compulsory geography courses. Authors' elaboration.

From 1985 to 2015, geography was studied in Finland in two compulsory upper secondary school courses: physical and human geography. Since the 2015 curriculum, geography has been studied in only one compulsory course, *Maailma muutoksessa* (*The World in Change*), a mix of physical and human geography. Textbooks in the research have been selected from Finland's two publishing companies with the broadest audience. The timeline of the study starts in 1985, when climate change was first mentioned in upper secondary school geography textbooks (Ikonen, 2009).

Representations of climate change in geography textbooks have been studied earlier (Bagoly-Simó, 2013, 2014; Choi et al., 2010; Ikonen, 2009; Ikonen and Tani, 2024; Meehan et al., 2018; Román and Busch, 2016; Tani et al., 2020a; Trædal et al., 2022) but a historical perspective on it is rare. Previous research has shown that schools are crucial in shaping students' knowledge and attitudes toward climate change (e.g., Falaye and Okiwilage, 2016; Harker-Schuch and Bugge-Henriksen, 2013). Based on these findings, we argue that it is important to also examine the historical perspective because school institutions have for decades influenced young people's opinions about climate change.

5. Methodology

We analysed and interpreted the research data by applying the fields of powerful geographical knowledge presented by Béneker (2018). The unit of analysis consists of text paragraphs (i.e., text fragments delimited by paragraph spaces) dealing with the impacts of climate change. We did not use pre-segmented topics or themes for research data. Instead, we interpreted the data (paragraphs) by categorising them according to Béneker's fields of powerful knowledge.

In Béneker's (2018) model, fields of knowledge overlap. Therefore, there cannot be a strict or simple model or a single way to "fit data into the boxes". Instead, the analysis is an interpretation based on climate change science and examples that Béneker (2018, p. 12) has provided. In Table 3, some examples of our interpretation are shown. The preliminary analysis was made by the first author, and it was then discussed with the second author. We are aware that other researchers could have made different interpretations, and therefore we hope that the examples shown in Table 3 will help the readers follow the analysis.

Béneker (2018): Fields of powerful geographical knowledge	Examples of topics found in upper secondary school geography textbooks
1. Conceptual and theoretical knowledge	- Theoretical knowledge - Changes in the climate system - Positive and negative feedback - Changes in albedo
Systematic knowledge	- Examples are in specific places - Environmental changes in a specific place, for example depletion of glaciers in the Alps - Specific societal changes for example in African agriculture and Migrations
2. Concrete geographical knowledge	- Measured examples - Changes in the continents, the oceans and the atmosphere
3. Knowledge of societal debates	- What arguments are used? -Different climate scenarios - What kind of changes ecosystems and societies are facing in the future?
4. Knowledge of knowledge	- What kind of data is available? - Who has collected the data and why? - What kind of research is available? - What is not known?

Table 3. Powerful geographical knowledge, according to Béneker (2018), and examples of topics found in upper secondary school geography textbooks. Authors' elaboration.

6. Analysis

In the following, we present our analysis and interpretation of textbooks and curricula. We have organised the analysis in a chronological way, using the publication years of the curricula as key points (Table 4).

Publishing year of curriculum	Mentions about climate change in curricula	Text paragraphs dealing with consequences of climate change in textbooks/number of geography courses
1985	0	2/4
1994	0	8/6
2003	1	6/4
2015	1	45/2
2019	2	54/2

Table 4. Number of mentions of climate change in geography curricula and number of text paragraphs dealing with impacts of climate change in upper secondary school geography textbooks. Authors' elaboration.

Although climate change is not mentioned in the 1985 curriculum (Kouluhallitus, 1985), its impacts are mentioned twice in geography textbooks that follow the curriculum in question. The two paragraphs discuss the possibility that atmospheric temperatures might rise *or* fall and climate change is a local phenomenon. We categorised these paragraphs into the themes "conceptual and theoretical knowledge" (rise of CO_2 emissions) and "concrete geographical knowledge" (local temperature change). The rise of CO_2 is considered by the authors as a theoretical example of a climate system, and local temperature change is measured in a specific place. All the other fields of knowledge proposed by Béneker (2018) were missing.

