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A cross-country comparison of climate change in middle school science and geography curricula

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ABSTRACT

The challenge of climate change means that school education is more important than ever in preparing young people for an uncertain future. The focus of this research is climate change education and its status in the compulsory middle school years (approximately years 7–10) across six countries (Australia, Israel, Finland, Indonesia, Canada and England). The authors investigated formal published national curriculum documents, specifically science and geography, to determine the presence of climate change topics, and the way they are addressed in these subjects. The key findings are that: (1) the term 'climate change' appears in the formal curriculum of all six countries in science or geography; (2) approaches to climate change in the curriculum differ substantially across different countries; (3) climate change is often presented as a context, example or elaboration for other science concepts rather than a discrete topic; (4) the presence of climate change in most curriculum documents is scattered and spread over multiple years and (5) knowledge about causes of climate change predominates over action and behavioural changes. These findings raise questions as to whether current school curricula provide sufficient guidance for teachers to develop students' understandings, skills and values regarding climate change.

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Introduction

The climate crisis is here and it requires urgent and concerted local and global actions. The need for multi-sectorial transformative actions is clearly recognised by all climate change experts, and by the United Nations' leading bodies, which continuously call on

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governments to step up their performance in meeting their commitments to keep temperature rise below 1.5°C.

Against the backdrop of this climate crisis, Ministries of Education have an important role to play in climate change education, mitigation and adaptation to prepare young people for uncertain futures (White et al., 2021). There is broad agreement across international organisations, the public, educators and students that school-based education needs to play a major role in educating young citizens about climate change (Lambert et al., 2012; UNFCCC, 2014). While this seems to be self-explanatory in this current time of climate change emergency, evidence suggests that globally, schools are lagging behind and that students seem to rely on external sources, primarily the media, to obtain their climate change education (Erasmus+ School Education Gateway, 2020; Schreiner et al., 2005). If students are indeed learning about climate change from the media rather than school this is problematic for three reasons. Firstly, the media is sometimes more prone than school-based education to present unreliable information (Chang & Pascua, 2016). Secondly, schools as institutions, are commissioned by society to provide students with worthy knowledge that takes them beyond everyday knowledge (Young, 2013). By neglecting to educate students about climate change, schools are depriving students of their 'entitlement to knowledge' (Young, 2013, p. 101), that is 'better knowledge, more reliable knowledge, knowledge nearer to truth about the world we live in' (p. 107). Thirdly, curriculum theorists suggest that increasingly and universally, curricula declare that their prime mission is to equip students with twenty-first century skills required for dealing with future uncertainties (Ecclestone, 2013).

If schools are not meeting this expectation of providing climate change education (Kwauk, 2021; Plutzer et al., 2016), the problem may reside not at the school level, but at the national school curricula and policy level. A country's national school curriculum is highly influential in shaping the overall delivery of education due to their statutory power. National curricula documents direct attention to what is important, and set standards and benchmarks for accreditation. These documents impact what teachers teach and how they teach (Holmes & McLean, 2019; Young, 2013). Regardless of the importance of curricula in influencing climate change education, very little research has examined the role of the national curriculum in addressing climate change education (Aikens et al., 2016). Many climate change education studies focus on educational approaches or examine climate change understanding among students, teachers and communities, with little attention given to the underlying architectural design of existing curricula (Chang & Pascua, 2016; Tolppanen & Aksela, 2018).

This study is significant in that an understanding of the breadth of formal school climate change education available to all students is not known. As far as we are aware, this is the first time that an international curriculum comparison has been conducted. We aim to address this issue by conducting a comparative analysis of six countries' middle-years curricula in science and geography. In this study, middle school is defined as the post-primary school years that precede the senior-secondary years of schooling. The actual years and ages vary from country to country and are described in the method. The subjects of science and geography were chosen because they are compulsory subjects in the middle years of schooling. A preliminary search indicated that climate change did not appear in other subjects. Focusing on climate change in these two subjects, we compared and contrasted the breadth and depth of climate change

education in these compulsory years of post-primary school education. The upper years of secondary school were not analysed because with the exception of the UK, science is not a compulsory subject. We wanted to capture the extent and type of climate change education that all school students are exposed to rather than only those who chose to continue with senior-secondary science and/or geography.

Literature review

In this study we use the term, climate change, to refer to any long-term trends or shifts in climate over many decades. Human-induced climate change has resulted in increased average global temperatures and an increase in the frequency, duration and intensity of extreme weather events (CSIRO and Australian Government Bureau of Meteorology, 2020). Climate change is caused by an increase in greenhouse gases primarily from the burning of fossil fuels. The term, global warming, refers to the long-term increase in global temperature.

