TEACHING THE FUTURE

Report: Teaching the future – climate, citizenship and digital teaching

Curriculum and pedagogical guidelines

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1. Introduction

Teaching a topic like climate change education should be based on up-to-date scientific information and data, much of which is not published in formats that schools and teachers can easily use. Technological innovation and the publication of the latest data and information takes place online and at a pace much faster than schools and education have generally been able to embrace.

The Teaching the Future project addresses the need for accurate and reliable online information essential in a functioning democracy. Scientific evidence relating to the climate system and the impact that people might be having on it spans many fields of study and includes work from thousands of scientists and research centres. The evidence comes from decades of intensive research and is based on observations, field and laboratory experiments, and model simulations.

Many aspects of climate have been published, including how the climate system works, what is happening to it, why (the role of natural and human influences), what may happen in the future, what the consequences could be for natural and human systems, and what could be done to manage the risks.

The assessments of climate change are scientifically rigorous, produced using transparent processes. Efforts to discredit them with audiences that are unfamiliar with the underlying science or the processes used in preparing them have resulted in a lot of misinformation, disinformation and fake news. Due to this mass of mis-information, it is important that education and teachers are able to recognise the challenges and create learning that critically deals with the validity of information.

Trust is a very important factor in climate education. Trust is closely based on teachers skills, understanding and beliefs about their capacity to determine the whether the information and data found online is reliable and authentic, so that it can be used in their classes. Result 1 is thus an instrument to assess the situation in secondary schools as well as the national curricula in partner countries. It will examine and illustrate participative approaches to involve pupils in active citizenship activities and in teaching and learning approaches. The purpose is to be able to offer relevant trustworthy climate education with suitable and reliable pedagogical approaches and tools.

This is the first result of the Teaching the Future project which seeks to set the tone for all project activities, providing a framework for school institutions and teachers on how to introduce climate science education in their classes.

A focus group methodology and templates to engage groups of teachers in schools was proposed. The approach was developed initially at the project kickoff meeting and further adjusted in online follow up meetings. The templates included a number of sample questions for the focus groups to discuss and interviews carried out with teachers. Each focus group of teachers from secondary schools explored current modes and challenges related to climate education at school, the sessions sought to facilitate discussion on aspects of climate readiness, the topics, curriculum, resources, needs and concerns.

The purpose was to allow a better understanding how different schools and countries would be capable of dealing with climate education. A review of national curricula was undertaken to compare the situations in different countries

Desk-based research was undertaken by all partners in the form of a review of latest peer reviewed published academic literature on climate education, methods, approaches, tools and resources in order to recommend the types of teaching and learning approaches for climate change education and active citizenship. An analysis of techniques like citizen science has been undertaken as well as the identification of some useful existing resources and tools used by schools.

This result seeks to provide recommendations to support the types of training and training content needed for teachers as well as preparing the ground for the implementation of the rest of the project. The report offers a comprehensive pool of knowledge able to provide a clear direction to the remainder of the project.

2. Review of academic literature

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Early in 2020, nine-year-old Sophie asked her teacher
“Is it true we’ve only got ten years to save the planet?”

In that moment, her teacher was unsure what to say…..
(Kirby and Webb, 2021)

Summary

The elements and facts that lead to the necessity of promoting the idea of introducing/ adopting Climate Change Education in schools are dealt with in Chapter 1. These aspects support the idea that Climate Change Education should include both scientific as well as social and moral features.

The state of the art concerning the aspects of interdisciplinary approaches and the place of Climate Change Education in the school curricula is described in Chapter 2. This leads to the need for approaches for training teachers so that they are able to work collaboratively and complementing each other.

Chapter 3 refers to various pedagogical approaches that seem fruitful for Climate Change Education in schools. These approaches extend the current demands of teaching practices to areas that are far beyond the practices used in traditional classes, thus demanding further ideas and developments in the process of training the teachers. The emphasis should be on developing and enhancing skills for critical thinking, innovation and research.

The identification of references and supporting material for Climate Change Education is essential in the process of considering it at the school level and there are already some interesting Ideas. This is addressed in chapter 4. It will be crucial to provide opportunities that are able to build on these ideas and develop further material with a clear emphasis on local issues and challenges, as well as local solutions.

These comments are in line to the ideas of professional development of teachers and the literature for this offers basic ideas for developing a training course for them.

The examples presented in chapter 6 are an essential resource which can be used in helping teachers to enrich their teaching, as they constitute paradigms for understanding and further work.

The recommendations provided in chapter 7 constitute a useful text that should target decision makers, including teachers as they respond to local conditions.

A. Introduction

Today, many young people live in fear of climate change. It has become **the defining global issue**. Owing to its wide-ranging and often catastrophic consequences, it is arguably the challenge around which every other issue revolves (Roemhild and Gaudelli, 2021). Climate change is not only a challenge to sustainable development, but it is also a human rights issue, because its effects compromise the dignity of those driven out of their homes by rising sea levels and desertification.

Climate change can be understood as a complex social as well as scientific issue characterized by uncertain and context-specific knowledge (Stevenson et al. 2017). Climate change education is about **learning in the face of risk, uncertainty and rapid change**.

According to UNESCO (2022), education is crucial in helping people understand and cope with the effects of climate change and to encourage changes in attitudes and behaviours needed to tackle the causes of climate change, to adopt more sustainable lifestyles and to develop skills that support different economies, as well as to adapt to the effects of climate change.

The educational sector has an important function in addressing climate change as a global issue, Facer (2019) confirmed **schools have a critical role to play in mitigation of and adaptation to climate change** and a responsibility to deliver education about it.

Mitigation requires making significant reductions in greenhouse gas emissions over the next 5-10 years in order to prevent runaway climate change. Adaptation requires us to develop not only infrastructural changes, but also to encourage the creative invention of new ways of living on a 'lively planet' (Ghosh, 2016). Karsgaard and Davidson (2021) maintained that the dominant approaches used in climate change education have been obsolete and that they constitute inefficient courses of action on climate change mitigation. Drewes et al. (2018) suggest educational institutions are crucial spaces for alternative norm development, and thus the visualisation of alternative futures.

Developing **education about climate change is complex and interdisciplinary**. It should include relevant content knowledge on the climate system, climate science, and on climate change impacts (Drewes et al., 2017). It also requires the following components to be considered: issue analysis, community and personal decision-making, political processes, social justice, inter-cultural sensitivity and inter-cultural competence, citizenship, behaviour change, stewardship, and connections between climate change and economics (McKeown and Hopkins, 2010).

Mainstreaming climate change education throughout formal education systems would be one of the most important and effective means of developing capacities for addressing the climate crisis (Stevenson et al., 2017). The complexity of the problem and the uncertainty of ways of responding means it is best addressed through curricular and pedagogies that fully **allow students to explore the nature of the problem, discuss and debate appropriate pathways forward and take positive actions**. However, generally there is a lack of sufficient time and curriculum opportunities to address climate change in the classroom. This suggests a need for using co-curricular and community initiatives for student investigations and learning.

Classrooms should be oriented towards taking up the challenge of rethinking the world (Kagawa and Selby 2010) while encouraging 'out-of-the-box' thinking (Glasser 2007).

A.1 The Climate Education Challenge

The educational response to climate change is highly uneven, with recent research showing a patchwork of reactions leading to differing levels of implementation (Lee et al., 2015). Nevertheless, it appears that some new educational approaches are beginning to emerge as educators work to engage climate change by shifting norms and practices (Shea et al., 2016).

Leal Filho and Hemstock (2019) examined the problems affecting climate change education, they confirmed teaching staff at both universities and at schools lacked confidence in their personal subject knowledge, and some of them felt that they were unprepared for the integration of action-based activities and content knowledge that characterises climate change education (Table 1).

Table 1 - Some of the problems that hinder the pursuit of climate change education (Leal Filho and Hemstock 2019)

Problem	**Impact**
Complexity & scale	Climate change relates to a variety of atmospheric, meteorological, social and economic factors which makes it a complex issue. The scale of climate change causes and impacts can be seen as overwhelming and individual acts can be rationalised as being inconsequential.
Lack of training and professional development opportunities	Not all teaching staff have the training or feel qualified to engage on climate change teaching
Limited teaching resources	The restricted availability of specific teaching resources which may clearly communicate on climate change in some countries
Curriculum constraints	Lack of flexible time-tables to allow discussions on climate change; inflexible and politically biased state curricula
Competing themes	Climate change needs to compete with a variety of themes which are equally important
Limited institutional support	In many cases climate change is on the one hand perceived as important, but institutional support to it is limited, which inhibits progress
Scepticism and controversy	Lack of interest to tackle the topic; fear of being controversial

The variable implementation of climate science instruction can thus be partly attributed to the unreliable depth of teacher disciplinary knowledge and preparation (Holthius et al., 2014). According to Kamenetz (2019), teachers stated that climate change and related issues were outside of their subject curriculum and normal area of expertise. Prior education research has shown that teachers are often not informed about climate science from their own educational backgrounds, and that this lack of familiarity presents challenges to addressing the subject in their classrooms.

Johnson et al. (2008) found that **teachers have a critical need for credible climate science content and age-appropriate hands-on activities that focus on local perspectives** and not just global averages. Teachers should also recognise their own personal emotional responses to the issue and those that might be held by their students are significant to whether attitudes and behaviours can be changed (Lombardi and Sinatra, 2013).

Tolppanen and Aksela (2018) highlighted the challenges involved in responding to students' climate change questions. One of the main concerns was that climate change is a complex issue involving environmental, cultural and political understandings as well as values that are partly reflected in students' questions which often touch on several different aspects simultaneously. In cases when teachers avoided discussing the affective components of climate, in an effort to minimise controversy, the students missed out on meaningful connections, deeper personal engagement, and improved emotional perspectives on the issue (Hufnagel, 2015).

Busch and Osborne (2014) analyse complexity and scale as two specific obstacles for teaching and learning about climate change. They state that climate change is a complex phenomenon that involves interdisciplinary knowledge and students find it difficult to draw from the knowledge taught in different school subjects to explain it. They highlight that data about global warming is usually presented operating with scales – both temporal and spatial – that are outside of students' daily experience.

Kamenetz (2019) reported that teachers were concerned with the complication of introducing climate change due to the political ideology that underlie this topic. Many reported on the difficulty of addressing climate related issues considering that some of their students' parents were deniers of climate change. The teachers that did not talk about climate change maintained that it is not their job to teach about it and those that did talk about climate change were also likely to say:

1. There should be laws that require teaching it
2. They have the resources they need to answer students' questions about climate change
3. Their students had brought up climate change in the classroom and
4. Their school encourages them to discuss climate change.

Karpova and Shahriar (2021) analysed the need for new educational approaches to increase environmental awareness of citizens and employees due to a general lack of knowledge among citizens (especially focusing on younger generations) and their underestimation of the current state of the environment. They highlighted the urgent need for an educational approach / changed curricula that would enforce or support the attitudes of youngsters towards more eco-friendly behaviours.

A.2 The challenge of teaching and learning about climate change

The purpose of undertaking this review of academic and professional literature is four-fold:

1) there is an enormous amount of information and data without any assessment of the feasibility of its use in teaching;
2) teaching about climate change in an era when climate has become a major politicized issue is a major challenge and goes beyond scientific understanding;
3) there is a lack of general agreement on the usefulness or validity of the existing strategies and pedagogical approaches to develop valid climate change education; and
4) there are deeply rooted misconceptions about the causes of climate change that in turn affect youth behaviour.

Article 12 of the Paris Agreement acknowledges the role of education as an important means to achieve the ambitious goals set by COP 21. Specifically, that education can contribute to fostering a better understanding of and ability to address climate change and its effects; promoting community

engagement, creativity, and knowledge in finding climate change solutions; and engaging all stakeholders in debate and partnership to respond collectively to climate change (Busch et al. 2019).

Teaching a topic like **climate change education needs to be based on up-to-date scientific data and information**, much of which is not published in formats that schools and teachers can easily use. Technological innovation and the publication of the latest data and information takes place online and at a pace much faster than schools and education have generally been able to embrace.

Climate Change Education and awareness-raising can be used to empower apprised decision-making, play an essential role in increasing adaptation and mitigation dimension of societies, and empower young people to utilize sustainable lifestyle (Karpova and Shahriar, 2021).

The Teaching The Future project aims to address the need for accurate and reliable online information essential in a functioning democracy. Scientific evidence relating to the climate system and the impact that people might be having on it spans many fields of study and includes work from thousands of scientists and research centres. The scientific evidence for climate change comes from decades of intensive research and is based on observations, field and laboratory experiments, and model simulations. Many aspects of climate have been published, including how the climate system works, what is happening to it, why (the role of natural and human influences), what may happen in the future, what the consequences could be for natural and human systems, and what could be done to manage the risks.

Lozar and Tonan (2019) confirm climate science and climate education is a complex interdisciplinary field of knowledge, to which many scientists from different fields can contribute. Climate assessments are scientifically rigorous, produced using transparent processes. Efforts to discredit them with audiences that are unfamiliar with the underlying science or the processes used in preparing them have resulted in a lot of misinformation and fake news. Due to this mass of mis-information, it is important that education and teachers are able to recognise the challenges and create learning that critically deals with the validity of information. Trust is a very important factor in climate education. Trust is closely based on teachers' skills, understanding and beliefs about their capacity to determine the whether the information and data found online is reliable and authentic, so that it can be used in their classes.

This review therefore aims to be an instrument to assess the situation in secondary schools as well as the national curricula in partner countries. It seeks to examine and illustrate participative approaches to involve pupils in active citizenship activities and in teaching and learning approaches. The purpose is to be able to offer relevant trustworthy climate education with suitable and reliable pedagogical approaches and tools. This review aims to set the tone for all project activities, providing a framework for school institutions and teachers on how to introduce climate science education in their classes.

A.3 Climate Change Education and Policy

Effective climate politics rely on public understanding and support for climate change mitigation (Meya and Eisenack, 2018). Empirically, climate change awareness is an important determinant of public support for climate policies (Rhodes et al. 2017). However, while scientific knowledge on anthropogenic interference with the climate system is increasingly consolidating, this does not automatically carry over into public awareness of the issues. On the contrary, some studies showed **relatively ow levels of public concern about the environment** in general (Hidalgo-Crespo et al., 2022; Bakaki et al., 2020; Franzen and Vogl 2013) **and about climate change** in particular in the US

and Western Europe since the mid 2000s (Arıkan, G. and Günay, 2021; Capstick et al., 2015; Stoutenborough et al. 2014). This calls for the implementation of innovative ways of science-based climate change communication and teaching.

According to Greer and Glackin (2021) policy plays a crucial, but frequently under-acknowledged, role in guiding what happens in our schools. They illustrate the layered role of Climate Change Education from policy influencers' perspectives (Figure 1), consisting of i) knowledge, generally identified in science and geography, ii) 'capabilities' which emphasises the development of young people's capabilities for living in the context of climate change and iii) expansive places education within the climate crisis and integral to society's climate change response.