Climate change was not mentioned in the 1994 curriculum (Opetushallitus, 1994). However, eight paragraphs dealing with its impacts are found in geography textbooks. One of these is shown in the following extract (translated by the authors):

"The estimated increase in carbon dioxide concentration is expected to reach 0.04% by the end of this millennium, resulting in a projected

rise in air temperature of 0.2-3°C. The impact of the rise in carbon dioxide levels on temperature has not yet been definitively confirmed. Despite the increase in carbon dioxide levels, the temperature actually decreased from 1940 to 1980. It was only in the 1980s that a slight temperature increase was observed, which has been attributed to the strengthening of the greenhouse effect due to human activities" (Aartolahti et al., 1996, pp. 57-58).

The paragraph above discusses a possible rise in temperature in the future. Based on our interpretation, it represents the field of *conceptual and theoretical knowledge*, describing changes in the climate system. Other paragraphs based on the 1994 curriculum discuss local and regional changes, such as changes in Fennoscandia and the oceans. These texts were then interpreted to comprise *concrete geographical knowledge,* giving locational examples. One of the textbooks (Ervasti et al., 2001, pp. 53-54) described a possible rise in atmospheric temperature in the polar regions. It discusses future scenarios in which the Antarctic ice sheet might even grow, according to one particular study:

"Finnish researchers Hirvas and Nenonen have investigated the effects of the greenhouse effect in Antarctica, and according to them, the increase in average temperature does not actually melt and reduce ice sheets, but rather the opposite happens: snowfall increases and the Antarctic ice sheets grow. The feared rise in sea levels and coastal flooding may not occur after all" (Ervasti et al., 2001, pp. 53-54).

According to our interpretation, the paragraph above includes *systematic knowledge* because it gives a concrete example of the impacts of climate change in a specific region, Antarctica.

The 2003 curriculum mentions climate change only once: "*climate change*" (Opetushallitus, 2003, p. 139). Geography textbooks based on this framework curriculum discuss the impacts of climate change in only six paragraphs. The textbooks show how the Earth is warming (Ervasti et al., 2005, p. 59; Kakko et al., 2003, pp. 66-67). These examples were categorised to represent *conceptual and theoretical knowledge* about the climate system. The textbooks give examples of rising sea levels and the depletion of forests (Ervasti et al., 2005, p. 59; Kakko et al., 2003, pp. 66-67). These examples were interpreted as *concrete geographical knowledge* about measured changes. Some examples of the future of Finland are given: forest zones are moving, and there will be less snow in the winter (Ervasti et al., 2005, p. 59). Based on our interpretation, these examples could be categorised as *systematic knowledge* because they give concrete examples in a specific place. Also, to our understanding, *knowledge of societal debates* is present in the following extract:

"Human-induced global warming may slightly delay the onset of the next ice age. However, fossil fuels, coal, crude oil, and natural gas, which are the main contributors to global warming, will run out within the next few centuries" (Kakko et al., 2003, pp. 64-66).

We interpreted the text above as representing *knowledge of societal debates* because it gives an example of a future scenario and combines societal primary energy resources. The fourth field of knowledge (*knowledge of knowledge)*, as defined by Béneker (2018), is missing from the textbooks based on the 2003 curriculum.

In the 2015 curriculum, climate change is mentioned once, in a bullet point in the compulsory geography course: "*Climate change and other global environmental risks*" (Opetushallitus, 2015, p. 148). The impacts of climate change are mentioned 45 times in the analysed textbooks, and all the fields of knowledge defined by Béneker (2018) were identified. The textbooks include texts about future temperature and sea level rise, ocean acidification and increasing storms. We categorised these future scenarios as representing *conceptual and theoretical knowledge* about the climate system. Some texts include examples of coastal ecosystems, feedback systems, and impacts for developing countries, which we analysed as representing *concrete geographical knowledge* because there were measured examples in specific locations and physical environments.

"Climate change increases the risk of various extreme weather events. Floods, storms, droughts, heatwaves, and wildfires are becoming more common. The greatest impacts on humans are concentrated in areas already facing

significant challenges, such as the equatorial regions, small island states, and northern indigenous peoples. At the same time, many unique ecosystems, such as mangrove forests, glaciers, coral reefs, and small islands, are under threat. Climate change also increases the risk of sudden changes: for example, weakening ocean currents or thawing permafrost would have significant impacts on surrounding areas" (Brander et al., 2016, pp. 61-62).