Theoretical framework

Our analysis of formal curriculum documents is informed by theoretical models of best practice about climate change education and environmental education. The field of climate change education in schools is relatively recent with the term, climate change, occurring in formal school curriculum documents only in the last decade or so. Consequently, it is difficult to find exemplars that have been implemented and evaluated in a large-scale manner. However, there are five framework models that recommend inclusions for climate change education from recent research. Each of these five frameworks has been developed based on studies with different methodologies to access and synthesise a wide range of expert perspectives for identifying what climate change education should encompass.

Mochizuki and Bryan (2015) argue that climate change should be taught in the context of education for sustainability, aligning with international recommendations (Læssøe & Mochizuki, 2015; UNESCO, 2021). In coining the term, 'climate change education for sustainable development' (CCESD) they present a detailed framework of what should be included. Their framework encompasses scientific, ecological, economic, political, ethical and social aspects of climate change. For these authors, the outcome is not merely learning knowledge and skills, but changing learners' behaviours in order to mitigate and adapt to act to reduce gas emissions and impacts. The framework comprises four pillars (1) learning to know: understanding the causes and consequences of climate change, (2) learning to do: transdisciplinary skills such as critical thinking, (3) learning to live together and (4) learning to be through global citizenship education such as developing empathy and interpersonal skills. Mochizuki and Bryan (2015) do acknowledge that such a model would require extensive changes in formal education from teacher education to curriculum change to policy development.

Monroe et al. (2019) conducted a systematic review of the literature that evaluated climate change education interventions. From a review of 49 intervention studies, there were two key findings, that climate change education should be personally relevant and meaningful and that climate change education should engage students. They were

able to identify four features that supported climate change education to go beyond science alone. The four features are (1) engaging in deliberative discussions, (2) interacting with scientists, (3) addressing misconceptions and (4) carrying out community projects. Deliberative discussion occurs when students engage in a meaningful discussion where they are able to debate and critique the views of themselves and others. This can occur when students debate climate change as a socioscientific issue (Dawson & Carson, 2020). Taking students outside of the classroom to interact with scientists (e.g. environmental scientists) and use real data promotes student engagement. Secondary school students can hold a range of alternative conceptions about climate change such as confusing the ozone layer with the greenhouse effect (Dawson, 2015). Holding these incorrect understandings can prevent them from further learning and inhibit their ability to make evidence-based decisions (Kurup et al., 2021). Providing opportunities to engage in local projects such as tree planting or global projects can lead to a sense of achievement and empowerment. The authors state that these features are best achieved in transdisciplinary projects that teach both scientific and social aspects of climate change.

In Australia, Eilam et al. (2019) developed a theoretical model based on the identification of essential characteristics of the nature of climate change and core climate change content. The nature of climate change was characterised as being complex and involving multiple system interactions, cross-disciplinary approaches, human action and a high level of uncertainty. They identified eight key climate change content themes that were organised along a continuum ranging from science-facts-based to humanity-based (and less science-facts-based) aspects of climate change. The eight key themes were: changes in the climate; drivers of climate change; future climate change; risks and impacts; adaptation and mitigation; socio-economic; policy and governance; and ethics.

Although not focused specifically on climate change education, the fourth model from a Delphi study on environmental education conducted by Clark et al. (2020) identified five core outcomes necessary for an effective environmental education program. After three Delphi rounds with experts in environmental education, the five core outcomes agreed upon were (1) actions and behaviour change, (2) connecting people to nature through outdoor education experiences, (3) improved environmental health through sustainable practices, (4) improved social and cultural aspects and (5) skills and competencies to engage with environmental matters.

The approach taken by Cantell et al. (2019) was to conduct an extensive literature review to identify the important components of climate change education which they presented as a bicycle model. They gathered evidence of the relative importance of each part of their model by 'road testing' it with 11 experts in climate and sustainability education. The bicycle model comprised wheels (knowledge and thinking skills), frame (identity, values and world view), chains and pedals (actions to reduce climate change), seat (motivation and participation), brakes (operational barriers), light (emotions and hope) and handlebar (future orientation). In terms of importance, the experts deemed knowledge, action, motivation and participation and emotions as most important.

Despite the different methodologies, sampling and research aims, there are some common themes across the climate change education recommendations from these synthesis studies. All advocate for an understanding of climate change and the associated science, thinking or transdisciplinary skills, values, outside experiences, behaviour

change and actions on climate change. Recently, other researchers (see, e.g. Reid et al., 2021; Rousell & Cutter-Mackenzie-Knowles, 2020), also recently recommend one or more of these climate change education dimensions. These five recommended models for climate change inclusions provide a useful framework for us to examine whether the presence of climate change in the school curriculum is sufficient and appropriate to prepare young people for their future lives.