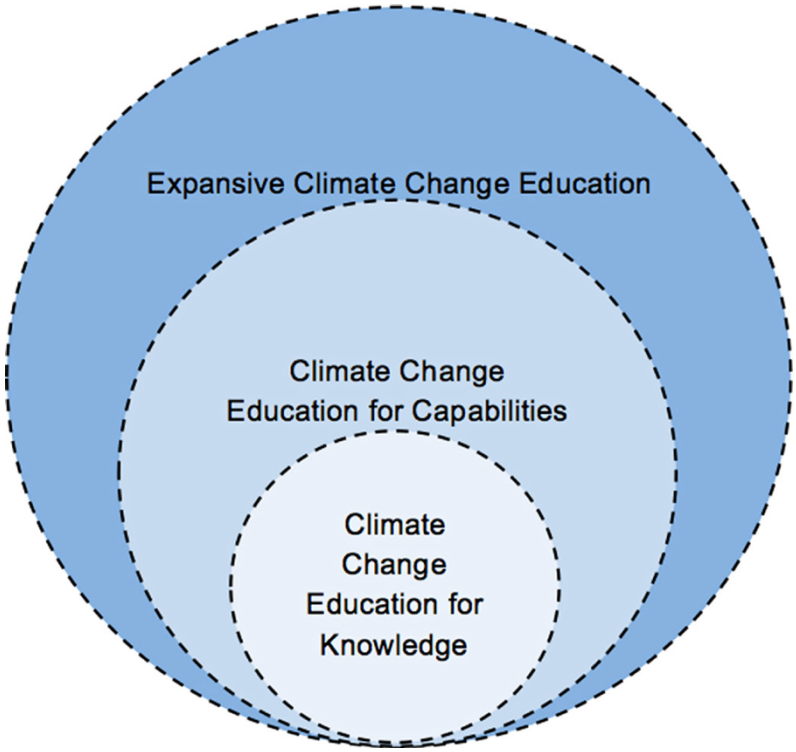


Figure 1 Three nested layers of influencers' views as to the role of climate change education

They discuss the views of (education) policy influencers in England on what climate change education is or should be. The policy influencers suggested the qualities of meaningful climate change education should ensure:

1. **alternative visions** of the future and alternative approaches to education (not linked to perpetual economic growth)
2. actions that **accept and embrace complexity**, and recognise (in ways appropriate to students' ages) the trade-offs associated with mitigation and adaptation, disaster risk and social justice (Stevenson et al., 2017).
3. **multiple types of knowledge** (Kagawa and Selby, 2010). This includes disciplinary knowledge that aligns with traditional school-based curricula, such as that taught in science or geography, as this supports students to establish a foundation for richer understandings, as well as teaching and learning across a wider range of disciplines and bridging disciplinary boundaries – including how to critique knowledge. This also emphasise the importance of developing young people's spiritual and emotional knowledge (Ojala, 2016).
4. a **re-orientation towards justice**, rather than climate change education fixating upon scientific knowledge, and climate change solutions being found in science and technology - recognising both global and local perspectives

5. **ecological worldviews are developed**, involving revisiting and transforming the relationship between humans and the more-than-human world, that is, with all other species on Earth, the rights of other species, and the importance of such recognition for their own and future generations' survival (Sterling, 2017).
6. **students are recognised and supported as agents of change**. This would require viewing students as more than recipients of information and observers and future inheritors of climate change-related problems

Feinstein and Mach (2020) commented how education can be a powerful tool in enabling effective adaptation to climate change. They identify three distinct but overlapping policy uses. Firstly, education can reduce community vulnerability and build resilience. Second, improving general education, measured in terms of literacy, school attendance, and overall academic attainment, can enhance adaptive capacity. Third, research-based adaptation learning support can accelerate social and policy change by maximizing learning before and during adaptive decision-making. They suggest the unique and transformative contribution of education lies in **preparing people for complex adaptive decision-making** and help them balance mechanisms that ensure stability with those that facilitate change.

Climate justice is a concept that addresses policies that encourage the just division, fair sharing, and equitable distribution of the benefits and burdens of climate change. It insists on a shift from a discourse on greenhouse gases and melting ice caps into a civil rights movement with the people and communities most vulnerable to climate impacts at its heart. McGregor and Christie (2021) consider the growth of this movement and the ways in which different stakeholders perceive challenges to, and opportunities for, developing climate justice education. They explore the potential for recognising activism and civic engagement as an educational process, considering both activists' views on education and educators' views on activism in this context. The activists recognised the potential for connections to social movements (especially youth-led movements), local communities, and addresses the affective dimensions of the climate crisis. Teacher participants were much less well informed about climate justice as a concept and were more ambivalent about the prospect of learning through and from activism.

Karpova and Shahriar (2021) recommended the following key climate policy measures:

1. Implementation of key rules and regulations at local and national level
2. The involvement of businesses in eco-friendly activities and on its promotion
3. More and stronger social advertising campaigns
4. The integration of climate-based education in school and university curricula, having in mind its interdisciplinary nature and
5. To develop educational apps to inform citizens about local and global climate occurrences.

A.4 Climate Change Denial

In today's society, there are powerful forces responsible for the spread of climate change denial (fossil fuel industry, conservative think tanks, etc.), which are based on political and economic powers. Such entities, organise climate change denial campaigns, which challenge the social construction of climate change as a problem. Moreover, Weart (2011) confirmed the denial discourse often cites questionable "scientific" counter evidence about alternative causes of global warming (not human responsibility) and fosters polarising perspectives designed to question the legitimacy of environmental problems. In such a context, a number of books for children have been

published, designed to counter the use of climate change education curriculum and media (Cooper, 2011).

Karpova and Shahriar (2021) addressed the lack of governmental policies that might prevent an undermining of the importance of climate change mitigation and (even if involuntarily) supported the current behaviour of the general population and businesses that undervalued the necessity of solution for the climate change. They concluded that by means of specific climate change education curricula and the use of transparency and accountability laws, diverse countries have shown their engagement in creating better environmental situation.

A number of studies focused on the misconceptions and 'alternative conceptions' about climate change held by students, teachers and scientific textbooks, reviewing the impact of climate change denial. Colston and Thomas (2019) undertook a critical discourse analysis with the aim of examining climate change denial books, specially directed towards children in order to see the effect such texts have on the creation of behaviours of children. They based their research on the diverse types of scepticism found in adult directed discourses, analysing the methods or strategies used on adults in order to identify whether or not they appear in the children's books. The authors revealed the rhetoric and translation of climate change denial for youth audiences, they highlighted the way in which linguistic choices interacted to (re)produce the social reactions, ideologies, and power dynamics sustained by organised climate change denial campaigns. This study revealed the **clear danger of organized climate change denial campaigns** that can reconfigure the core values of environmental citizenship along the focus of economic development at all costs.

Colston and Thomas (2019) examined climate change denial books, specially directed towards children in order to see the effect such texts had on the creation of behaviours. They analysed the methods and strategies used on adults and examined whether or not they appeared in the children's books. They found common arguments related to climate change scepticism campaigns and denial. The basic arguments were rooted on uncertainty strategies that used denial, needing information, tolerance, assimilation and acceptance as arguments that support the idea of coping with climate change rather than doing something about it. Pseudo-scientific claims were used to undermine science while asserting science authority. Furthermore, questions about who pays the cost of policy actions, whether we should decentralise or centralise the system, and whether the costs of acting outweigh the benefits were used. These were based on economic development, regarding climate change as a problem in the political realm instead of one that needs to be urgently solved. Case studies of climate change denial texts pointed to the rhetorical currency of politicizing, deconstructing, and delegitimising the scientific consensus about global warming.

To sum up, this study revealed the clear and present danger of organised climate change denial campaigns that can translate the core values of environmental citizenship along frames of economic development. They recommend science communication scholars who teach climate literacy must continue to investigate new educational and rhetorical tools for responding to climate change sceptics. They concluded effective climate change communication requires an understanding of the complex working of the climate system and the influence of human-caused atmospheric warming on this system as well as the resulting impacts on extreme weather; food and water security; biodiversity and ecosystem health; and human health and security.

B. Climate Change Education: curriculum and disciplines

Climate change is characterised by complexity and uncertainty, and schools need to teach the issue with the latest climate change updates, especially concerning global warming, to equip students to mitigate and adapt to the expected global conditions. Such education is believed to be the most important strategy for building climate knowledge (Kagawa and Selby, 2012).

Since the 1980s, there have been calls to incorporate environmental education as an essential part of learning in schools. However, according to the OECD (2012), students are likely to acquire most of their information on the environment at school, but only a few students globally learn about environmental issues in standalone environmental science classes. Even in the best performing countries, there are major gaps in knowledge and access to information among students. Environmental education has often been administered through less formal teaching channels such as extra-curricular activities and awareness/outreach programs that are beyond the normal school curriculum and as a result in general they do not provide sufficient coverage on topics like climate change.

Agenda 21 urged nations to coordinate and integrate sustainable development education in both formal and non-formal sectors, and to integrate environmental education in the curriculum of primary and secondary schools. Article 6 of the UNFCCC and Article 12 of the Paris Agreement ask countries to make education (formal, informal, and non-formal), public awareness and participation, and capacity building a priority, in order to enable long-term and sustainable change.

In curriculum terms, climate change is not just a scientific phenomenon. It is a complex socio-scientific issue that demands more than the teaching of content. McKeown and Hopkins (2010), described climate change education as comprising two parts: climate and change. ‘Climate’ they explain involves the natural sciences, while ‘change’, or educating for change, involves engaging the social sciences and humanities.

Shepardson et al. (2012) presented a scientific curriculum for climate change education, arguing that in order for students to understand and have adequate information about climate change, they **need to understand climate as a system**. In their model they presented six key domains which they argue are crucial in understanding climate change as a system. These domains were:

- Natural causes and changes to the climate system
- Atmosphere and pollution
- Snow and ice levels
- Oceans (levels, temperature and life)
- Land and vegetation
- Human impact

To expand beyond a scientific approach to climate change education, Andrey and Mortsch (2000) have presented that climate change education should address:

- Climate change as a **complex issue**
- **Numerous uncertainties** in climate science
- Climate change impacts are **borne disproportionately by people in different parts of the world**
- **Causes** of climate change that are **embedded in our preferred lifestyle.**

To extend this list, Schreiner et al., (2005) argued that climate change education should also discuss how:

- Climate change is a **media issue**
- Climate change is an **invisible phenomenon**
- Climate change occurs on a **long time scale**
- Individuals are not held personally accountable for actions that cause climate change
- There are many **competing environmental and political interests**
- Individuals' contribution is significant to climate change

Trott (2019) proposes climate change education should, in itself, become a main school subject because is increasingly being understood as an issue of social and intergenerational justice. However, in terms of existing disciplines, Earth Science is a natural home for climate change education, but it remains a relatively minor area of disciplinary focus even for countries with formal earth science programmes. teachers also face a challenging emotional and political context given the charged discourse that accompanies conversations about future conditions.

Following a survey of Italian students from Calabria and Sicily, De Pasquale and Sabato (2021) concluded that environmental issues **should be taught as a multidisciplinary topic**, but with a fundamental role in geography education. On the possibility to act in order to fight climate change, students considered a change of habits was needed, reducing waste and valuing sustainability.

Communicating climate change involves text, pictures, charts, graphs, and can be used by, for example, scientists, politicians, journalists, and students for various reasons. Interest organisations can sometimes spread organised denial of anthropogenic climate change (Krange et al., 2019). If teachers or students use graphs or other data influenced by these interest organisations, they could be misled and potentially make judgments based on misinformation. Citizens need to understand and reflect on these descriptions, predictions and communications to develop informed argumentation and standpoints on climate change issues. Informed, critical, and engaged citizens are vital to a democratic way of living.

Steffensen (2021) suggests that Mathematics can be used to motivate students to become 'critical citizens, so Maths teachers should implement teaching about climate change. Students can then understand how mathematics formats their lives and be empowered on issues relevant to a lived democracy and become critical citizens. Students can become aware of the nature of mathematics; identify how mathematics can be used; critique its use in society; and, **apply mathematical competencies to empower themselves both personally and as critical citizens** (Ernest, 2002; Skovsmose, 1994). Mathematics based statistics and models can influence how we perceive climate change and related challenges; it is suggested that mathematics should have a critical reflection on issues such as climate change. For example, the interpretation of graphs used to investigate potential consequences for people.

Measurements are relevant for understanding climate change. Barwell (2013) suggests Mathematics contributes to describing, predicting and communicating climate change, including measures of global temperatures, sea-levels, or degrees of glacial melting, . Lloyd and Oreskes (2018) described one such disagreement where climate researchers came to different conclusions using the same raw data. The processes of predicting climate change makes use of advanced mathematical modelling. They underlined that prediction is by definition, uncertain, thus while most climate scientists agree on anthropogenic climate change, debates exist regarding its predicted tempo and how severely the impact will be.

A vital part of students' critical mathematical competencies helps students develop an awareness and critical reflections regarding how the mathematical formatting of climate change can take place.

Students should be enabled to reflect, make argumentation, make well-founded judgements, and have the competencies to apply learning outcomes to meet complex challenges. In this context, Skovsmose (1994) described 'mathemacy' as using mathematical arguments to take justified stands as a means for social and political reforms as well as for self-empowerment. This mathematical literacy has been described by OECD (2022) as "the capacity of individuals to reason mathematically and solve problems in a variety of 21st century contexts". Mathematics education should develop student engagement in discussions on socially relevant issues, that could involve ethical dilemmas involving values and critical consciousness. This constitutes a variety of competencies such as critical thinking, reflection, communication and collaboration, research and inquiry, problem-solving, ethical obligations, global awareness, and environmental literacy (Care et al., 2018). Climate change education needs to provide opportunities to exercise critical thinking while using 'mathemacy' to interpret data and graphs and science to explain the causes of global warming.

Karsgaard and Davidson (2021) confirmed that approaching the climate change mainly through natural sciences reinforces **the exclusion of important social, political, cultural and economic components**. This compromises the capacity of young people to process their awareness and personal experiences of climate change, and prevents them from developing essential citizenship skills. They expressed the need to approach the question of "why" instead of "what" and "how". They suggested that by making students engage in the topic of climate change as a social issue instead of an external force or reality, the students would see and understand climate change first-hand. Facilitating discussions in the classroom on the controversies of climate change helps prepare students to participate in public debates in society as informed and critical citizens.

Romero Ariza et al. (2021) recognised the importance of climate change in education. They also agreed that climate **should be addressed as a socio-scientific discipline due to the immense social, economic and political implications**. This approach offers an interesting scenario to promote debate and exercise critical thinking. In this context, climate change education has been already been used by Dawson and Carson (2018) as a powerful means to develop strong argumentation (Walsh and McGowan 2017).

Very few publications directly addressed the role of the arts and humanities in climate change education. Braidotti (2013) stresses the specific contribution of the Humanities to the public debate on climate change, through an analysis of the social and cultural factors that underscore the public representation of these issues. While it is evident that many arts and humanities practitioners and institutions are substantively engaging with the issue of climate change (Siegner and Stapert, 2020), this potential was found to be a relatively untapped resource in the existing literature associated with climate change education.