The paragraph above was interpreted to represent *knowledge of societal debates* because it includes claims about future scenarios for societies and ecosystems. Some texts, for example, discuss the IPCC's work and claim that predicting the future is difficult. These are categorised as representatives of *knowledge of knowledge* because they include information about where the knowledge comes from and what the limitations are.

Climate change is mentioned twice in the 2019 geography curriculum: "mechanisms of climatic changes" and "causes and impacts of current climate change" (Opetushallitus, 2019, p. 245). The impacts of climate change were addressed in 56 paragraphs in the analysed textbooks (Figure 1), and all of the fields of knowledge defined by Béneker (2018) could be identified. There are paragraphs that deal with global justice, climate migration, loss of biodiversity, and, for example, weather extremes. These paragraphs were categorised as representing *conceptual and theoretical knowledge*, which includes societal and environmental geographical knowledge. Other paragraphs give examples of theoretical phenomena like aerosols, depletion of permafrost and increased methane emissions, and thermal expansion of ocean water. These paragraphs were categorised as *concrete geographical knowledge* because they give measured examples. Some paragraphs address examples from Tuvalu, South Asia, the USA, Europe, Finland, and China, in other words examples in specific locations and therefore categorised into the field of *systematic knowledge.*

"Climate change has so many harmful effects globally that it is also referred to as a climate crisis. The risks of warming are greater the more the climate warms. The number of people suffering from lack of drinking water and the risk of species extinction double if the Earth warms two degrees compared to pre-industrial times instead of 1.5 degrees" (Cantell et al., 2021, pp. 32-33).

The paragraph above was interpreted as an example of *knowledge of societal debates,* including a societal example: the lack of drinking water. Only three paragraphs in the two books discuss the impacts of the future (Brander et al., 2021, p. 42; Cantell et al., 2021, pp. 29-30). The textbooks admit that predicting the future is difficult. We categorised these paragraphs as representing the field *knowledge of knowledge* because they reveal that there is still a lack of knowledge in climate science.

Figure 1 presents the number of paragraphs in geography textbooks by the year the curricula were published and shows the analysed paragraphs by Béneker's (2018) definition.

7. Results

This study examined how knowledge of climate change science has transformed into the Finnish National Core Curriculum for upper secondary school geography and upper secondary geography textbooks from 1985 to 2024.

The key findings concern knowledge transformation on different levels (society, institutions and classrooms). Climate change was absent in the upper secondary school National Core Curricula in 1985 and 1994. It was first mentioned in the 2003 National Core Curriculum but found in the textbooks of the 1980s. By our interpretation, textbooks can be seen in knowledge transformation at the classroom level because of their importance to teachers (see Karvonen, 2008; Moate, 2021; Puustinen et al., 2024; Tani, 2020b). Knowledge transformation from disciplinary knowledge can happen first in classrooms through the works of textbook authors and teachers before institutions or society.

Textbooks based on the 1985 curriculum present knowledge of climate change from the 1970s. During the 1970s, climate science discussed whether the climate was warming or

cooling. At that time, there was no consensus. The WMO conference was held in 1979, where the impact of human activities on climate change was presented. In the textbooks, there is speculation that the climate might get warmer or colder, and climate was seen as a local phenomenon, but knowledge presented at the WMO conference is missing. Climate change was seen as a natural scientific phenomenon, and the social dimensions were missing. Textbooks at that time did not provide powerful geographical knowledge about climate change to their readers: *systematic knowledge*, *knowledge of societal debates*, and *knowledge of knowledge* were missing. This leads to a position where the potential of powerful geographical knowledge is not fully achieved (Béneker, 2018). Geography should offer a holistic approach to understanding climate change, providing students with natural, human and social-scientific human-environmental relationships (see He et al., 2024; Taylor and O'Keefe, 2021).