Why include climate change within the curriculum

Climate change is widely accepted as the most pressing and challenging threat to humanity in the twenty-first century (Noss, 2002). The science of climate change has been incrementally accumulating over decades, with each period producing more substantiated and elaborated evidence regarding the scope and impacts of the climate change threats. In 1988, the United Nations' established the Intergovernmental Panel on Climate Change (IPCC) (Jamieson, 2014). Since then the scientific community's understanding of the climate and its intricate relationships with the economy, society and global politics has experienced a paradigm shift. In the twenty-first century, scientists unequivocally caution that there is no time to lose. Scientists highlight the importance of addressing the coupled human-Earth systems, by stating that 'mitigating and adapting to climate change while honoring the diversity of humans entails major transformations in the ways our global society functions and interacts with natural ecosystems' (Ripple et al., 2020, p. 11).

Various international organisations have noted the importance of educating the public and the younger generations in particular, regarding the severity and urgency of the climate crisis. Climate change education is repeatedly promoted by international bodies, which aim to influence government policies and provide strategic direction. For example, the Lima Ministerial Declaration on Education and Awareness-Raising highlights the importance of including climate change in school curricula (UNFCCC, 2014). This call has been reiterated in the 2015 Paris agreement, to which all countries participating in this study are signatories (UNFCCC, 2015). Article 12 of the agreement confirms that: 'Parties shall cooperate in taking measures … to enhance climate change education, training, public awareness, public participation and public access to information … ' (UNFCCC, 2015).

These international organisations, while being influential in shaping policies, have no statutory powers in relation to national curricula. From this perspective, they may be regarded as mainly inspirational. However, judging by the urgency, severity and universality of the climate crisis, it seems only natural to expect that curriculum developers across the world should pay attention to conceptualising, planning for, and including climate change within their curricula.

Climate change education in schools

Across UN countries, there has been progress in climate change education with climate change education occurring in almost all countries although using a broader definition than in this research (UNESCO, 2019). In their report, more than half of climate change education was occurring in education settings and this comprised primary,

secondary and tertiary settings. However, the most common approach to climate change education was public awareness (47%) compared to only 17% overall for formal education. There is a concern that public awareness programs are often voluntary, one offs and 'preaching to the converted' and often delivered to easy to reach metropolitan audiences. Further, the UNESCO report shows that cognitive learning (i.e. understanding and knowledge) prevailed not the social, emotional and behavioural aspects advocated by Mochizuki and Bryan (2015).

Most school-based climate change education research seems to focus on examining the perspectives of students and teachers as well as approaches to classroom implementation (Chang & Pascua, 2016; Dawson & Carson, 2020; Lombardi et al., 2016). When studies have attempted to investigate education policy documents and curricula, their findings consistently suggest that climate change is under-conceptualised and under-represented (Aikens et al., 2016).

A review of the literature reveals two important aspects related to the inclusion of climate change in national school curricula. The first is that leading official documents recommend the inclusion of climate change education in the curricula of year 7 and above (Arnould, 2013). This is illustrated in the U.S.A Framework for K-12 Science Education (National Research Council, [NRC], 2012), which emphasises the inclusion of climate change education in science for middle – (lower-secondary) and senior-secondary students. Similarly, UNESCO has supported this approach by developing a teacher training resource, entitled: 'Climate Change in the Classroom: UNESCO Course for Secondary Teachers on Climate Change Education for Sustainable Development' (UNESCO, 2013). The second aspect relates to approaches to climate change inclusion in the curriculum. The literature suggests that the most prominent approach to implementation is a broad cross-curriculum approach, in which climate change is dispersed across various curricular subjects (Lehtonen et al., 2019).

The finding that climate change education tends to commence in middle school, and that in these compulsory years it is mostly taught in science and geography, inform the rationale and motivation for this study. In middle school, students are aged about 11–15 years of age and are taught by specialist teachers with formal training in their subject areas. This period of early adolescence is where lifelong beliefs and values are formed and future career choices selected. The subjects of science and geography are the focus of this study as they are mandated high-status subjects compared to subjects such as outdoor education.

Aim of study

Drawing on our collective expertise as science education researchers, we aimed to compare and contrast six countries' approaches to climate change education in the middle school years of formal education through an examination of formal curriculum documents published by government authorities in Australia, Israel, Finland, Indonesia, Canada and England. By comparing these curricula, the study aims to develop a comprehensive overview regarding curricular approaches to climate change education in the middle years of schooling and subsequently make recommendations around curriculum development.

The research questions addressed in this study are:

1. How is the topic of climate change represented in science and geography across six countries/states?
2. How are approaches to representing climate change topics similar or different across the countries/states?

Method

This study uses a descriptive qualitative research methodology (Creswell & Creswell, 2018) using document analysis of primary sources, that is, formal published curriculum documents from national and state education organisations of the six countries or states. Each of the authors is science education researchers in their respective countries and conducted the data collection and analysis within each country. This helped to reduce language and interpretation issues and contributed to the credibility of the curriculum analysis.