Duxbury (2010) argued that artists have the potential to directly engage society with affective experiences and new perceptions of climate change which can lead to significant changes in attitudes and behaviour. Siegner and Stapert (2020) evaluated a climate change curriculum implemented via an integrated social studies and language arts framework in a middle school classroom. The designed curriculum was interdisciplinary and socio-scientific, developed as part of collaboration between a private school, a climate education non-profit, and a government agency (NOAA).

Stevenson et al. (2017) reviewed student and teacher understandings of climate change and conceptions of climate change education. They suggest teachers should not be expected and do not

need to have extensive knowledge of climate change before engaging and co-learning with their students in thinking about the, transition to a more sustainable future. Climate change education needs to explore **mitigation** and **adaptation** at both the local and global level (Kagawa and Selby, 2010) and the interrelationships between these levels.

Climate mitigation involves actions are part of a response to limit climate change, with a transition from unsustainable values and, practices. This **requires students to assume responsibility and develop the capacity to become engaged in collective actions** that can contribute to reducing greenhouse emissions and transforming communities and societies to enact more sustainable policies and structures. On the other hand climate adaptation education includes disaster education. This means **learning about and how to respond safely** to climate impacts, such as forest fires, floods, droughts, prolonged heatwaves, cyclones, tsunamis and storms.

In contrast to many studies, Kirby and Webb (2021) commented that the point of school curricula was not to ensure that students get an accurate understanding of it, but to provide them with **opportunities to engage with content deeply enough to respond responsibly to it**. Stevenson et al. (2017) suggested that climate change education cannot be confined to traditional structures and formal curriculum spaces of education. They proposed that **more informal and hybrid** (e.g. school/community) **spaces may be necessary for learning and action**. These can provide opportunities for students to engage in enquiry/project-based and action-oriented learning as well as creating community involvement for instance student clubs and competitions to engage students in investigations and actions related to local climate impacts, or forms of citizen science that engage students in community-based research (Dillon et al. 2016), social media networks that allow youth to discuss climate issues and initiate climate change actions.

According to Drewes et al. (2018), examples of how teachers formulate and implement particular climate change concepts into curricular decisions and the effect on student learning are sparse. Tolppanen and Aksela (2018) used qualitative content analysis to find out what students want to learn about climate change and what type of questions 16-19-year-old students asked about climate change. These questions were placed into five categories derived from their content, solutions, climate framework, human action, effects on humans, awareness raising (Table 2).

Table 2: Types of climate change questions presented by gender

		In Sample n (%)	Solutions for climate change N (%)	Climate System Framework N (%)	Human Action N (%)	Effects on Humans N (%)	Raising Awareness N (%)	Questions presented, in total N (%)
Gender	Female	132 (66%)	89	69	32	26	15	231 (65%)
	Male	68 (34%)	43	48	14	12	7	124 (35%)
Total			132 (37%)	117 (33%)	46 (13%)	38 (11%)	22 (6%)	355 (100%)

The analysis showed that, although the students participating in the study were all interested in climate change, there was great variation in their areas of interest, regarding the topic. In essence, **the multidisciplinary and complex nature of climate change was reflected in students' questions**. Furthermore, in alignment with previous research (Tirri et al., 2012), their findings indicated that even in a scientific context, students do not ask questions merely related to science: on the contrary,

students ask a wide range of questions, ranging from politics to psychology and from economics to individuals' behaviour. Schreiner et al. (2005) have discussed the importance of bringing the multidisciplinary nature of climate change into education and the findings of this study indicated that, at best, a multidisciplinary approach could be achieved by addressing students' questions on climate change.

C. Pedagogies for climate change education

According to Monroe et al. (2019), there is currently a void regarding climate change education pedagogies and the appropriate strategies needed to address the issue, mainly caused by the lack of implementation of this issue in the curricula of educational organisations.

Ouariachi et al. (2019) defined the engagement with climate change issues through three main dimensions:

- the **cognitive dimension** - what is known and the willingness for mental effort
- the **emotional dimension** - how strongly people feel about climate change
- the **behavioural dimension** - how much are people ready to address climate change

This multi-dimensional approach has been supported by other climate change related research (Casas Jr. et al., 2021; Cajele, 2020; Feinstein and Mach, 2020; Waldron et al., 2020; Lorenzoni et al., 2007).

Rousell and Cutter-Mackenzie-Knowles (2019) used 'the type of educational approach' to analyse the different educational methods and practices presented in the climate change education literature. They confirmed there has been a tension between knowledge-based approaches to science education and interdisciplinary, affect-driven and experiential approaches to climate change education in the literature associated with school education. They identified four approaches which dominated the literature on climate change education. These were generally top-down approaches, whether the focus was on scientific knowledge, formal curriculum, behaviour change, or mitigation/adaptation (Figure 2).

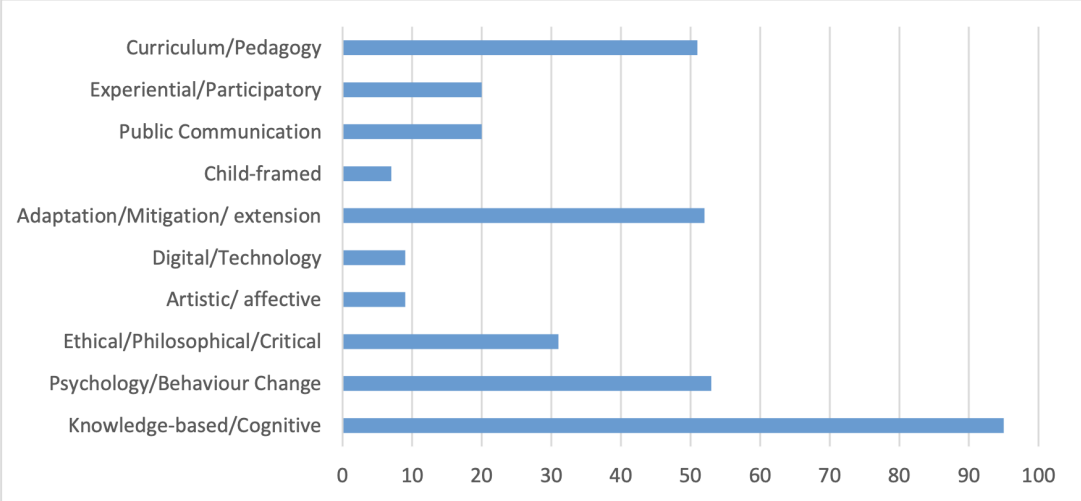


Figure 2: Approaches to climate change education research

Their research identified a distinct emphasis on scientific knowledge-based approaches to climate change education, with a secondary, and closely related, emphasis on curriculum and pedagogy associated with formal education in schools and universities. Nearly half of all publications specifically referred to scientific knowledge and cognitive understanding as the primary approach towards climate change education. The research has focused on children and young people's scientific knowledge of climate change, often describing it as limited, erroneous and highly influenced by mass media (Lombardi and Sinatra, 2010). Studies suggested that **scientific knowledge-based approaches had been largely ineffectual in altering the attitudes and behaviour**

of children and young people towards climate change (Powdthavee, 2021; Kuthe et al., 2020; Voulvoulis and Burgman, 2019; Brownlee et al., 2013; Dijkstra and Goedhart, 2012).

Behaviour change was also acknowledged as a primary approach for climate change education irrespective of scientific knowledge, and has been taken up in a wide range of public contexts outside of formal educational settings (da Rocha et al., 2020; Muroi and Bertone, 2019; Howell, 2014; Semenza et al., 2008; Kollmus and Agyeman, 2002). Psychological approaches associated with behaviour change represented about one quarter of all publications reviewed, revealing a significant trend in the literature over the last decade. However, while many studies reported that scientific knowledge does not correlate with changes in attitude or behaviour towards climate change, there remained little to no consensus as to what approaches might be most effective in promoting environmental action.

Research indicated that cognitive increases in knowledge about climate change showed little or no correlation with pro-environmental attitudes or behaviour in the population (Dijkstra and Goedhart, 2012). Selby and Kagawa (2010) even observed a tendency towards climate change scepticism and denial in mainstream science education programs. These authors specifically suggested science educators were complicit in downplaying the ethical implications of climate change injustice, and framing climate change 'as an issue calling for a scientific or technical fix rather than as a pathology of an ethically numb, inequitable and denatured human condition'.

Mitigation and adaptation approaches were referenced in about one quarter of the literature, and were generally associated with community education and local governance. They were often used in climate change education programs which aimed to reduce the risk of disaster in vulnerable communities and ecosystems (Oberman and Sainz, 2021; da Rocha et al., 2020; Kagawa and Selby, 2012; Gero et al., 2011). Mitigation initiatives aimed to reduce the human impacts contributing to climate change (Burton, 2007), adaptation initiatives aim to build adaptive capacity and reduce the vulnerability of individuals, communities and environments in response to changing climatic conditions (Anderson, 2012). These approaches seek to reduce the impacts of human activity on climate, and reduce the negative impact of climate change on both human and natural systems.

In contrast to the emphasis on top-down education and disaster management, Rousell and Cutter-Mackenzie-Knowles (2020) suggested a series of innovative, bottom-up approaches have begun to emerge. These included **participatory approaches which empower communities of learners** to design their own climate change projects and modes of engagement with the issue (Kioupi and Voulvoulis, 2019; Haarstad et al., 2018; Feierabend and Eilks, 2011).

A small number of studies focused specifically on **affective approaches which can provoke emotional and somatic responses to climate change issues** and concerns (Ojala, 2021; Bryan, 2020), through for example engagement with art, imagery and narrative (Bentz, 2020; Duxbury, 2010; Leiserowitz, 2006). Digital technology has also emerged as an approach which has multiple applications for producing innovative and empowering forms of climate change education (Markowitz et al., 2018; Lee et al, 2013). A small number of articles were orientated towards child-framed approaches to climate change education, which draw on the unique perspectives and experiences of children and young people to inform new frameworks and methods for teaching and learning about climate change (Busch et al., 2019; Lawler and Patel, 2012).

According to Karsgaard and Davidson (2021), the **previously used dominant approaches towards climate change education are obsolete** and consolidate inefficient course of actions on climate change mitigation. They suggest critical global citizenship education (GCE) as the solution to the individualistic ways in which climate change mitigation should be approached. In other words, they state that a **transformational and justice-oriented curriculum needs to be created and implemented** encouraging students (and youth in general) on participating and cooperating in more collective actions from a global perspective.

C.1 Global Citizenship Education (GCE) and critical thinking

The UN Sustainable Development Goals (United Nations, 2018) addresses Quality Education in Goal 4. The goal and its target areas are embedded in, and closely linked to, the other 16 Sustainable Development Goals (SDGs). For instance, Quality Education lines up with other social goals, such as Gender Equality (SDG 5) or Reduced Inequalities (SDG 10), not only in terms of what they aim to achieve, namely the development of women's role in the general improvement of social conditions, but also in terms of targeting equal access regardless of gender (SDG 4.2).

As suggested in SDG 4.7, global citizenship is a key component of ESD. Global Citizenship Education (GCE), with its focus on global interconnectedness and shared responsibility, is said to provide an alternative form of thinking, and can thus serve as a framework for radical transformation, from the smallest-scale aspects of education systems to the largest-scale. This approach deserves a more pivotal role in current education systems, which often still focus on seemingly independent local consequences of climate change and then on national approaches to mitigating only those local effects. What is needed, therefore, is a critical reconsideration of current practices in global education systems, especially with regard to teacher education.

The official indicator for the success of SDG 4.7 is the extent to which:

(i) global citizenship education and
(ii) education for sustainable development, including gender equality and human rights, are mainstreamed at all levels in
    (a) national education policies,
    (b) curricula,
    (c) teacher education and
    (d) student assessment (SDG Tracker, 2022).

Globally binding guidelines would allow for more efficient coordination of education for climate change by inducing countries to frame their national efforts within a global context. Under such circumstances, teacher education could develop its full potential as an important pathway to radical transformation.

Climate change is the issue in sustainable development upon which every other issue is dependent: if the global threat of climate change is not tackled, all other efforts toward a more sustainable future are at risk. The consequences of climate change clearly constitute a human rights issue, in that they compromise inalienable human rights, most of those who are already the most vulnerable members of our societies in terms of socio-economic capital.

Global Citizenship Education is an educational discourse (and related practices) that, at its core, seeks to engage young people in learning about interdependencies that tie together injustice, ecological devastation, and human diversity (Roemhild and Gaudelli, 2021). This has the goal to promote a more peaceful, harmonious, and just world (UNESCO, 2015).

With regard to education, GCE, as outlined in SDG 4.7, and ESD, calls for a more consistent and serious recognition of climate change in every part of global education systems and integration of the topic into every aspect of those systems. This acknowledges climate change as one of the key issues of the 21st century by including it in what constitutes quality education, and integrating the issue into teacher education are the first two steps toward meaningful, lasting change.

Karsgaard and Davidson (2021) undertook an educational review that addressed the need of the implementation of climate change education in the curriculum and critiqued the current framework in which this topic is established. They suggested using critical Global Citizenship Education (GCE) is the solution that responds to the individualistic ways in which climate change mitigation is approached. In other words, they stated that a transformational and justice-oriented curriculum needs to be created and implemented encouraging students (and youth in general) on participating and cooperating in more collective actions from a global perspective.

A broad range of practices falls within this framework (Figure 3), including efforts to engage students in:

- Understanding **the state of the world**, particularly as it relates to interdependencies that bind the world together.
- Understanding **geopolitical forces** that threaten the global order that has emerged in the 20th century.
- Learning about **critiques and challenges to the injustices** perpetrated (Davies, 2006; Gaudelli, 2016; Goren & Yemini, 2017).

Figure 3: The components of Global Citizenship Education

Global Citizenship Education (GCE) seeks to empower learners of all ages to assume active roles, both locally and globally, in building more peaceful, tolerant, inclusive and secure societies. Key learning outcomes, learner attributes, topics and learning objectives are based on the three domains of learning – cognitive, socio-emotional and behavioural.

- Cognitive domain: knowledge and thinking skills necessary to better understand the world and its complexities.
- Socio-emotional domain: values, attitudes and social skills that enable learners to develop affectively, psychosocially, and physically and to enable them to live together with others respectfully and peacefully.
- Behavioural domain: conduct, performance, practical application and engagement.

These domains are interlinked and need to be integrated into the learning process. According to Basit and Maryani (2021), the development of students' critical thinking skills is very important, since these skills are recognised to provide meaningful understanding and to make them more responsible towards their environment and climate change. Students need to be able to grasp the overall concept of climate change in order to be able to make proper judgments and moderate their actions accordingly.

In order to enable meaningful cognitive understanding to students through education (Yuliyanto et al., 2018), it is important to enable students to think critically and independently in order to enhance their problem-solving skills. They suggest this can be done with the implementation of the RADEC (Read-Answer-Discuss-Explain-Create) model, which has been shown to improve students' mastery of cognitive concepts (Sopandi and Handayani, 2019).