The 1994 curriculum was released four years after the first IPCC (Climate Change, 1990) publication. Despite that, climate change was not mentioned at all in the curriculum. Textbooks of that period were still repeating 1970s climate change science discourse: the climate might get warmer or colder, but with no consensus. The textbooks offer their readers powerful geographical knowledge by covering all of Béneker's (2018) fields of knowledge. One textbook (Ervasti et al., 2001, pp. 53–54) mentioned that knowledge about the future is limited. This limitation of knowledge is transformed from the IPCC (1992) report. It is somehow surprising that, despite the IPCC reports, the textbooks still presented the 1970s discourse at some stage. It can be argued that the authors possibly did not carefully follow the climate change discussion of the IPCC. It is worth mentioning that in one textbook published during that period the authors picked out one study that claimed that Antarctica's ice sheet would grow (Ervasti et al., 2001, pp. 53-54). This is quite the opposite of what the IPCC had presented (Climate Change, 1990; IPCC, 1992), and, surprisingly, textbook authors neglected the IPCC reports at that point.

The term climate change appears for the first time in the 2003 geography curriculum. The impacts of climate change were discussed in only six paragraphs in the geography textbooks. The IPCC (2001) admitted that there was still uncertainty about the knowledge of climate change. Still, these ideas did not transform into textbooks: *knowledge of knowledge* (what the limitations are, where the knowledge comes from) was missing. This does not fully provide powerful geographical knowledge for the readers (Béneker, 2018). One textbook even gives a simple and naïve solution for the future: fossil fuel usage will end in the coming centuries, and this will solve climate change issues (Kakko et al., 2003, p. 66). The textbook does not give examples of alternative energy sources or solutions at this point. It seems that textbook authors neglected the time span of climate change, which in fact covers hundreds of years. The IPCC (2001) estimated that the globally-averaged surface air temperature would rise by 1.4 to 5.8°C by 2100, and the average sea level would rise 0.09 to 0.88m by 2100 (IPCC, 2001, pp. 1-6). By 2003, it was clear that climate change would significantly impact societies and ecosystems, but the textbooks only briefly discussed these topics.

After the 2015 curriculum, climate change became a major topic in geography textbooks. In 2015, textbooks based on the two compulsory geography courses discussed the impacts of climate change in 45 paragraphs. The textbooks offered holistic reading about the impacts, and climate change science has transformed into geography textbooks. Textbooks at that period offered powerful geographical knowledge to their readers.

Textbooks based on the 2019 National Core Curriculum contained 56 paragraphs on the impacts of climate change, including perspectives of all Béneker's (2018) fields of knowledge. The textbooks provide their readers with powerful geographical knowledge and a holistic picture of climate change. In our interpretation, the knowledge transformation from science to textbooks is clearly present. The textbooks present the IPCC reports quite precisely, although they admit that science still needs to know more about it.