Sample

The six countries were selected because of their broad representation of socio-cultural, socio-economic, religious diversity and language, suggesting potentially diverse approaches to climate change curriculum development and implementation. As each country has different school structures, the year group, age range and subject names vary from country to country. Table 1 summarises the year groups, age range and subject areas of focus for each country.

Data sources and analysis

This study analysed the formal published national or state curriculum documents (curriculum, syllabus and supporting documents) in science and geography in six different countries. In the first stage of analysis, the curriculum documents were examined for relevant terms, such as 'climate', 'climate change', 'global warming', 'greenhouse gases', 'albedo effect', etc. However, after the initial search, the researchers came to the conclusion that a broad word-search was not meaningful, as each curriculum was different in nature. For instance, some curriculum documents are more focused on content, while others may focus more on objectives or processes (Ross, 2000), resulting in a different level of detail. As an example, although more science is studied in Finland than in England, the Science curriculum in England is around three times longer than that of Finland. Therefore, the search terms were limited to 'climate change' and

Table 1. Middle year ages ranges and subjects for each country.

Country	Year group	Age range	Subjects
Australia	7–10	12–15	Science Humanities and Social Science (Geography)
Israel	7–9	13–15	Science and Technology Geography
Finland	7–9	13–15	Chemistry and Physics Biology and Geography
Indonesia	7–9	12–14	Natural science Social Science
Ontario, Canada	9–10	13–15	Science Canadian and World Studies (Geography)
England, UK	7–9	11–14	Science Geography

'global warming'. In addition to examining the context in which these terms were used in, the researchers also examined whether a clear connection to climate change could be made from other aspects of the curriculum. Namely, in the non-content-driven curricula, researchers noted cases in which sustainable development was discussed in a way that omitting climate change out of the discussion would be problematic. These nuances are presented in the results section. In the next stage, the subject, year groups and context in which the terms, climate change and global warming appeared were recorded. By context, we mean whether the term was used to denote a content topic, a theme or an example and whether it was compulsory or optional.

Results

In this section, for each country, a brief overview of the national curriculum status and structure is provided. The presence and context of the terms, climate change or global warming is summarised.

Climate change in the Australian curriculum

The Australian curriculum (Australian Curriculum Assessment and Reporting Authority [ACARA], 2021) was developed in 2012 and is currently undergoing a review. Science is one of eight learning areas and is typically taught for 3–4 h a week over four school terms in each year from 7 to 10. Science is comprised of three strands, science understanding, science inquiry skills and science as a human endeavour. The science understanding strand is made up of four sub-strands: biological sciences, chemical sciences, physical sciences and earth and space sciences. Geography is one of four areas of Humanities and Social Science and is typically taught over one school term in each year from 7 to 10. Geography has two strands, geographical knowledge and understanding, and geographical inquiry and skills.

Both science and geography have year-level content descriptions and elaborations. The content descriptions outline what students need to learn while elaborations provide examples of the types of content that could be learnt. It is not intended that all elaborations be taught. In addition to the learning areas, there are three cross-curriculum priorities, one of which is sustainability. The cross-curriculum priorities are intended to be taught, as appropriate over all learning areas.

The term, climate change, only appears as an elaboration in the Year 10 Earth and Space Science sub-strand on global systems (ACSSU189) through 'investigating the effect of climate change on sea levels and biodiversity … and … examining the factors that drive the deep ocean currents, their role in regulating global climate … .' In the year 10 science as a human endeavour strand, climate change is mentioned as an elaboration on three occasions (1) about models and theories being contestable (ACSHE191), 'considering the role of science in identifying and explaining the causes of climate change', (2) about advances in scientific understanding (ACSHE192), 'considering how computer modelling has improved knowledge and predictability of phenomena such as climate change and atmospheric pollution' and (3) using scientific knowledge to evaluate claims, explanations and predictions (ACSHE194) by 'considering the scientific

knowledge used in discussions relating to climate change'. Note that the numbers above denote the content descriptions.

In year 9 geography, the term, climate change is used as an example of a challenge to food security alongside land and water degradation, shortages of fresh water and competing land uses (ACHGK063). It is worth adding that although not specifically mentioning climate change, in year 9 inquiry and skills, students may reflect on and evaluate 'in response to a contemporary environmental challenge … ' (ACHGS071). In addition, in the year 10 topic environmental change and management, there is an outcome on 'human-induced environmental changes that challenge sustainability' (ACHGK070) plus 'the causes and likely consequences of environmental change' (ACHGK073) as well as 'management of the environmental change' (ACHGK074).