C.2 Participatory Action and Climate Change Discourse

According to Holthuis et al. (2014), student interaction, rather than just listening intently, is one of the most important factors in learning. Karsgaard and Davidson (2021) suggest providing programs for young people that create an environment of heightened feelings of belonging, competence, connectedness, safety, mattering and well-being can be an effective means of cultivating the confidence and efficacy competences needed to overcome the catastrophic outcomes of climate change. All this could be packed in the form of a collective project-based, problem-solving scheme that provides students with alternative pathways that spread awareness and behaviour change (Akiva et al., 2017).

Project-based learning (PBL) is one approach that can be used to integrate participatory action on climate change into the curriculum (Figure 4). This type of learning is centred on learning in the real world and allows for the active participation of learners to obtain both subject knowledge and skills (Killen, 2010). The approach is grounded in experiential learning theory (Kolb & Kolb, 2005) following an action research process involving identification of the problem, determining how to address it, taking action, reflecting on the outcomes, and disseminating the knowledge to others (Efstratia, 2014).

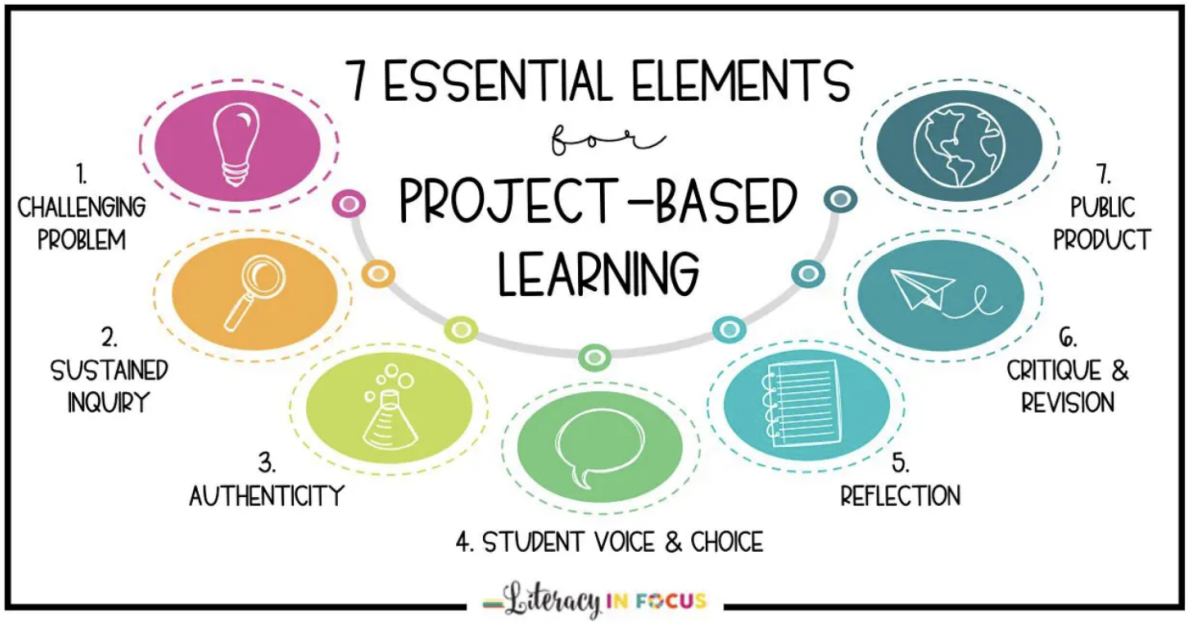


Figure 4: Essential elements of Project Based Learning (Literacy in focus, https://www.litinfocus.com/7-essential-elements-for-project-based-learning/)

Engström (2018) suggests climate education must allow youngsters to engage in climate change discourse, both critically and accurately. The young generation will feel more engaged if they can take action about an issue. It is a method where inspiration is established by participating (Trott, 2019). Stories can be used to communicate climate change knowledge shape opinions and preferences. Analysing such narratives can help explain how they are constructed and how they influence us on personal and societal scales. In this respect, Wynes and Nicholas (2017) showed the important role of more high-impact aspects in education and they argue that high-impact actions, through providing accurate guidance and information to 'catalyse' individuals, would also be an important dimension of scaling bottom-up action.

C.3 Enquiry-based approaches and citizen science

According to Wals (2011) climate change education necessitates learning that is enquiry-based, reflexive, creative and participatory in supporting learners to develop competencies that are transferable to new, uncertain and as yet unknown, or poorly defined, situations. According to Mieg (2019), enquiry-based learning is a didactic principle in which students learn by independently conducting their own research. A meta-analysis found that students who participated in enquiry learning (without guidance) tended to learn more than students who received traditional instruction, and that teacher-directed enquiry was even more effective (Furtak et al., 2012).

In order to address students' questions holistically and to support students' development into systemic thinkers, Tolppanen and Aksela (2018) argue that, rather than giving direct answers to students' questions, the teacher should direct the students towards guided enquiry. Learning by guided enquiry involves a process of active exploration that uses critical, logical, and creative thinking skills to answer questions by teacher guidance. It involves a process in which students attain knowledge from several sources and examine their questions from different perspectives (Kuhlthau

et al., 2015). A teacher with sufficient content knowledge on climate change can guide this enquiry process by first asking the student questions that help break down their original question and then direct them to look at the big picture again.

Jiménez-Fontana (2022) described enquiry-based learning as a research-based approach, promoting student immersion in scientific processes usually in a cooperative way. It is a basic strategy of knowledge, engagement and action that searches for answers to problem situations presented. The learning processes include opportunities to develop competences for dealing with complex topics. It involves learning about climate by conducting research that provides evidence to promote the development of scientific knowledge. The students work in small groups as autonomous learners, emphasising the active development of knowledge. Cooperative work, dialogue and the exchange of ideas are stimulated. The joint construction of meaning starts from relevant problems or questions and clear and concise guidelines are provided so that the students can independently find appropriate answers. Students are thus encouraged to make decisions, assume critical positions and put forward opinions.

Citizen science is an expanding field in education which bridges the gap between science and society. This benefits not only scientific research, but also learning in a formal science context. There has been some progress in involving young people as citizen participants and/or co-researchers in climate education research. As a result, **citizen science is becoming increasingly popular as a tool with which to engage students in large-scale scientific research** while also attempting to achieve educational objectives.

Lüsse et al. (2022) confirm that citizen science fosters an understanding of engagement with science as well as the perception of the relevance of scientific topics. It enhances pupil motivation, interest and knowledge as well as improving scientific and communication skills. Project designs with a high level of pupil involvement are particularly advantageous in terms of achieving learning objectives (Figure 5).

Figure 5: Citizen science process (California Academy of Sciences, https://www.calacademy.org/educators/citizen-science-toolkit)

Gunson et al. (2021) argued that citizen science approaches have the potential to positively influence climate change knowledge raising awareness and provide information to young people, transforming attitudes, impacting emotions and activating responsible values and behaviour. By encouraging local level research, students have the opportunity to observe, analyse and evaluate the impact of climate change. Later on, a global perspective could be instituted through bilateral collaborations that give the students access to engage with the ideas of others. Of course, in order to do so, the youngsters first needed to leave behind their own beliefs and assumptions and reflect upon their local practices. Consideration of learners' emotions encourages feelings of agency, which in turn according to Busch (2016) may promote action.

Ojala (2015) suggests the **enquiry should focus attention on futures and possible pathways to a sustainable future** to promote hope in students. The materials and programs should be learner-centred so that they allow learners to create their own understanding and develop new skills through active, hands-on, enquiry-based learning opportunities. Kellett (2005) argues that young people should be 'acknowledged as experts on their own lives and as a result be positioned as actual researchers – as experts on their own lives

Cutter-Mackenzie et al (2019) challenged environmental educators and researchers to further consider, discuss and critique young people's roles in research. They proposed that this debate should focus on the potential of them as collaborators in research rather than objects of investigation or discussion. The methodology "pupils as active researchers" has received very limited attention in school education research. They suggested the discourse around pupil-framed methodologies needs to extend beyond simply listening to what they have to say, and begin to position the pupils as researchers who can directly influence the methodology, analysis and outcomes of a given study.

C.4 Community education and service learning

Community education was also identified as a significant focus area for climate change education research. Many of these studies involved partnerships between various public and private stakeholders, such as local councils, universities, resource management bodies, NGOs and community groups (Crabbe and Robin, 2004). A number of cross-national (de Oliviera, 2009) and cross-municipality (Herriman and Partridge, 2010) comparisons of local councils attempted to track the results of climate change education initiatives at the community level.

The Sandwatch project (Cambers and Diamond, 2010) was an inspiring example of direct community participation in climate change education and action on remote islands in the Caribbean. Sandwatch provided a specific methodology for children, young people and adults to work together to monitor, analyse and take action on climate change in their own communities and environments. They also learned how to share their findings and experiences through the production of local print media, videos, online networks and social media.

Climate change education research was also associated with mass media, national parks, museums and zoos. The literature on public policy, for example, called for science educators to actively inform climate change policy (Hill et.al., 2010), along with critical analyses of the implications of international climate policy for remote agricultural communities. Several studies found that the role

of mass media strongly affected people's attitudes towards climate change, but rarely resulted in behavioural changes. Howell (2014), for example, found that participants' attitudes changed after exposure to the climate change documentary "The Age of Stupid", but that this did not necessarily translate into changes in their environmental behaviour. Both Lowe et al (2006) and Leiserowitz (2006) found that participants were highly motivated to act on climate change after watching the fictional disaster film "The Day After Tomorrow", but they lacked the knowledge of what actions they could undertake to mitigate climate change.

National parks and other 'nature-based' spaces are cited as significant places for the general public to experience and help document the effects of climate change (Brownlee et al., 2014), for example through phenology and other forms of 'citizen science' (MillerRushing et al, 2017). Museums have emerged as key places for the public to engage with climate change, often through interactive media and immersive learning environments (Cameron and Neilson, 2015). Salazar (2011) described how museums have been approaching climate change education as a form of public pedagogy, in which citizens are equipped with the 'knowledge and epistemologies to participate in actions and debates about climate change'. Zoos and aquariums are similarly being framed as possible places where people can make personal connections with climate change issues, specifically through the activation of caring and empathy towards animals whose existence is being threatened (Grajal and Goldman, 2012). Like many museums, zoos are also now developing web-based simulations and interactive learning activities which continue to engage the public beyond the boundaries of the audience's visit to the zoo.

Lawson et al. (2018) highlighted an emerging idea on behavioural theories to address climate change education through a parent-child relationship context. They proposed reaching adults through their children as a productive but understudied communication pathway for climate communication. They suggested there is a link between intergenerational communication and language use which is not influenced by political ideologies or viewpoints that act as anti-reflexive forces. This approach is favoured by means of the children and parent relationship. Reaching adults through their children represents a productive but understudied communication pathway for climate communication. Thus, children could be the means by which climate denial tendencies could be overcome.

Waldron et al. (2019) acknowledged that the current way of teaching about climate change, as a geographical process with a focus on individual, private mitigation action, has not been effective. They suggested a more holistic educational experience is needed, which can be achieved through a robust and justice-orientated educational response in which students are provided with space for reflection and opportunities to engage in models of citizenship, emphasizing collective decision–making processes. Service learning is one such approach.

Service learning is a holistic pedagogy integrating academically relevant service activities that address human and community needs into a curriculum. Students connect knowledge and theory to practice by combining community actions with reflection in a structured learning environment. It provides students with opportunities to develop civic engagement skills. By working with community members, students can enhance their group, organizational and interpersonal skills. They also can gain important experience working with diverse members of their communities. The service learning process takes students through the six stages of Investigation, Preparation, Action, Reflection, Demonstration and Evaluation.

Coleman et al. (2017) described how students worked with community partners to identify and address community needs in an academic setting concerning the social, economic, and environmental issues related to climate change, together with developing structured reflections designed to achieve desired learning outcomes. Jiminez and Moorhead (2021) investigated how to empower students to become change agents by employing concepts and strategies such as hands-on learning, systems thinking, and service learning. Their research revealed four key themes:

(1) the importance of **local context** (both the school and the broader socio-political context),
(2) the pedagogy in relation to **student psychology**,
(3) teacher and staff views on **effective pedagogy** for teaching about climate crises, and
(4) **mental health**, as experienced by both students and their educators.

They suggested "teachers and their students regularly struggled with tensions of authority (e.g., school/government, parent/child, teacher/student) and outlook (e.g., "doomism"/hope, empowered/disempowered). Nonetheless, they expressed a variety of thoughtful ways to cultivate their students' lifelong advocacy for the environment and other related social justice issues." (Jiminez and Moorhead, 2021:1).

C.5 Systems Thinking

de Sousa, Hay and Liebenberg (2019) focused the importance of systems thinking when dealing with complexity. Climate change is a systemic challenge and therefore systems thinking can help to understand its system complexity by understanding how complex interconnections of multi-level factors influence public health, social, behavioural, or environmental problems (Lich et al., 2017). So, they suggested teachers to need promote teaching and learning strategies to address this. Systems thinking was promoted a strategy for achieving meaningful learning. Systems thinking was described as a key competence for environmental education that can be used to help people understand the complexity and the dynamics of natural, social, and economic systems (Schuler et al., 2018).

Based on a Climate System theoretical framework, Tolppanen and Aksela (2018) argued that a systemic approach is called for in climate change education. This argument was supported by the results of their study, which revealed that students ask a diverse array of questions that are multidisciplinary in nature. This array of questions represents the same themes as those identified in the literature as important for climate change education. Based on this link between theory and practice, they argued that students should be given more opportunities to explore answers to their own questions through a process of teacher guided inquiry.

C.6 Thing-centred pedagogy

Climate change is felt, imagined and thought about through diverse knowledge, sensory engagement and movement, practices and experience (Scoones and Stirling, 2020), and is connected with what can "change you, expand you" unpredictably (Massumi, 2015:11). To address this, Vlieghe and Zamojski (2019) suggested the development and use of thing-centred pedagogy with a focus on a subject area or school topic in the statutory curriculum (or beyond) that is worthy of attention and encourages us to think. The thing is studied rather than learned, everyone shares differing thoughts or opinions; relates the thing to what they already know/understand; and puzzles over it, as even the teacher cannot have full knowledge of the thing. A thing-centred pedagogy suggests teachers

need to attend to the “thing called climate change”, and this includes listening closely to students’ current concerns, as were for example expressed during the climate strikes.

Kirby and Webb (2021) presented a theoretical discussion with excerpts from teacher interviews, to think through new schooling practice possibilities that take seriously the importance of human-induced climate change. They draw on the ideas of “thing-centred pedagogy” (Vlieghe and Zamojski, 2019), where the teacher draws attention to the “things” that are worth preserving in the world and requires students to verify their equality through their ability to make meaning of this. The subject-matter of climate change is intrinsically unbounded, reaching into every fissure of human experience. Young people are encouraged to engage with the multiple ways in which they experience climate change, including how it extends deep within and beyond them.