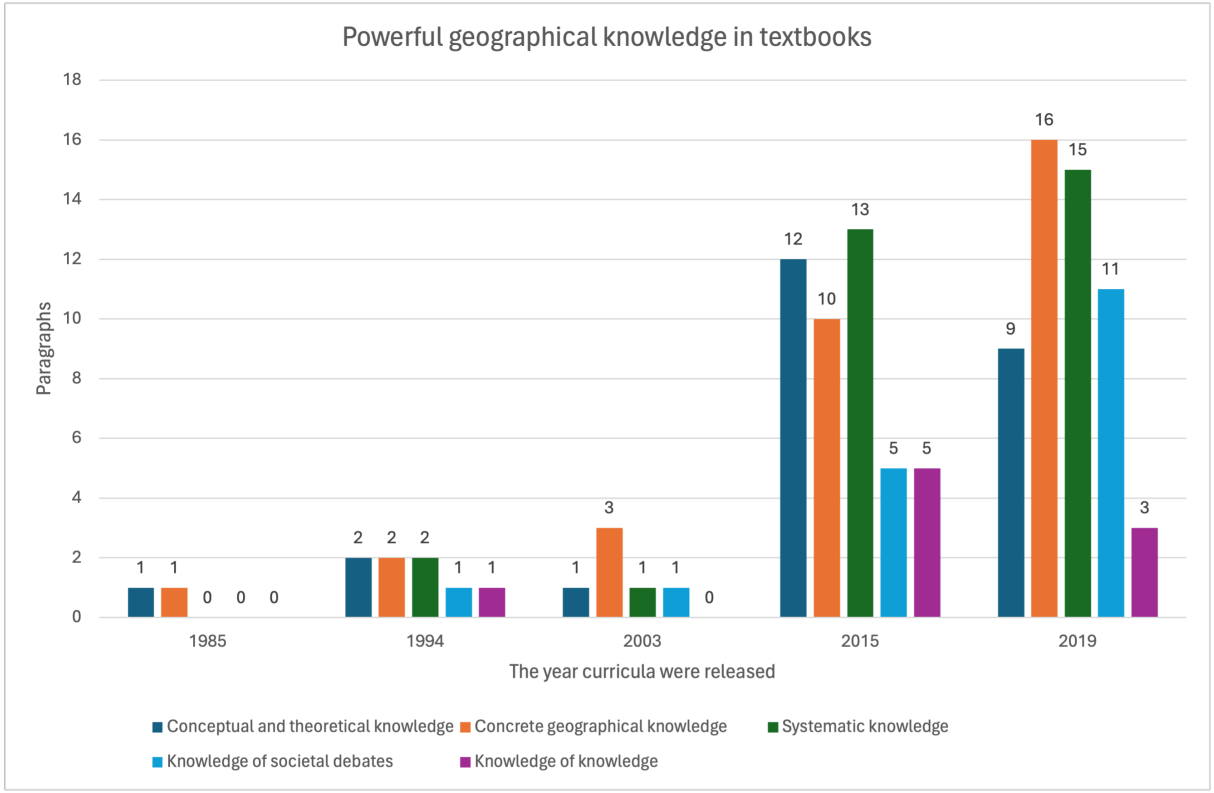

Figure 1. The impacts of climate change and fields of powerful geographical knowledge (see Béneker, 2018). Upper secondary geography textbook text paragraphs based on five curricula. Authors' elaboration.

8. Discussion

This article compares knowledge and representations of climate change over time. We have analysed how disciplinary (climate science) knowledge has been transformed into Finnish upper secondary Core Curricula and textbooks between 1985 and 2024.

According to our results, the first mentions of climate change impacts are found in textbooks from the 1980s, but climate change was first mentioned in the Core Curriculum only in 2003 (Ikonen and Tani, 2024). Since 2003, climate change has been present in curricula. According to our results, the impacts of climate change have been present in Finnish geography textbooks since 1986.

By interpreting Béneker's (2018) schema of powerful geographical knowledge, we found that textbooks based on 1985 and 2003 lack powerful knowledge to interpret the impacts of climate change. Textbooks based on 1994, 2015 and 2019 Core Curricula offer a holistic perspective on climate change's impacts. We argue that textbooks based on those Core Curricula allow their readers to access societal, political, and moral debates (see Béneker, 2018; Lambert et al., 2015; Maude, 2016; 2017). We also agree with Chang (2024, p. 79) that an integrative and holistic approach ensures students develop the critical thinking skills, personal responsibility, and collaborative abilities needed to address climate change. International research also emphasises geography teachers as key facilitators of knowledge-making for geographical phenomena (like climate change) in the 21st-century classrooms (Chang and Aman, 2017). For these reasons, our study of geography textbooks can provide an understanding of climate change and its history in Finnish schools, as geography teaching can be seen as very textbook-oriented (Moate, 2021).

This study does not answer how Core Curricula were formed and why climate change was absent in 1985 and 1994 from those curricula. In Finland, curriculum design is carried out through a deliberative process that involves various stakeholders, interest groups, experts, and ordinary citizens (Säily et al., 2021). This tendency has received little attention in research (Moate, 2021, p. 357) and is an exciting topic for further study.

One limiting factor in this study is that we did not compare the two publishers' textbooks. We did not compare the textbooks to determine which offers more powerful knowledge. This comparison has yet to be analysed.

Climate change has been a well-known phenomenon since at least the mid-1970s. Despite this, knowledge of it has slowly transformed from climate science into upper secondary school geography. One explanation for this lies in the way textbooks are written and published. In Finland, textbooks are written mostly by teams of teachers, educators and researchers. According to Mikander (2016, p. 34), teachers are expected to have the best knowledge of what kind of textbook is best for students, even though researchers are expected to have the latest disciplinary knowledge. Writing a textbook is a long process that can take years to complete (Ruuska, 2014, p. 19). This timespan offers one explanation for why it takes so long to transform knowledge from academia to textbooks. It seems that 1980s textbook authors followed climate change discussions in science in the 1970s and transformed knowledge into textbooks in a few paragraphs.