In summary, the topic of climate change is barely mentioned in the Australian curriculum in science (except for year 10 science as an elaboration (example)) only and in geography as an example of a challenge to food security and a possible example of environmental change. It could be surmised that although there are implicit opportunities for a teacher to choose to teach climate change it is not explicit or mandated.

Climate change in the Israeli curriculum

The Israel National curriculum for the middle years was developed in 2016 and has 15 subjects including Science and Technology (six hours per week) and Geography (two hours per week). Both subjects are Core (Knesset, Centre for Research and Information, 2010, 2015). The curriculum documents of each subject provide almost all the required resources for teaching. The information under each subject is organised into six strands of: (1) Administrative details; (2) Main topics; (3) Content knowledge, (4) Competencies such as interpersonal skills; (5) Values; and (6) Materials for teaching, learning and assessment. In Science and Technology, environmental literacy is an overarching theme and learning outcome embedded within the curriculum from its conceptualisation through to the content specifications.

Climate change is conceived as a topic of environmental literacy. Across Strands 1–5, the terms climate change and global warming appear four times. In Strand 6 (Materials for teaching, learning and assessment), climate change and global warming become more prevalent and there is an extensive list of resources across all three years (Government of Israel Ministry of Education, Sciences Branch, n.d.).

In the Geography curriculum, sustainable development is presented as a guiding value and an organising theme, with climate change being a topic of sustainable development. For example, under overarching goals, it states: 'Understanding and acknowledging the role of humans in modifying the landscape and protecting the environment' (p. 2) and the value goal states: 'Cultivation of values of respect for nature and the landscape, and enhancing awareness of the value of sustainability' (p.3) (Government of Israel, Ministry of Education, Portal for Education Workers/Pedagogical Space, n.d.).

The terms, climate change and global warming, are present throughout the curriculum documents at all year levels. As examples, in the content specifications, there are 10 appearances (six of which are in core topics), 7 of 34 digitised activities in year 7 relate to climate change; and climate change appears 79 times in the assessment kits. Overall, the extent of climate change topics includes all eight themes identified by

Eilam et al. (2019). That is, changes in the climate; drivers of climate change, future climate change, risks and impacts, adaptation and mitigation, socio-economic, policy and governance, and ethics.

In summary, both climate change and global warming appear extensively throughout the whole of middle years in both Geography (predominantly) and Science and Technology. This is facilitated, in part, by the overarching themes of sustainable development and environmental literacy, respectively. The inclusion of climate change in some digital resources and multiple assessment items assists teachers to explicitly address climate change.

Climate change in the Finnish curriculum

In Finland, students study 17 subjects in middle school (years 7–9). Science is taught as Physics, Chemistry, Biology and Geography (each taught 1–2 h a week, equalling 3.5 h a week in total) and Health Science (1 h a week). All schools in Finland follow the national core-curriculum, which municipalities and schools use as a foundation to build their own, more specified curriculum. This study focuses on the national core-curriculum developed in 2014 (Finnish National Agency for Education, 2014).

The Finnish National core-curriculum is value-based and one of the core values is to direct students towards a sustainable future. As climate change is a key barrier to a sustainable future, in essence, climate change education should be addressed in all school subjects. That said, climate change is explicitly mentioned only in the general section of the curriculum, as well as in biology and geography. In biology, content such as studying the habitats of animals (BI-T3) and observing changes in our environment (BI-T6) are tied to climate change. Furthermore, teachers should guide students to make ethical decisions (BI-T13) and encourage them to partake in societal discourse (BI-T14) regarding climate change and other environmental challenges. In Geography, climate change is made a cross-cutting theme, alongside other environmental themes, such as lifecycle assessment. Climate change should be tied to topics such as limited natural resources (GE-T4) and appreciation of the nature and biodiversity (GE-T11). In both biology and geography, climate change is also connected to participatory action (L7) (Finnish National Agency for Education, 2014).

Although climate change is not mentioned explicitly in physics and chemistry, in both subjects there is a strong emphasis on reaching a sustainable future, meaning that addressing climate change is implicit. For example, in Physics, the curriculum states that, 'students are guided to use their knowledge in physics to build a sustainable future and evaluate personal choices regarding the sustainable use of energy resources' (FY-T4) and in Chemistry, students need to 'use what they are learning in chemistry to build a sustainable future and to evaluate their own consumption choices from the perspective of sustainable consumption and products lifecycle' (CE-T4) (Finnish National Agency for Education, 2014, p. 389, 394). In both cases, it can be argued that these themes cannot be fully addressed without examining them from the perspective of climate change.

In summary, the national curriculum in Finland provides opportunities to incorporate climate change issues into all science subjects. However, other than in biology and

geography, teachers are given the freedom to decide how big of a role they think climate change plays in building a sustainable future.