C.7 Other considerations

Climate change education demands a focus on the kind of learning, critical and creative thinking and capacity building that will enable youth to **engage with the information, enquire, understand, ask critical questions and take what they determine are appropriate actions to respond to climate change**. It involves creatively preparing children and young people for a rapidly changing, uncertain, risky and possibly dangerous future. Just how dangerous totally depends on the actions we take today. Guy et al. stated (2014), “designing and implementing programs about climate change may require a balancing act of increasing knowledge of climate change and acknowledging how cultural ideology plays a role in perception and learning”. In other words, good education is not sufficient, as additional strategies are needed when addressing politically nuanced controversy.

Drewes et al. (2018) reflected that teachers’ pedagogical and curricular decisions shape how learning occurs and are part of the larger educational ecosystem within which learners contextualise knowledge. What ‘comes to matter’ in a classroom setting is influenced, in part, by how teachers enact their own knowledge, thereby moving ideas from one context to another via their pedagogical practice (Ingold, 2016). Anderson (2012) considered that the unpredictable nature of climate change requires an approach to learning that is flexible and that builds capacity for responding to specific hazards as well as for reducing general vulnerabilities.

Cutter-Mackenzie and Rousell (2019) identified the need for different **approaches to climate change education that are orientated towards political, affective, creative and participatory responses** to the issue. While climate change education is increasingly identified as essential for all children and young people, their actual voices on environmental issues have often been taken for granted in the broader field of environmental education research. They demonstrated that cooperative (Devine-Wright et al., 2004), interdisciplinary (Feierabend and Eilks, 2011), participatory (Ohman and Ohman, 2013), place-based (Bardsley and Bardsley, 2007; Hallar et al., 2011) and experiential (Pruneau et al, 2003) learning programs each had significant impacts on the attitudes and actions of children and young people towards climate change.

D. Teaching Resources

Some climate change education research has centred on the development, evaluation and use of teaching and learning resources. Nantsopoulos and Mogias (2020) explored the existence of issues related to climate change in the eight Elementary school textbooks of the Study of the Environment course (reading book and workbook). Their analysis revealed that climate change issues occupied a relatively limited place in the textbooks studied, appeared almost exclusively in the latent content of both textual and pictorial materials, with only a few textual superficially presented references and scarce illustrations. Climate change issues recorded in the textbooks mainly concerned environmental pollution from anthropogenic activities, water and energy savings, waste management, weather and climate relationship to humans, and renewable and non-renewable energy sources.

Digital media was represented in the climate change education literature across a diverse range of formal and informal contexts. Examples included the use of gamification to engage public audiences with climate change scenarios and actions (Lee et al, 2013), the development of web-based applications for conducting citizen science (Batsaikhan, 2020; Newman et al., 2012), the use of interactive digital simulations (Harker-Schuch, 2020; Svihla and Linn, 2012), social media (Senbel et al., 2014) and web-based climate change education networks between schools (Higham and Djohari, 2018) and with other organisations (Gibb, 2016). As far as online educational resources were concerned, according to Asimakopoulou et al. (2021) teachers surveyed preferred using materials found by their own personal research. Haslett and Wallen (2011), reported on the development of open-source and web-based climate change education resources which can be reconfigured for different purposes.

Skanavis et al. (2019) presented the creation of “Climapp”, an environmental mobile application focused on climate change and health aspects, with the intention of raising the knowledge and altering the attitude and behaviour towards this crucial environmental issue, based on support from internet (Figure 6). They explored whether mobile learning could effectively contribute to communication about climate change and whether a mobile application could increase knowledge and ultimately the raise the environmental awareness of individuals. They presented a technological tool that can contribute to a better understanding of climate change, using means that are more accessible to youngsters.

“Climapp” included an innovative communication / networking tool in support of environmental campaigns focusing on climate change. It provided an environmental approach allowing users to communicate a comprehensive environmental campaign, focusing at disseminating information and raising environmental awareness. It has incorporated three key recommendations on communicating climate change: (1) make it of local interest, (2) make it visual, and (3) make it connected. Moreover, it provides a local discourse and shows a general preference towards portraying local scenarios, in which players make decisions at home or within their communities,

such as how to reduce carbon emissions. Integrating new technologies into environmental teaching gives educators the advantage of incorporating interactive multimedia material in their courses.

The main advantage of using this application was that it allows students to personalise their learning process according to their own needs and abilities. The learning process thus becomes learner-centred. Furthermore, knowledge was socially and individually constructed on the basis of experience. E-learning applications and especially m-learning (mobile learning) applications, facilitate students to networking and communication (Economou et al., 2012).

Empowering people at an early age and inspiring collective as well as individual actions is of considerable importance in environmental awareness campaigning. Change was more likely to happen at a local level when community perspectives were embedded in the residents' personal environmental agenda. Appropriate solutions and actions were more effective when based on experiences already familiar to a given community (Dulic et al. 2016).

Petersen et al. (2020) reported on the use of virtual reality for virtual field trips and the implementation of these resources in an enquiry-based learning scheme. By using virtual reality the albedo effect was introduced and the effects on climate change due to ice sheets of Greenland melting was presented. In their study, the students witnessed the melting ice sheet and explored the consequences of global warming. The virtual field visit addressed the challenges of the invisibility of the phenomenon, the long timescale before Earth suffers the full consequences, the complexity of research, perceived lack of personal responsibility, and the perceived insignificance of individual contributions (Schreiner et al., 2005).

The virtual reality field trips provided high levels of sensory engagement with climate change impacts. Following the virtual experience, enquiry-based learning was used to actively engage the learners in a knowledge-building process based on the generation and exploration of answerable questions. Petersen et al. (2020) research results suggested that implementing an immersive virtual fieldtrip within the investigation phase of an enquiry-based learning activity had a positive effect on students' knowledge, self-efficacy, interest, expectations and intentions to change behaviour.

Gaming is another digital approach which has been used in climate change education. Video games are considered to be highly relevant tools for delivering information and influencing action in young people (Ouariachi et al., 2019). There are now dozens of games on climate change ('climate games') available (Gerber et al., 2021; Pfirman et al., 2021; Wu and Lee 2015; Reckien and Eisenack 2013). Several authors have highlighted the high potential of simulation games for climate change communication and teaching for several reasons (Flood et al., 2018; Gugerell and Zuidema 2017; Mendler de Suarez et al. 2012). However, hitherto there is little empirical evidence on the effectiveness of games for climate change communication and in teaching and learning (Smith et al., 2019; Klöckner 2015; Haug et al. 2011).

Hügel and Davies (2022) presented the steps taken to create a serious game for young people (aged 15–17) as a means to increase engagement in planning for climate change adaptation in Dublin. The iAdapt game used open data, interactive in-browser 2.5D mapping and spatial analysis, and exemplar socio-technical adaptation interventions. Its primary aim was to empower young people to understand and engage with the complexities, uncertainties, and processes of climate adaptation planning by using scientifically validated flood data predictions, grounded in a place-based setting and with diverse examples of diverse adaptation interventions. Participants experienced the difficulties of decision-making under conditions of democratic governance and uncertainty. The game helped educate, increased awareness, and stimulated discussions around the multiple possible pathways to planning for climate adaptation.

Playing an immersive game can lead to a significant increase in awareness, knowledge and attitudes, and an overall positive change in attitude and behaviour towards climate change (Soekarjo and van Oostendorp 2015). Ouariachi et al. (2019) dealt with the problem of designing video games with the purpose of facilitating relevant engagement in climate change activities for students and young adults. The researchers conducted interviews with experts relating to the quality of game design affects development of skills and experimental learning, gained through simulated scenarios. They concluded that it was relevant to design a high quality, entertaining game, that will allow players to activate all three dimensions of engagement: cognitive, emotional and behavioural. According to the experts, the players required engagement in the game so they can construct new knowledge.

Ouariachi et al. (2019) concluded modern generations thrive on interactivity, they suggested the information and messages that need to be conveyed to them need to be presented in a personalised manner, promoting individual interest and research through increasing awareness about the individual and collective consequences. Feedback was also deemed to be very important, as it needed to be positive towards the behaviour that was to be promoted. Students were interested to learn through exploration and their active engagement by role-playing in the simulation. All the learning materials provided to students, not only video games, should not only be interactive, but have multiple outcomes and degrees of success in solving the issues.

Simulation games are increasingly popular tools for opening up future perspectives, especially in the arena of sustainability policy-making and decision support. Vervoort et al. (2022) developed principles for the design and evaluation of simulation games that seek to impact on future climate governance. They were based on five perspectives: (1) purpose and positionality; (2) conceptions of the future and imaginaries; (3) beneficiaries, key stakeholders and participants; (4) the politics of game features and design; and (5) evaluation. They suggested that so far game design has typically not focused on how visions of the future might be constituted, extended, or challenged.

Meya and Eisenack (2018) evaluated the potential of climate change simulation games for communicating and teaching international climate politics. Simulation games allow active engagement and thereby promote experiential learning as players get individual, first-hand experiences (Mendler de Suarez et al. 2012) of otherwise abstract phenomena. This experience may create an enormous learning potential due to the emotions they trigger (Wu and Lee 2015). They also offer a safe learning environment to test different scenarios and experience resulting geophysical, economic and political system dynamics. Learning from failure provokes the consideration of alternative approaches. Simulation games help players become aware of mismatches between their own mental models with the dynamics of complex systems (Sterman et al. 2013). They can make science more easily accessible, offer a common language and a shared game experience provides common and scientifically sound grounds for starting discussion (Eisenack 2013).

Meya and Eisenack (2018) used a pre- and post-game survey on climate politics with observed data from individual in-game decisions was used with secondary school students playing the simulation game KEEP COOL (Kwok, 2019; Eisenack, 2013). They found that players significantly changed their

beliefs about international climate politics. They become more confident in the potential for politics to mitigate climate change, more optimistic about effective international cooperation on climate change mitigation and perceived themselves as more responsible for climate change mitigation. Players did not transfer their in-game decisions directly to their beliefs about international climate politics. Instead, by testing defective strategies within the game they become more optimistic about international cooperation in climate politics, highlighting the value of experiential learning as a central asset of simulation games on climate change. These findings demonstrated that simulation games can be promising, innovative tools to teach and communicate complex climate issues.

Using different digital resources and tools in presenting complexity, such as visual effects in terms of pictures, diagrams, graphs, media and games, are of assistance in explaining various topics, especially cycles which are of the essence in understanding climate change (Hipkins 2020). Gamification is an incredibly powerful asset to use in teaching since it may assist students with different ways of learning. These technologies offer much scope for designing advanced learning experiences that can take place in a variety of outdoor and indoor settings.

E. Teacher professional development

Given the predominance of research in climate change education and the environment, it was surprising to find the literature on teacher education on climate change was relatively limited. Most studies focused on the climate change knowledge of pre-service teachers. Indeed Larosa et al. (2021) suggested, even though teachers have the resources to teach, many of them do not feel ready or competent to teach about climate change. Teachers think that teaching the topic is difficult because the content of the curriculum is not clearly identified. They feel that these topics were not a priority for students because there were no graduation assessments (national exams). They thus confirmed the training of teachers should be an important area for future development.

Drewes et al. (2018) explained that teacher professional development was the best route to helping teachers improve their professional knowledge and adjust their classroom practice to promote higher student achievement In addition to building content knowledge, the training should be designed with respect to local practice as this approach is more likely to translate into changes in classroom practice.

According to Drewes et al. (2018), recent professional development activities have been mainly designed with proximity to practice in mind. Specifically, training modelled pedagogical activities that teachers were expected to implement with their own students. Many activities included hands-on investigations where the participants directly engaged with data, conducted experiments and worked on enquiry-based outdoor activities demonstrating the effects of climate on their own local context.

O'Gorman and Davis (2013) argued that teacher education faculties should play a significant role in climate change education not only through student learning, but also through their societal connections with within the broader educational community. Chang and Pascua (2017) proposed that given the complexities and uncertainties of a climate changing world, educators need to work with the latest research and data and that this ought to impact the way the topic should be taught and learned, with a view to helping young people succeed in a climate changing world.

Teachers ought to have the opportunity to extend their own knowledge about the climate (Bryce and Day, 2014) and about argumentation in science and technology classroom (Martín-Gámez and Erduran, 2018). Kirby and Webb (2021) said we that we need to take student concerns seriously as they addressed the complex role of the teacher in relation to what it means for students to act for climate change in allowing the political dimension to appear through students' responses. Considerable uncertainty about the future is entailed. Given the unboundedness of the subject-matter of climate change the uncertainty proliferates across multiple domains (Henderson and Mouza, 2018).

Romero Ariza et al. (2021) provided research evidence of the positive impact of enquiry-based professional development for teachers about the socio-scientific issues and critical thinking. When implemented as an immersive experience with teachers, the participants showed the capacity to read beyond data and use them along with scientific explanations to back up their arguments. In addition, they demonstrated awareness of their key role as teachers in promoting critical thinking. Immersion is considered an appropriate strategy for teacher professional development (Loucks-Horsley et al. 2003). In immersion activities, teachers took the role of students in order to

experience the target teaching method. This position allowed them to critically reflect on what can be learnt and get an experiential reference of other ways of teaching.

F. Climate change education examples

The climate change education literature revealed a number of examples of interesting actions, interventions and ideas which are presented in this section.

F.1 Systems thinking (de Sousa et al., 2019)

de Sousa et al. (2019) report on a research study with teachers in six primary schools who developed a 'systems thinking' concept map for teaching and learning to help them understand the interconnectedness of soil and climate change. Their paper presents a systems thinking approach used as a means to deal with complexity in under-resourced rural schools in one province in South Africa.

In this qualitative study the concept map was chosen as a pedagogical tool to promote meaningful learning and illustrate how a systems thinking approach dealing with a complex and multi-layered phenomenon, can promote systems thinking among teachers from primary schools. The concept maps developed by the participants were analysed to explore how teachers understand the interconnectedness of soil and climate change when developing a systems thinking concept map for teaching and learning. The researchers facilitated a workshop where the participants were trained how to include systems thinking activity into teaching activities dealing with soil and climate change for meaningful learning. To help participants to internalize and apply the use of systems thinking as teaching strategy in the classroom, participants were given a systems thinking activity where they had to develop a concept map as a teaching and learning strategy. The activity was in a form of a visual concept map that each group of participants had to develop to show how interconnected soil and climate change is by using systems thinking.

The analysis of concept maps and focus group interviews confirmed that teachers found it challenging to show how interconnected soil is and they lacked the ability to think in systems and make connections. The authors proposed a tool (Figure 7) for meaningful learning that guides a teacher through different levels of systems thinking.