At least since the 1990 IPCC report (Climate Change, 1990), climate change has also been a prominent topic of discussion outside the school institution in the mainstream media and press. This has probably also influenced textbook authors and curriculum developers. The way the media and press presented climate change in earlier decades should also be studied. Additionally, it would be essential to examine the work of textbook authors and curriculum developers, focusing on the sources used and how textbooks and curricula are formed.

Another interesting topic for further study would be to examine why climate change was considered of such little importance that it was excluded from the 1985 and 1994 curricula. Comparative temporal textbook study in other countries would also be useful to clarify how climate change was understood outside Finland.

9. Conclusion

The Key finding in this study was knowledge transformation at different levels (societal, institutional, and classroom). Transformation does not always occur hierarchically. Based on our results, disciplinary knowledge can be found first in the textbooks at the classroom level by the work of textbook authors and later in the institutional Core Curriculum by curriculum developers.

We hope our study can inspire other researchers who want to examine how climate change has been dealt with in geography curricula and textbooks in different countries. Researching the Finnish context of geography curricula and textbooks can lead to a better understanding of geography because geography is, after all, a global science. Analysing curricula and textbooks from a temporal perspective can help us understand the changes the school system, its aims and contents have undergone. The Finnish context can reveal different perspectives on how climate change is presented and help us understand different cultural understandings of climate change.

Curriculum	**Textbooks**
Kouluhallitus, *Lukion opetussuunnitelman perusteet 1985,* Helsinki, Kouluhallitus, 1985.	Aartolahti T., Rikkinen H., Rikkinen K. and Viitala P., *GEO 1+2*, Helsinki, Weiling+Göös, 1986. Ervasti V. Kytömäki J. Paananen J. and Tapana P., *Lukiolaisen Terra 2*, Helsinki, WSOY, 1990. Ervasti V., Kytömäki J., Kytömäki P. Paananen J. and Tapana P., *Lukiolaisen Terra 1*. 5th ed. Helsinki, WSOY, 1993.
Opetushallitus, *Lukion opetussuunnitelman perusteet 1994*, Helsinki, Opetushallitus, 1994.	Aartolahti T., Kosonen O., Rikkinen H. and Rikkinen K., *GEO 1+2*. Helsinki, WSOY, 1996. Ervasti V., Kytömäki J. and Paananen J., *Terra Nova Toimiva maapallo + Ihminen ja ympäristö*, Helsinki, WSOY, 1999. Ervasti V., Kytömäki J. and Paananen J., *Globus Toimiva maapallo + Ihminen ja ympäristö*, Helsinki, WSOY, 2001.
Opetushallitus, *Lukion opetussuunnitelman perusteet 2003*, Helsinki, Opetushallitus, 2003.	Ervasti V., Kytömäki J. and Paananen J., *Globus Sininen planeetta ja yhteinen maailma*, Helsinki, WSOY, 2005. Kakko I., Kenno P. and Tyrväinen H., *Lukion maantiede 1 Sininen planeetta*, Helsinki, Otava, 2003. Kakko I., Kenno P., Tyrväinen H. and Fabritius H., *Lukion maantiede 2 Yhteinen maailma*. Helsinki, Otava, 2006.
Opetushallitus, *Lukion opetussuunnitelman perusteet 2015*, Helsinki, Opetushallitus, 2015.	Brander N., Hiekka S., Paarlahti A., Ruth C. and Ruth O., *Manner GE1 Maailma muutoksessa*. Helsinki, Otava, 2016. Cantell H., Jutila H., Lappalainen S. and Sorvali M., *GEOS1 Maailma muutoksessa*. Helsinki, Sanoma Pro, 2020.
Opetushallitus, *Lukion opetussuunnitelman perusteet 2019*, Helsinki, Opetushallitus, 2019.	Brander N., Hiekka S., Paarlahti A., Ruth C. and Ruth O., *Manner GE1 Maailma muutoksessa*, Helsinki, Otava, 2021. Cantell H., Jutila H. Kolehmainen J., Lappalainen S. and Sorvali M., *Lukion maantiede GEOS1 Maailma muutoksessa*, Helsinki, Sanoma Pro, 2021.

Table 5. Analysed curricula and textbooks in this research. Authors' elaboration.

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