Climate change in the Indonesian curriculum

The Indonesian middle school curriculum (developed in 2013) has eight core subjects which include Science and Social Studies (Ministry of Education and Culture, 2014). Natural science is offered 5 h a week in middle school. Natural science (also known as *IPA Terpadu*) refers to an integrated and holistic body of knowledge about the universe from science studies of biology, physics and chemistry. According to Mnguni et al. (2020), science prepares students to understand issues within society and stimulate changes of action for a better society. The natural science subject is comprised of 33 basic competencies or 33 topics in the curriculum, including understanding the causes and effect of climate change in year 7. The climate change unit is taught for one term over 7–15 lesson-hours with two basic competencies:

1. Basic competence for knowledge dimension: analysing climate change and its impact to the environment.
2. Basic competence for skills dimension: writing a paper about climate change adaptation and mitigation (Ministry of Education and Culture, 2018).

The content taught in the year 7 unit covers:

- The definition of greenhouse effect.
- The causes of greenhouse effect.
- The greenhouse effect mechanism.
- The definition of global warming.
- The causes of global warming.
- Global warming effect to ecosystem.
- Human contribution in global warming issue (Ministry of Education and Culture, 2020).

Typically, teachers tend to emphasise the greenhouse effect and global warming discourses and not explicitly climate change issues or concepts. This is due to a dependency by teachers to rely on textbooks where the concepts of the greenhouse effect and global warming are emphasised. In respect to this unit, students are (1) expected to collect various information about climate change, (2) analyse cause and effect of climate change towards the ecosystem and (3) propose ideas about addressing climate change in both a written and oral report.

Social science is taught for 4 h a week and neither climate change nor global warming is mentioned. Social science is taught in an integrated way encompassing sociology, history, geography and economy. The geography aspect of social studies relates to natural resources, economy and socio-culture.

In summary, while the Indonesian science curriculum has a whole year 7 unit on climate change which includes content on causes of global warming, ecosystem impact, human contribution and ways of tackling climate change, the widespread use

of textbooks by teachers means the focus is largely on the science of the greenhouse effect and global warming.

Climate change in the Ontario, Canadian curriculum

In the province of Ontario, Canada, students attend elementary school until year 8 and secondary school commences in year 9, hence the focus on years 9 and 10. The Provincial curriculum was introduced in 2007 and is divided into nine compulsory subjects including Science and Canadian and World Studies (where Geography is located). In addition, there are seven transferable skills that include global citizenship and sustainability.

In Geography, the term, climate, as linked to climate change is mentioned explicitly six times in the year 9 and 10 curriculum in sample questions to develop geographical skills. The term, climate change is mentioned explicitly 43 times in the year 10 science curriculum in the Understanding Earth and Space Science: Climate Change (Academic) and Earth's Dynamic Climate (Applied) (Ontario Curriculum Grades 9 and 10 Science, 2013). The outcomes for the Climate Change unit are:

- Global climate change is influenced by both natural and human factors.
- Climate change affects living things and natural systems in a variety of ways.
- People have the responsibility to assess their impact on climate change and to identify effective courses of action to reduce this impact (p. 78).

The outcomes for the Earth's Dynamic Climate unit are:

- Analyse effects of human activity on climate change, and effects of climate change on living things and natural systems.
- Investigate various natural and human factors that have an impact on climate change and global warming.
- Demonstrate an awareness of various natural and human factors that contribute to climate change and global warming (p. 90).

In summary, the Science curriculum has a compulsory year 10 unit on climate change for both academic and applied streams ensuring all students potentially receive a comprehensive understanding of the causes and consequences of climate change. Students also have opportunities to identify ways of reducing climate change.

Climate change in the English curriculum

In England, the national curriculum (developed in 2014) consists of a set of subjects which are standard for primary and secondary schools. All local-authority-maintained schools in England must teach the national curriculum. The blocks of years are called *key stages* (KS) and the curriculum covers which subjects should be taught and the standards children should reach at the end of the key stages. In secondary school, Key Stage 3 (age of 11–14) covers years 7, 8 and 9 and Key Stage 4 (age of 14–16) covers years 10 and 11. The focus of this analysis is Key Stage 3. There are 12 compulsory subjects including

Science at 3–4 h a week and Geography with 1–2 h a week (Department for Education [DfE], 2014).

Environment-related topics in the national curriculum are limited to the subjects of chemistry, biology, physics, design and technology, and geography. Climate change is explicitly mentioned in the national curriculum within the subject content of Chemistry under the topic 'Earth and atmospheric science' and Geography under the topic of 'Human and physical geography'. While the term, environment, appears within several subjects and topics, global warming does not appear as an explicit phrase in the Key Stages 3 and 4 Framework Document (DfE, 2014).