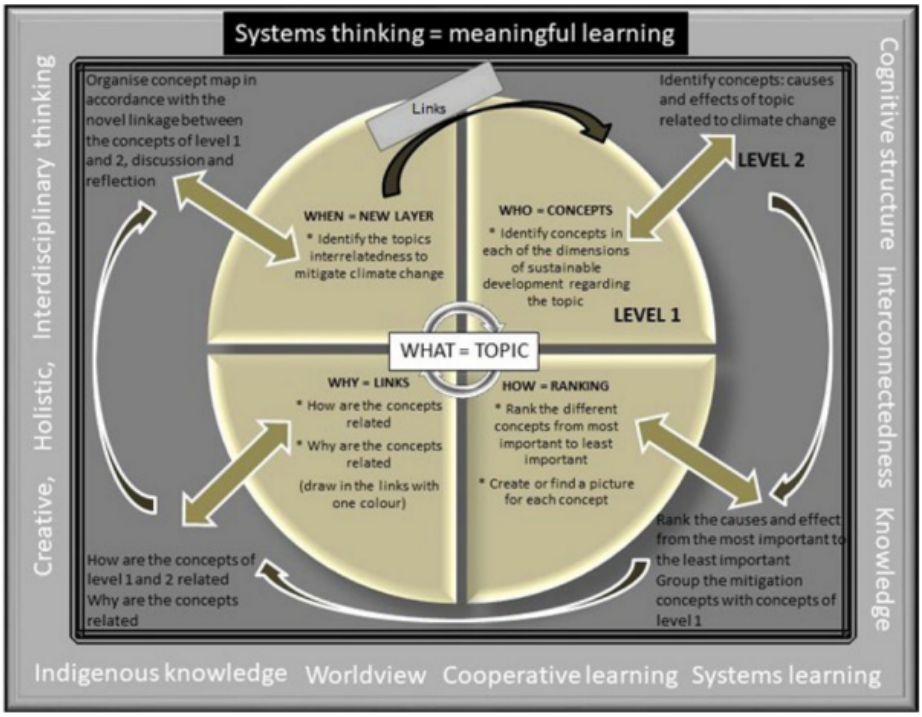


Figure 7: A systems thinking tool for meaningful learning developed by the researchers

During the workshop, seven steps were proposed
Step 1 – Level 1 Ask questions (who, how, why, and when) related to the social, environmental and economic dimensions.
Step 2 – Apply thoughts to Level 2 and identify the causes and effects of the topic related to climate change, asking how the topic fits into the dimensions of sustainable development.
Step 3 – Rank the different concepts from most important to least important. Create or find illustrations for each of the concepts.
Step 4 – Simultaneously on Level 2 rank the causes and effects from the most to the least important. The linking concepts should be grouped with the concepts of level 1.
Step 5 – Ask why and how concepts are related in order to achieve meaning learning through systems thinking. Create links between concepts. Ask how and why the level 1 and 2 are related.
Step 6 – Ask when all of the aforementioned is happening (a spatial-timeframe) to identify the interrelatedness of the topic and apply a rich and extensive conjugation for systems thinking. The links that must be dealt with on level 2 are to lastly organise the concept map in such a way that it links the concepts on both levels.
Step 7 – A discussion and reflection must take place about the interrelatedness of the concepts in the dimensions of sustainable development to mitigate the impact of climate change.
de Sousa et al. (2019) suggested If teachers are not taught to think holistically and become systems thinkers then the danger exists that their learners will also miss out on learning the skill to think in systems.

F.2 The Bicycle Model for Climate Change Education

The climate change education model (Figure 8) is presented as a bicycle because climate change education, like a bicycle, is one entity that requires all of its parts to function together (Tolppanen et al. 2017). The wheels: provide knowledge and thinking skills, though knowledge is essential, gaining more knowledge should not be the aim of climate change education, but rather, it should provide the opportunities to critically analyse environmental information in order to gain deeper understanding. Climate change education should highlight that the consequences of climate change are uncertain and impact different regions and people in different ways. The goal is a holistic approach that combines scientific understanding of the climate change phenomenon with knowledge of humanist-societal causes and consequences.

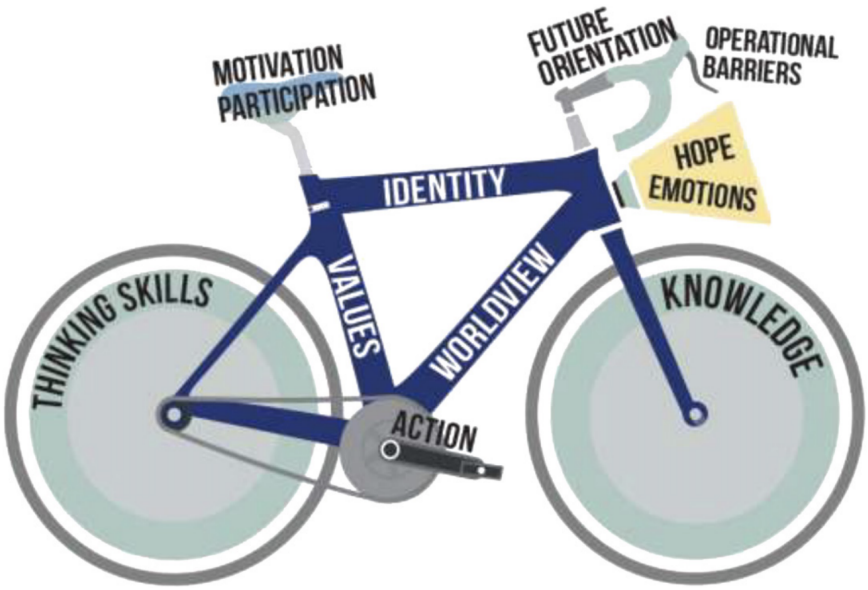


Figure 8: The bicycle model on climate change education (after Tolppanen et al. 2017, 459).

The bicycle frame provides identity, values and worldview, the foundation for climate change education. Climate change raises issues related to humanity, society, culture and ethics which interest many students. The wicked nature of climate change is reflected in conflicts of values. The role and identity of human beings as consumers who cause environmental problems is central. Though we hope for a sustainable future we may not want to give up habits or consuming lifestyle (Ratinen 2013).The chains and pedals provide actions to curb climate change which can be encouraged as part of climate change education if learners are guided to participate in climate change mitigation. The saddle stands for motivation and participation, as students either may not view climate change as their problem or feel that they cannot affect climate change mitigation. So climate change education should not be described as a distant issue or something too complicated to understand or act on.

The brakes relate to the operational barriers which need to be understood if environmental responsibility is to be promoted. These can be human tendencies such as desire for comfort or habits, but may also be a caused by structural reasons, such as infrastructure like a public transport network or finances. The lamp provides hope and other emotions showing the way forward. Negative attitudes and feelings, such as fear and uncertainty, are linked to students' attitudes and capacity-building (Ojala 2015). So climate change education should stimulate hope and compassion in people. Even if teachers do not have ready answers to climate issues, sharing ideas and searching for answers to challenging questions brings hope (Hicks 2014). Finally the handlebar provides a future orientation, a key component of climate change education. The complexity of the phenomenon makes it difficult to sketch scenarios and practice decision-making, even when its accuracy is not fully assured. future thinking requires creativity and arouses a wide range of emotions (Hicks 2014).

The results of this research showed that experts consider the model as a useful contribution to climate change education (Tolppanen et al. 2017), and though the model has its shortcomings, experts found it to excite them and ignite new thoughts on the nature of climate change education.

The model is also a rich pedagogical reflection on what should be prioritized and considered in the field of sustainability.

F.3 Leadership and youth voices (Cutter-Mackenzie and Rousell, 2019)

Climate change education presents a significant platform not only for youth voices, but also for a genuine activation of children and young people's political agency in schools, universities, and the public domain. Cutter-Mackenzie and Rousell (2019) focused on the importance of climate change education targeting young people as the next generation of leaders. They draw upon the Australian government funded project "Climate Change and Me" that has involved 135 students as co-researchers, investigating young people's voice on the topic.

Science-based approaches that have dominated the field of climate change in school are generally top-down in nature. Yet, this research suggests a series of bottom-up approaches emerge and are significant: participatory approaches that empower communities of learners to design their own climate change projects and ways of engagements. Also climate change education was oriented towards political, creative and participatory response, and especially when targeting children, give them a voice and make them legitimate participants and co-researchers so that they can influence the methodologies.

F.4 Global Citizenship Education Youth Programmes (Karsgaard and Davidson, 2021)

Karsgaard and Davidson (2021) conducted participatory research of Global Citizenship Education (GCE) by means of an international education project that gathered 99 students from 13 different countries in a climate change learning experience. Based on the main idea of the subject of natural sciences reinforcing the exclusion of important social, political, cultural and economic components that compromise the capacity of the youth to process growing awareness and personal experiences of climate change, and to develop essential citizenship skills; they expressed the need to approach the question of "why" instead of "what" and "how". This is, they suggested that by engaging students with the topic of climate change as a social issue instead of an external force or reality, students would see and understand first-handily climate change.

In this course of action, many barriers were encountered. The lack of youth representation in policymaking, the little civic engagement, etc. Moreover, students understood that they were part of a marginal group underrepresented and that politicians justified this reality by asserting that "the youth" has limited capacities of understanding for such participation in the decision-making process (Gordon, 2007). According to Gibbone (2014), youth remain excluded from climate policy decisions, despite the fact that those decisions will affect them to a far greater extent than the decision-makers.

This study demonstrated that through the use of the intersectional approach of GCE, students can be prepared to unlearn the conventional and ineffective responses that the power dominant structures of today keep on enforcing and supporting (Andreotti, 2014). This perspective brings the opportunity of new ways that the authors have utilized along their project. By an encouraging, initial research on local level, students had the opportunity to observe, analyse and evaluate the impact of climate change. A global perspective was then instituted through bilateral collaboration that allowed the students to engage with the ideas of others and reflect upon their own local practices.

In conclusion, the study evidenced how providing youth programs that “create an environment of heightened feelings of belonging, competence, connectedness, safety, mattering and well-being” can be an effective means of cultivating the confidence and efficacy competences needed to overcome the catastrophic outcomes of climate change (Akiva et al., 2017). All this packed in the form of a collective problem and solution scheme that provided students with alternative pathways that spread awareness and behaviour change. The deliberative exchange about potential futures, rather than the indoctrination of students and behavioural prescriptions was important (Öhman, 2009).

F.5 Student workshops intergenerational learning (Larose et al. 2021)

Larose et al. 2021 described a six-week workshop that involved two groups of French students (27 elementary school 10 years old pupils and 8 high school, 16-year-old students), that were asked to learn and teach each other about climate change and other relevant subtopics. The aim was to identify how to engage students and pupils in a learning experience that can make them aware of the challenges of sustainability and how to involve them in sustainability issues. The pupils were surprised by the findings of the causes of greenhouse emissions (farming among others) and really concerned about health and water issues. After a reflection phase, a list of lifestyle changes was created by students and proposed in their meetings with town officials.

The project’s significance lies in the students’ ability to make proposals to mobilize the attention of their classmates, their teachers, their parents and adults in general. The teacher’s role is, of course, to allow students to develop knowledge to understand climate change and also to support the various actions often implemented by students to do their part in mitigating its consequences.

The collaborative learning project engaged students in a learning experience that would make them aware of the challenges of sustainability in our society. They hoped to create an effective way to involve them in sustainability issues at a personal and local level. At the end of this workshop, the students learned that the greenhouse effect is a natural phenomenon but that the increase in greenhouse gases is anthropogenic, or human-caused. From the youngest to the oldest, they understood why a mobilization from simple citizens to elected representatives is necessary, in order to reduce greenhouse gas emissions and find mitigated responses to reduce the consequences of the change already underway.

Unfortunately, cross-age and cross disciplinary collaborations such as this are not easily created in schools. Furthermore, teachers who teach these topics rarely consult each other. Many say that they have no time to collaborate and organize a multi-disciplinary project with their students, although a multitude of studies have shown that cross-disciplinary teaching is an excellent way to create a better learning situation for students; all their lessons are connected and they can understand the real-life links among all the subject areas (Peters-Burton and Holincheck, 2020).

F.6 Participatory action research (Trott, 2019)

Due to an increasing emphasis on children's rights, children's participation in studies about social issues has become a trend. Trott (2019) described a participatory action research project in collaboration with children to act on climate change within local community settings. The method used digital photography as the basis for problem identification, group dialogue, and social change action. The critical importance was to establish a participatory process and collaborative action in

strengthening children's sense of agency. In this study, learning about climate change strengthened children's motivation for action, and their participation in youth-led action projects empowered their sense of agency.

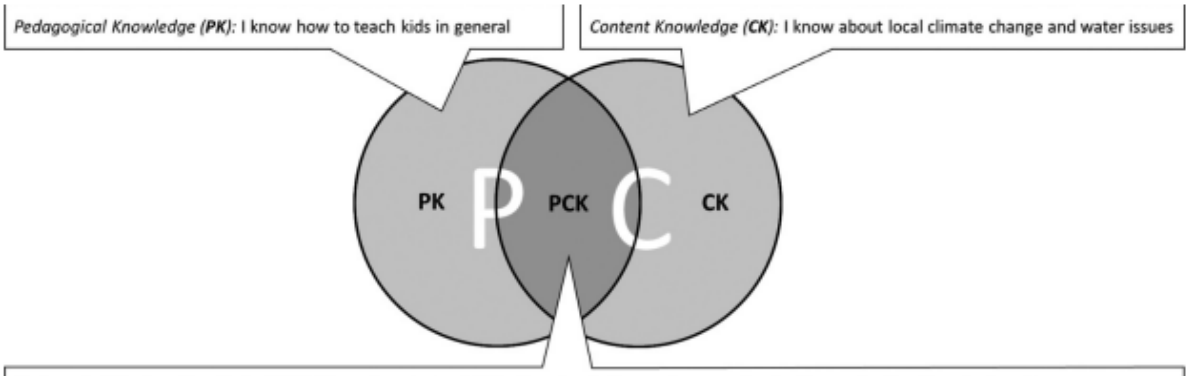
F.7 EduChange: a teacher training course on climate adaptation (Favier et al. 2021)

The research looks at Pedagogical Content Knowledge (PCK) of pre-service teachers in connection with teaching wicked problems such as climate change. Favier et al. (2021) describe the design of a course called EduChange, which focused on teaching climate change adaptation issues, and explores the development of the PCK of the preservice teachers during the course. It does so by systematically explaining the design of the course in relation to the pre-service teachers' PCK and the wicked characteristic that climate change education should tackle.

The EduChange course aimed to improve the Content Knowledge and PCK for teaching the wicked problem of climate change adaptation. The participants were pre-service teachers from four European countries. The interdisciplinary international approach and the inclusion of literature research and poster presentation tasks and fieldwork activities were appreciated by the participants and helped them to develop Content Knowledge (CK). The confrontation with the "otherness" (France and Haigh, 2018) was valuable for learning, not only because pre-service teachers saw things differently from what they knew but also because they were confronted with different perspectives and shared experienced in conversations with each other. Teaching about climate change adaptation also requires Pedagogical Content Knowledge (PCK) (Figure 9).

A diverse range of pedagogical workshops were included in the training week. The pre-service teachers subsequently developed lessons and conducted them in a local secondary school. During reflection week, participants met again and shared their experiences. Surveys and focus group interviews showed that the future teachers were positive about the course, and that it contributed to the development of their PCK.

However, contrary to the literature (Magnusson et al., 1999; Sobel, 2005), the results showed that participants considered the formal education (lectures, workshops, fieldwork) more important for the development of their PCK than designing, conducting and reflecting on their own education. Perhaps this is because the formal activities were strongly connected to teaching practice, and were characterised by many discussions about the implications, and reflection on experiences.



*Pedagogical Content Knowledge (**PCK**):* I know how to teach kids about local climate change and water issues via place-based education

Component	*Explanation*
1: "Orientation"	Awareness of one's own beliefs about the purposes of teaching about local climate change and water issues
2: "Curriculum"	Knowledge about the position of climate change and water issues in the curriculum
3: "Student understanding"	Knowledge about preconceptions and attitudes of students regarding local climate change and water issues
4: "Instructional strategies"	Knowledge about how to transform knowledge about local climate change and water issues so that it becomes accessible for students, how to design place-based education tasks, and how students learn when they work on these tasks
5: "Assessment"	Knowledge about how to assess students' progression in knowledge about local climate change and water issues

Figure 9: PCK Framework, specified for teaching about climate change and water issues via place-based education (Shulman, 1986)

The issues identified were:

(1) There was no clear definition of what should be the focus of climate change education. There were multiple interpretations about which competencies young people should develop, depending on the point of view.

(2) The problem is characterised by many interdependent components. Climate change education involves not only the wicked problem of climate change itself but also the educational setting (e.g. the curriculum and educational vision of the school), the societal setting (e.g. influence of media, parents and friends on students' perceptions about climate change), and psychological processes such as distancing and delay discounting. Also, it requires professionalisation of teachers – not only the development of CK and PCK but also more general collaboration skills and entrepreneurial skills.

(3) Climate change is characterised by interdependencies at different scales. As climate change itself crosses many disciplines, climate change education also requires an interdisciplinary approach. Teachers of different school subjects (with different CK and PCK, including different orientations) should work together. So, climate change education connects the microscale (lesson) and mesoscales (school curriculum). The National Standards (macro scale), which focus on knowledge and not on attitudes, influence climate change education at meso- and microscale.

(4) Climate change education is not connected to one school subject, which makes it difficult to position responsibility.

(5) There is no definite solution to climate change education. As climate change issues evolve, and the educational and societal context is also subjected to changes, educators are forced to focus on a moving target.

(6) There is no single true approach to climate change education. Whether the approach can be viewed as "good" or "bad" depends on one's orientation towards climate change education.

(7) Organizing high-quality climate change education requires not only competent teachers, but rather the synergy between many different stakeholders: teachers, teacher trainers, parents, educational policymakers, local communities, waterboards, climate change researchers, educational researchers, etc.

(8) Attempts to enhance climate change education can lead to broader educational change, for example, towards cross-curricular education and inquiry-based pedagogical approaches, the diffusion of technologies in classrooms, and stronger connections between education and local stakeholders (e.g. communities and water boards).
(9) Such changes can be resisted or encouraged, according to circumstances at the school.
(10) There was no single approach to climate change education. Instead, we can only attempt to fit climate change education with the context.

F.8 Immersive training on climate denial (Romero Ariza et al., 2021)

Romero Ariza et al. (2021) investigated the impact of an intervention based on enquiry about climate change, on pre-service teachers' critical thinking expressed through graphs interpretation and argumentation. They explored how pre-service teachers related to an immersion experience aimed at the development of critical thinking to their future role as teachers?

The arguments provided by a sample of 80 pre-service teachers (60% female, 40% male), average age 22, who took part in the discussion of graphs and the contributions to on-line debate about the causes of climate change of 77 participants (58% female and 42% male) were analysed. They were exposed to the arguments of climate change deniers, then they were asked to express their opinion about these claims in an electronic forum and then they enquired about the issue for a week using different information sources. Finally, they were asked to revise their initial opinions and to discuss in a new electronic forum their position about climate change after the inquiry process.

In terms of valuable learning outcomes, argumentative skills were identified as key components of critical thinking, since they require reasoning and the evaluation of alternative viewpoints according to the quality of the evidence that support them (Jiménez-Aleixandre and Puig 2012). The results showed that after searching and analysing information about the causes of climate change, more than half of the students were able to take a critical stance against claims denying the responsibility of humans in the issue. Additionally, they were able to use data and scientific explanations to back up their position and they have improved their socio-emotional competencies (empathy, concern, preoccupation and a sense of responsibility or personal engagement in the issue).

G. Recommendations

G.1 Policy recommendations

Although there is a clear scientific consensus on anthropogenic climate change (Lynas et al., 2021; Bertoldo et al., 2019; Oreskes, 2018), politicians and policymakers struggle to interpret and make decisions regarding how society should deal with it and by and large climate change education has so far not been prioritised. Concerns about climate change and education need to be brought to the attention of local, state, and national legislatures and governing bodies. The climate crisis is a global disruption and requires comprehensive and coordinated responses by policy-makers at these local scales. Key climate change issues intersect with policy, advocacy and social justice.

Some researchers have made policy recommendations. Leal Filho and Hemstock (2019) suggested climate change education should preferably be developed in a more systematic way by means of formal policies and programmes, since these offer a sense of continuity, as opposed to being ad hoc and short-termed, as it is often the case with many of the current and past initiatives. They propose:

- climate change education should be planned and delivered flexibly – not prescribed, as it depends on the local context and reality
- climate change education ought be combined with efforts in the field of education for sustainable development
- there should be better use of climate change education by UNFCCC or in conjunction with the Paris Declaration.

As part of a briefing to the ministers of G20 nations, Dagher et al. (2020) addressed the policy challenges of assuring quality education to empower today's youth to address problems associated with climate change and ecological degradation. Their key recommendations were that G20 governments should:

- mandate sustainability and environmental education domestically and regularly track environmental and climate literacy internationally.
- invest in environmental educational infrastructure and educator training.
- promote games drawing on real world problems and develop partnerships for environmental education in local communities and
- organize a G20 annual Youth Summit for Climate, Environment, and Sustainable Development Solutions.

In advance of COP22 and COP23 and in parallel to the synthesis of scientific research that the Intergovernmental Panel on Climate Change undertook, Busch et al. (2019) reviewed climate change education research published in the journal Environmental Education Research. Their key policy messages for education and awareness raising were:

- adults and youth hold erroneous or limited knowledge about climate science.
- scientific literacy and numeracy seem to exacerbate, rather than overcome, worldview-driven polarization around climate change (Kahan et al., 2012)
- the topic is so inherently complicated and that reality makes it both exciting and challenging at times
- teachers need to make climate change a topic for youth to care about enough to take action

Kranz et al. (2022) advocated for an implementation of the political perspective in climate change education, as it is a powerful concept that contributes to understanding the climate crisis and the

most effective actions against it. They undertake a systematic literature review to examine how climate literacy programs address the political aspects of mitigation and adaptation. They propose that climate education should incorporate political literacy to educate climate-literate citizens.

Dunlop and Rushton (2022) undertake an analysis of the sustainability and climate change strategy for education and children's services systems in England. The authors suggest the strategy focuses on economic concerns, with educational priorities driven by a 'net zero' policy agenda, and an over-reliance on science-focused knowledge and skills. The strategy suggests an absence of governmental responsibility and attention to the political dimensions of climate change as well as pro-environmental action at all levels, including from policymakers.

The following policy developments to integrate climate change education have been proposed

i) make curriculum modifications in a diverse range of disciplines
ii) get involved in research – providing cutting edge science
iii) establish collaborative partnerships – establish education networks
iv) encourage community engagement – serving as a hub for communities on adaptation and mitigation with collaborative planning

G.2 Education recommendations

Helping students make sense of climate change controversy will require student interaction, rather than just listening intently to express valid concerns about policy, economic choices, and the costs and benefits of various mitigation scenarios are voiced (Öhman and Öhman, 2013). Karsgaard and Davidson (2021) say that if education systems are to become accountable to youth, a full-scale shift in the approach to climate change in the classroom needs to be taken, focusing on justice, political skills, active learning and social network support. Some authors recommended the following activities or approaches:

1. Community-based learning plans that promote citizenship education and connect complex environmental and social factors of climate mitigation and adaptation
2. Implement collaborative climate learning methodologies that go beyond knowledge production and engage in community
3. Foregrounding political learning in climate education, where students come to understand decision-making powers so that they have the tools to participate in collective actions
4. For students to learn to critically examine the "Knowledge basis, interest and values of their societies

Guy et al. (2014) stated "designing and implementing programs about climate change may require a balancing act of increasing knowledge of climate change and acknowledging how cultural ideology plays a role in perception and learning". The mentioned themes directly support that claim. In other words, good education is not sufficient, as additional strategies are needed when addressing politically nuanced controversy. Some examples that had proven to have positive impact on learners are:

- Debates, small group discussion with worksheets
- Hands-on labs and field trips
- Role-play and simulations that mimic reality
- Assembly format with (music and) graphics to engage
- Visual imagery: documentaries, animated educational videos, drawing or cartoons
- enquiry-based activities

Aebli's (1983) criteria for fostering constructivist learning suggests learning should start with the student's prior knowledge, then activities that help untangle complex processes into successional

steps. The content should be reduced to focus only on key ideas necessary to learn the new materials being presented and technical terms should be avoided.

More cross-curricular approaches are needed, sometimes represented in the literature as “science communication”. However, Rousell and Cutter-Mackenzie-Knowles (2019) propose that climate change education should be distinct from both science education and environmental education. The scientific, social, ethical, and political complexities of climate change call for participatory and creative approaches from multiple disciplines which empower children and young people to meaningfully engage with entanglements of climate facts, values, power and concerns across multiple scales and timeframes.

Materials and programs should be learner-centred that encourage learners to create their own understanding and develop new skills through active, hands-on, enquiry-based learning opportunities. Lawson et al. (2018) suggest five key principles:

- focus on local issues,
- longer term learning and more in-depth lessons,
- hands-on projects,
- enthusiastic teachers and
- encouragement of parental participation

Climate education research has been shifting towards what can actually be done about climate change. Much of the work so far has been based on science or environmental education.

Monroe et al. (2015) called for creating effective messages for specific audiences that develop educational experiences that include the role of citizenship, and the social and economic elements of climate change (Waldron et al 2019; Shealy et al 2017). Rousell and Cutter-Mackenzie-Knowles (2019) review identifies the need for participatory, interdisciplinary, creative, and affect-driven approaches to climate change education, which to date have been largely missing.

Research by Monroe et al. (2019) reports on six themes that truly contribute to an effective climate change education with its related strategies. It must be mentioned that the mere practice of the strategies does not guarantee the absolute effectiveness of climate change educational programs. Instead, they can be addressed as meaningful ways to enhance the already existing programs or the starting point for the inclusion of this theme in the curricula. The themes/strategies were the following:

1. A personally relevant and meaningful approach (usually related to local practices)
2. The implementation of active or educational interventions to increase the learners’ engagement on the presented issue
3. The use of deliberative discussion to help learners better understand the various viewpoints and knowledge on the topic
4. The creation of interactive situations with scientists and to experience the scientific process to ensure the authenticity of the evidences
5. Uncover and address misconceptions about climate change and try to logically explain and prove the illogical arguments in which they are rooted
6. Designing and implementing school or community projects and promote first-hand exposure to real-social issues that affect or impact future generations

Some examples that have proven to have positive impact on learners are:

- Debates, small group discussion with worksheets
- Hands-on labs and field trips
- Role-play and simulations that mimic reality

- Assembly format with (music and) graphics to engage
- Visual imagery: documentaries, animated educational videos, drawing or cartoons
- enquiry-based activities

The young people themselves need to "collectively envision a better future, and then to become practical visionaries in realising that future" (Kagawa and Selby, 2009:5). This requires the development of new modes of climate change education which are open to radical and visionary alternative for the future, necessarily drawing on practices associated with environmental activism, social and political intervention, digital innovation, citizen science, and the creative arts. Öhman and Öhman (2013) suggested helping students make sense of controversy may require that others voice valid concerns about policy debates, economic choices, and the costs and benefits of various mitigation scenarios.

Addressing these recommendations in education requires multidisciplinary pedagogical approaches that promote student enquiry and systems thinking. However, implementing such approaches is typically made difficult by the dominant historical purposes and structures of school systems and the current political climate of accountability. Therefore, to advance climate change education, more research is needed on how governments, principals and teachers can help ease the tension between old educational structures and new pedagogical approaches.

The following activities or approaches have been recommended:

1. Community-based learning plans that promote citizenship education and connect complex environmental and social factors of climate mitigation and adaptation
2. Collaborative climate learning methodologies that go beyond knowledge production and community engagement
3. Prioritise political learning in climate education, where students come to understand decision-making powers so that they have the tools to participate in collective and individual actions
4. Learn to critically examine the knowledge basis, interest and values in their communities
5. An intersectional and interdisciplinary approach, supporting inclusive practises

H. Conclusion

Teachers are the main contributors to change of opinions and actions in younger generations. With innovative approaches to teaching and learning, students are likely to be able to adopt critical thinking as one of the main 21st century skills. The best way teachers can do that is by immersing themselves into new teaching methodologies that allow them to understand students' needs and objectives.

If education systems are to become accountable to young people, a full-scale shift in the approach to climate change in the classroom needs to be taken, focusing on scientific data, democratic engagement, justice, political skills, active learning and social network support.

Taking into consideration the fact that education is a process that aims at developing skills, morality, capabilities, knowledge, social consciousness etc. to human entities in order to enable them

a. to adapt to the environment we are living and
b. to adapt the environment so that it provides conditions for fulfilling the sound needs of the human species

Regarding the review, the following significant issues concerning the need for Climate Change Education have been identified:

- Have/ Take Political Will/ Decisions, from a moral context and values supporting the idea that Climate Change Education is an important aspect to address for the human condition.
- Need for decision on whether to introduce a specific topic or subject in the curriculum or whether an interdisciplinary approach should be adopted
- Consideration of the learning approaches that have to be adopted giving emphasis to the development of consciousness and human identity.
- The preparation of the teachers and/ or other learning facilitators so that they can deliver the Motives and Know How to the future citizens for consideration of the repercussions of climate change and the development of skills for proper action towards the survival of the human condition

As a result, the Teaching the Future project should develop and promote activities for:

i. Helping decision makers adopt a context that will ensure the realisation by all stakeholders involved in education of the importance of developing consciousness and skills for action and adaptation to the emerging aspects due to climate change;
ii. Helping the designers and developers of the school curricula to identify the areas of the curriculum that have to consider the issues related to climate change as well as to suggest and encourage activities that will promote a set of goals covering purely scientific aspects as well as moral and socioeconomic elements that contribute to a proper education of the future citizens; and
iii. Helping the development of training elements of the teachers and other learning facilitators that will support them in a new and complex learning environment that will develop humans for surviving and adapting to the new era that is influenced by the climate change. Moreover, they should be empowered so that they give to the future citizens the means for facing the climate change and its repercussions.

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3. An overview of the focus groups and teacher interviews

3.1 Introduction

All project partners were asked to organise meetings and interviews with focus groups of local teachers and educators in order to collect necessary information on how climate change is being taught in schools and what would be required in order for this topic to be better understood by students as well as the teachers themselves. The goal was to collect as much information as possible through a carefully designed questionnaire to enable teachers to look deeply into the curriculum they teach and their methods of teaching, as well as available resources. The key was to gain an insight and introspection of the existing situation. The information gathered was used to make a series of national reports. This is the overview of the findings.