In the KS3 Chemistry curriculum within the topic of Earth and atmosphere, it is stated that students should be taught about ' … the production of carbon dioxide by human activity and the impact on climate' (DfE, 2014, p. 64). In KS3 Geography, within the topic of Human and physical geography, it is stated that students should be taught about, ' … weather and climate, including the change in climate from the Ice Age to the present; and glaciation, hydrology and coasts' and ' … how human and physical processes interact to influence, and change landscapes, environments and the climate; and how human activity relies on effective functioning of natural systems' (DfE, 2014, p. 92).

In summary, climate change appears minimally in years 7–9 in England. In Science, climate change is likely to be portrayed as a scientific phenomenon while, in Geography, anthropogenic climate change receives minimal attention.

Discussion

As stated previously, the aim of this study was to investigate and compare and contrast how the topic of climate change or global warming was represented in the formal middle years' curriculum documents of science and geography subjects across six countries. The intention is not to criticise a country's curriculum nor claim that one curriculum is better than another. Rather, the intention is to determine whether the breadth and depth of curriculum on climate change are likely to be sufficient when compared to theoretical models in the literature review. On a positive note, the term, climate change, is present in the curriculum of all countries in science and/or geography. In all countries except Israel, climate change occurs predominantly or solely within the science curriculum.

Both Indonesia (year 7) and Ontario, Canada (year 10) have specific science units dedicated to climate change which examine the science of climate change, human impacts, and adaptation and mitigation. The Canadian science unit is the most comprehensive in terms of breadth and depth of content as it includes climate change science, its impact on living things and the natural environment and the role of humans in causing and acting to reduce the impact. The Canadian students' older age and longer prior science education may also enable a deeper understanding and engagement with issues compared to the younger year 7 students in Indonesia. In Finland and Israel, similar aspects are addressed, but they are implemented into different parts of the science and geography curricula rather than being in a specific unit. This may make it difficult for students to develop a comprehensive understanding of climate change. In contrast to Finland, Canada, Israel and Indonesia, climate change is barely mentioned in the curriculum documents of Australia and England. When mentioned, climate change is likely to

be presented as a context for other science concepts and skills and more likely to be optional or implicit.

The fields of science and geography address the topic of climate change in different, but equally important and complementary ways. These differences are due to the fact that each field has different goals, and is based in a different epistemology (i.e. a different perception of what knowledge is and how it is constructed). The goal of science education, for instance, is to promote scientific literacy, which includes both core ideas in science, and an understanding of scientific practices. In the context of climate change, this means understanding the mechanisms that exist within and amongst earth's various systems, and the evidence that we have acquired – using scientific observation and models – regarding the changes that are occurring in these systems. Geography, in contrast, is an interdisciplinary field that stands at the intersection between the 'hard' sciences and the social sciences. Its goals are therefore to foster understanding of phenomena that arise within the physical space (earth systems) but have strong relations of mutual influence with the social sphere (human dimension). In the context of climate change, this means, for instance, studying the impact of physical phenomena like droughts and dust storms on social phenomena like population migration due to desertification. Geography is thus well suited to studying global environmental challenges and their attempted solutions – such as addressing environmental inequality by looking at differences between the 'carbon footprint' of countries with different levels of industrial development.

We believe that climate change education must incorporate a combination of both these approaches. On the one hand, developing a strong foundation of scientific literacy is critical to achieve climate literacy (Hestness et al., 2014; Shepardson et al., 2012). Various studies have demonstrated the importance of understanding scientific earth system mechanisms (Jacobson et al., 2017) and acquiring scientific practices like argumentation (Dawson & Carson, 2020) to the study of climate change. On the other hand, as Mochizuki and Bryan (2015) argued, scientific knowledge alone is not sufficient to understanding this topic's full complexity. Mehren et al. (2018) similarly argued that complex phenomena such as climate change require cognitive models that incorporate natural, social and human-environment systems. These two arguments echo the view that this interdisciplinary phenomenon requires an interdisciplinary approach.

Research on best practice in climate change education (e.g. Cantell et al., 2019; Mochizuki & Bryan, 2015) advocates for an education that goes well beyond climate science and includes ethics and values, social, economic and political aspects, emotions and behavioural changes. All of the countries' curricula seem to prioritise climate change science above these other aspects. Therefore, based on the curriculum analysis, it seems that in most countries, teachers are not provided with an imperative to teach climate education broadly and extensively.

There are several reasons why climate change may not be given the prominence in school curricula that would be expected given its real impact on our current and future lives. Although climate change education can be seen to be prioritised under the international umbrella of UNESCO and the UN Sustainable Development Goals, and the mandate of 'education for sustainability', in some countries such as Australia, there is an increasing policy and practice focus on international testing programs such

as PISA. This means that state-level, education sector and school-level plans now tend to emphasise literacy, numeracy and science knowledge content at the expense of pressing social concerns (Aitkens & McKenzie, 2021).

Increasingly, other contemporary science-based topics such as genetic diseases and reproductive technologies are competing with climate change in science classrooms. Similarly, for geography, topics such as biodiversity, urbanisation, and soil and water quality may be considered more important and contemporary.

The politics and culture of a country may also affect the extent to which climate change appears in the school curriculum. The government through educational policy development and education funding drives curriculum development which may limit the extent of climate change education. Most countries have an overcrowded curriculum and climate change is competing with topics such as atomic theory, Newton's laws of motion and natural selection that have been taught in schools for decades.

Limitations

There are several limitations which need to be considered. There is a limit to what can be inferred from an examination of national curriculum documents even though the authors understand the context of their respective countries. Thus, we are not able to comment with certainty on the actual implementation of climate change in middle school science and geography. It is recommended that in future research, Ministry of Education curriculum stakeholders as well as teachers responsible for classroom implementation be interviewed. This would lead to clarity about the extent to which climate change is actually taught in schools, plus the enablers and inhibitors to climate change education. In addition, an examination of local textbooks, curriculum resources and assessment materials is needed.

We understand that by focussing on the middle years of schooling we may have missed climate change topics in other year groups between Kindergarten and year 12. We are aware that in Western Australia, for example, there is an Earth and environmental education course in years 11 and 12. However, these subjects are not compulsory. Given that science is only taught for about an hour a week in primary schools by non-specialist teachers it also seemed unlikely that there would be widespread teaching of climate change. It may also be possible that climate change education appears in subjects other than science and/or geography. We also acknowledge that by not searching for other climate-related terms such as environmental change or sustainability, we may have missed potential climate change topics. Some countries such as Finland address sustainability education extensively of which climate change is a part. Thus, we may have underestimated the extent of climate change in the curriculum.

Recommendations for policy makers engaged in curriculum reform

Our findings indicate that some countries are better enabling teachers and schools to support their young people in these uncertain futures. Mandated curricula set the intent for what teachers can explore in classrooms. Ensuring that the curricula provide the appropriate focus and yet also the opportunity to explore concepts with localised examples is increasingly relevant, given the urgency of our global crisis (UNFCCC,

2014). As stated in the introduction, schools carry the responsibility to engage our young people in developing understandings about contemporary issues that interconnect with everyday experiences (Young, 2013). Schools require contemporary curricula to enable effective educational architecture (Chang & Pascua, 2016) to ensure teachers can scaffold student learning (Ecclestone, 2013). Teachers require carefully constructed curricula direction and then support if they are to then develop meaningful and personally relevant learning opportunities for their students (Monroe et al., 2019). This is lacking in all countries examined in this research.

Although there is a strong argument for climate change education opportunities to be deeply and emphatically embedded in our geography and science curricula, they are not in many countries. The concepts involved in climate change may be present in science or geography; however, they lack the opportunistic and depth of embedding that is required for the necessary reforms. Despite resourcing and guidance from many organisations, including the OECD and UNESCO it is necessary to ensure ongoing and significant policy support for climate change education. This is only one way that our young people can feel more supported to engage in proactive ways with their uncertain futures.

Recommendations to schools and teachers in enacting climate change education

Based on the urgent need for young people to understand and act on the consequences of climate change in science and geography it is recommended that climate change become a compulsory topic in middle school science and geography. These two subjects are recommended because of their high status and value in schools as well as the expertise of science and geography teachers to address the underlying science of, for example, energy use, sea level rises, severe weather events and greenhouse gases. In relation to an overcrowded curriculum, opportunities to teach climate change need to be seized upon. In countries like Australia, there are multiple opportunities to introduce climate change into middle school science and geography. Teaching an understanding of topics such as water quality, and natural disasters such as floods, bushfires, heatwaves and drought can occur with the role of climate change being made explicit.

Age-specific curricula support is necessary to ensure schools and teachers can enact locally relevant learning opportunities that empower and engage young people. While Indonesia offers climate focussed science at year 7, the more comprehensive curricula from Ontario, Canada are left to year 10. The urgency of the climate crises drives an imperative to ethically and morally educate our young people as soon and as well as possible.

Similarly, distributing the curricula opportunities across science and geography might provide a breadth of learning opportunity, as in Finland and Israel. However, it is an interdisciplinary and deep-learning experience that enables personal connection to the impacts we are mostly all experiencing now that is essential. Reflecting the urgency of the situation and the need for immediate change from the policy level right down to our everyday practices and beliefs towards a sustainable and climate-aware living practice are imperative. In addition to the considerations of positioning learning about our global crises in disciplinary ways, we must overlay the need to engage in values, social, economic and political aspects that include emotional and cultural implications, including climate anxiety (Verlie, 2022)

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