3.2 Methodology

Each focus group sought to include between 4 and 10 participants plus a moderator. It was essential to involve people who were aware of the situation and subject under discussion in their context and country/region. The target group included not only subject teachers (classified as either STEM or Social Science teachers) but also senior staff members involved in the curriculum and its development - such as managers, coordinators and pedagogical advisors (labelled as others); teacher trainers in subjects relevant to the teaching of climate change. It was important to confirm that for the purpose of these groups, Geography has been labelled as a Social Science subject, even though when looking at the curriculum it consists of a lot of Natural Science elements and it uses methods that are predominantly found in STEM subject areas.

Focus groups were used to identify and explore how teachers think and behave, and they threw light on questions that will help understand what is being taught, how and why. Interviews were carried out either in groups or where necessary separately, both face-to-face and online platforms were used.

By using a focus group approach the partners not only collected the information asked for from the questions discussed, but it was also possible to enable and report on group interactions. This provided significant insights of the flexibility and opinions of the groups. Some partners worked with one large focus group, while in others groups were divided according to the availability of teachers, subjects, etc. In some cases, in order to collect an appropriate amount of data, more than one focus group was used. Some teachers and other relevant staff were interviewed separately to the focus groups, due to their availability, their specific expertise and experience, as well as the availability of moderators.

Each focus group had, a moderator who interacted with the participants by asking them a series of questions that were provided in a specifically designed questionnaire. The purpose was to gain insights into how the group approached teaching about climate change. In addition to this, the groups indicated the impacts of learning and teaching about this topic. The moderator tried to stimulate the discussion in the direction of participants by asking them to be as detailed as possible in their responses, in order to get as much information as possible. Where necessary, the moderators used images, concepts and other resources to stimulate discussion. Focus-group moderators posed

questions in a way that didoes not lead group members to provide the desired responses, but rather to gain honest and insightful responses which were true representations of their way of teaching.

It was essential that the individuals selected for the interviews were representative samples of teachers and educators, who weare able to offer insights consistent with practise on teaching about climate change others within the schools on teaching about climate change. By carefully choosing participants wisely, the information collected could be considered a reasonable representation of the process which occurs in schools, and a relevant picture of how climate change is being integrated into the teaching in each school.

The questions asked were divided into a several categories, which in accordance with the type of question, and this division has been used later on in the processing of their responses. The question categories used were

A: Curriculum- basic information
B: Teaching climate change
C: How should climate change be taught?
D: Most Important Challenges
E: Resources
F: Needs of the teachers
G: Concerns

Under analysis, some of these categories have been integrated in the final data representation.

All interviews were recorded either by screen/voice recorder or as a transcript was made if the interviews were in the native (non-t English) language. The focus group meetings lasted between 45 and 90 minutes depending on the number of participants included in the focus group. In cases where the moderators found it useful, they organised additional meetings to gather additional answers to the questions that seemed to need the collection of more detailed responses. For specific information, individual meetings with teachers were organised.

Once all the meetings had been completed, all the information was summarised by each partner in the report they provided and these reports are reviewed in this report. All the data partners provided were carefully analysed and the main principles have been laid out.

3.3 Participant profile

Information was collected from 51 teachers and learning support staff from different schools and countries. The participants were either teaching specific subjects or they were advisors or teaching assistants. All of them were interviewed and data was gathered.

The majority of participants were teaching in Secondary schools and teaching using the national curriculum of the country (Chart 1). A minority of teachers were using an international curriculum.

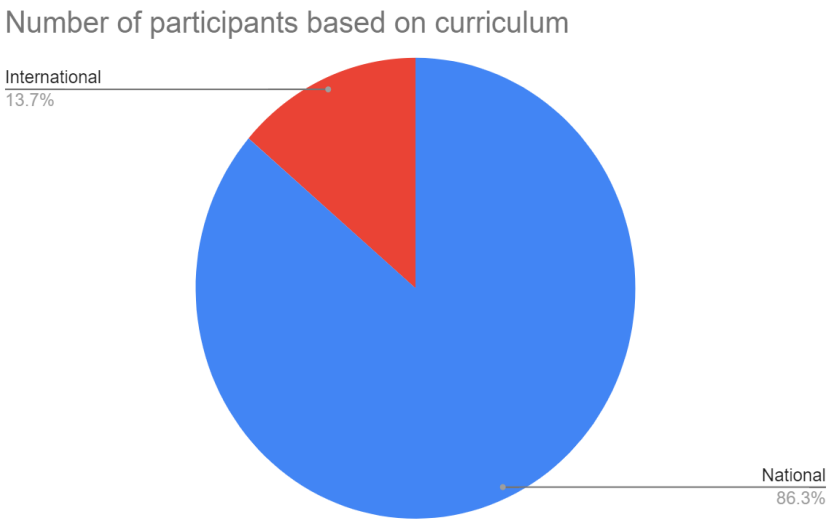

Chart 1. The curricula taught by focus group participants

Based on their roles, three groups of teachers were involved in the focus groups (Chart 2), STEM teachers, Social Science teachers and Others reserved for senior staff members involved in the curriculum, such as managers, coordinators and pedagogical advisors. Geography teachers were categorised as Social Sciences teachers, even though their subject lies between both natural and social sciences.

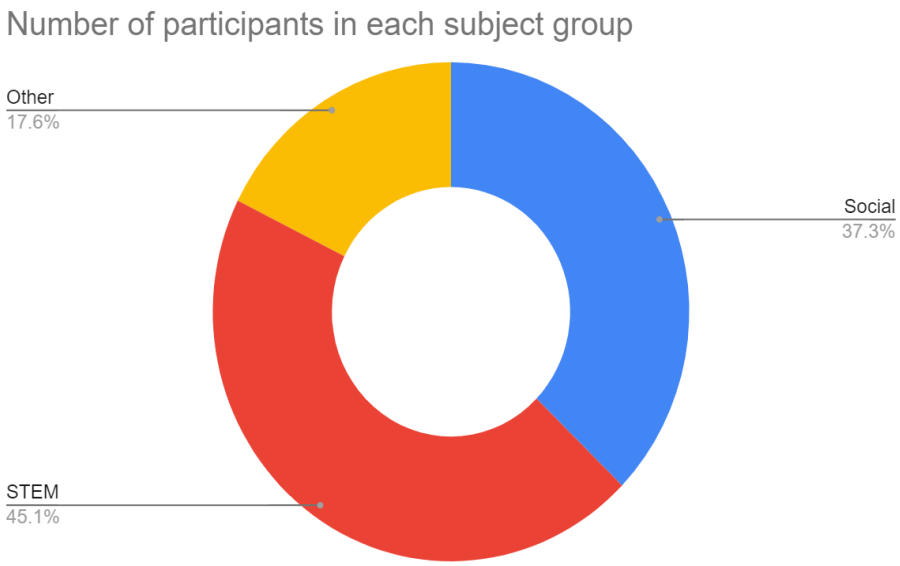

Chart 2. Teacher roles

3.4 Teaching climate change/ methods and challenges

By examining the information collected from all participants it was clear that the main topics taught mostly covered the effects of climate change on the environment and that the objective was to mostly demonstrate anthropogenic consequences, rather than to teach about natural mechanisms that have

an impact on climate change. **It was however considered essential to show students the natural mechanisms of climate change and connect these mechanisms to the consequences.** Teachers do try to make these connections while teaching, but the curricula they were guided by needs to include both perspectives, as the integration of both was deemed essential for further understanding of the topic, and one could not be complete without the other.

All the focus groups stated that the **best way to teach climate change is to use an interdisciplinary approach**, where all aspects are included; since climate change has many "sides", students need to understand the scientific background, but also the social humanist part of it. So all subjects should be included in order for students to fully understand the reach of climate change. STEM needs to be there to explain scientific parts and complex mechanisms but social sciences and humanities may see climate change from another side and show its impact on all parts of society. Teachers stated that using this approach allows them to increase interest of the students as well as knowledge retention. Through cooperation with different fields, students can see the bigger picture and understand the root of climate change, its mechanisms, and its consequences.

Teachers also suggested that that students learn more through **teaching and learning through project-based learning and hands-on activities that are adapted to different age groups.** Learning in such a manner was beneficial since students can do their own research and gain knowledge along the way. By being directly included in research and seeing the impact in nature, students can connect better with the topic and they show greater passion and higher levels of interest. This, a teacher says, allows students to have higher levels of understanding, and to cooperate with one another in completing individual tasks.

It was thought essential to clearly state the benefits derived from students doing their own research, not only can they learn to identify different resources and information sources, but they will also see how to recognise credible and reliable sources. In addition to this, **students should learn how to gather and present data and make their own conclusions and connections**. By being independent learners, students improve their critical thinking and research skills. Both of these are essential not only for the rest of their schooling but also for their future away from school. Problem-solving skills taught and developed in this manner can be used further in life.

Most teachers stated that **their biggest challenge was preparing the resources to be presented** since most of the information they want to present was not extensively covered by their curriculum; so teachers needed to dedicate a lot of time preparing and adapting the information they want to present to students. Planning activities and projects was also time-consuming, and adaptating and using data can be difficult for teachers. This was perceived as one of the major challenges and though teachers strive to overcome it, nevertheless, it falls onto their shoulders to develop resources, and further assistance from relevant bodies is needed as well as connecting with other teachers and sharing ideas.

3.5 Resources for teaching about climate

Resources used by individual teachers varied greatly, but they could be divided into two groups; i) resources recommended by the curriculum that classes follow and ii) resources teachers find on their own. **Resources provided by the curriculum were mostly used and many teachers relied solely**

on them, using them as essential materials, rather than as a guide. This was due to lack of time and teachers being over-stretched, so doing their own research was very difficult for them to do and hard to fit into the existing program. In addition, many had a limited number of hours that they could invest in teaching the topic, since there is a curriculum plan and program they need to follow. This also leads to using the resources provided rather than doing additional research.

Those that did additional research stated that **the adaptation and integration of such information for use in classes was very hard**, due to the scientific language used and the specificity of the topics that could be found in research papers. Individual research on the topic could also lead to finding too much good, usable data that needs to be adapted for teaching, and sometimes the core information would be lost as a result of the adaptations made. Both of these aspects were important since they provided significant information regarding the topics being taught.

Online material was useful, especially videos made by credible organisations with references. This was especially the case when videos were made in such a way that students found them understandable as well as interesting. The teachers said they rely heavily on video content from YouTube made by scientists, and there are many channels that have made videos which explained complex topics in a simple way. This should be backed up with research papers and references used listed below. Usage of these is increasing, and teachers said they can help students better understand the concepts since it was presented in a format familiar to them. Other online materials used could be found on credible websites, and some teachers used them to track scientific papers and data needed for further research.

All **resources found by teachers needed to be adapted to the needs of students**- scientific data presentation, analysis and conclusions need to be drawn; this is likely to be time and energy-consuming for teachers. All teachers agreed on this, resources do exist, but mere shuffling through them is tiring, especially finding the right ones, which are accurate, short and understandable. Many **teachers stated that they could get lost in the vast amount of data and research** available, and that it takes a lot of time to go through it all, and pick and adapt them for usage in their classrooms.

3.6 Needs and Concerns

The needs and concerns of teachers were closely connected in each of the focus groups. Availability of resources was the main concern of interviewed participants and their reliability in the first place. Teachers said they needed more information that could be directly used in the classroom. The teachers said they would benefit from the information being laid out in such a manner that it can be directly used in their classes. In order for this to happen, teachers would need to connect with climate researchers and educational experts to share the types of data presentation would be most useful for them. This requires a lot of horizontal and vertical exchange of data and knowledge, as well as support from the researchers. While it was considered understandable that scientific research papers needed to be written in a specific manner, and researchers cannot digest the information specifically for teachers to use in the classroom, however to help teachers better understand the data and cut down the amount of time needed for adaptation, cooperation between teachers and researchers would be beneficial. It was thought that researchers could introduce new ideas and provide additional resources

and books for teachers to use once they knew what was needed. Through this cooperation, both parties would gain knowledge and polish skills.

Teachers stated that the time provided in the curricula was somewhat short and more time would be needed to present climate change topics. This means that the number of hours that curricula makers stated for teaching climate change was very short especially considering the specificity and extent of the topics. Teachers were forced to condense existing material into bite sized chunks, which significantly lowered the level of knowledge and interest of the students. Condensing a topic that is very complex and broad is likely to lead to a loss of vital information, misrepresentation and lower levels of understanding of the concepts, furthermore, it decreases the understanding of the significance of the topic to students.

Support from the educational community, relevant ministries and NGOs is essential to help with conducting projects and spreading the word and making an impact. This requires sharing the information and listening to the teachers and their specific needs. By including all aspects mentioned in the process, the time needed to incorporate the topic will be decreased, and the data and information provided would be better adapted and accurate for class use, leading to increasing standards and levels of understanding and knowledge.

Teaching is a job where training and good practice workshops are necessary to develop expertise. Through building their competencies, teachers would increase the quality of teaching and student engagement. This would be an opportunity where teachers could exchange ideas. This would be advantageous for all involved. All the teachers interviewed stated that they would benefit from exchanging ideas with others. This again would helps teachers reduce the amount of time needed to adapt existing information and resources, making their lessons more interesting and students more engaged.

Some participants mentioned that more funding in this area was needed so projects, hands-on activities and field trips may be organised and conducted. Even though teachers were resourceful, in order to do such activities some funding would be needed, so projects which were funded would be beneficial, since students learn best through practical work, and having these from time to time surely assists in grasping the bigger concepts and local impacts of climate change.

By having this sort of distribution between subjects and other staff, there is a better insight into the functioning of teaching climate change. This allowed having a good preview into the practice of teaching, as well as the understanding of the habits of teachers and students; the way they teach and what they need in order to be more effective and efficient in presenting topics related to climate change. Also, different views on the topic assisted in learning how hard can it be to incorporate such important topics, and how teachers need to corporate with one another in order to accomplish better results.

4. National curriculum analysis

Desk based review and analysis of the national curriculum of partner countries was carried out.

4.1 Summary

In each of the countries that participated in the Teaching the Future project, the national pre-university curriculum usually lasts for 12-13 years. Pre-university education was usually split into two parts, primary and secondary education. The level and approach used of climate change education depended on the age of the students.

While climate change education is mainly implemented from an early age through science subjects (Geography, Biology, STEM), major efforts are being invested into implementing specific topics and pedagogical approaches to climate change education.

In Italy, with the Guidelines as of the 20th of August 2019 “Introduzione dell’insegnamento scolastico dell’educazione civica”, climate change has been introduced to all the curriculum at all levels. This is the first time in Europe that environmental education entered the national school curriculum as a compulsory subject area - Civic Education. In the Serbian curriculum, in secondary schools, students study 20 subjects. Climate change is only briefly mentioned in the subjects’ curriculum. Nonetheless, students can choose a subject called Sustainable Development Education, which includes climate change education.

Spanish education law was updated in 2020[1], resulting in an emphasis on Education for Sustainable Development, paying special attention to the SDGs, among which SDG 15 "Climate Action" stands out as key to this project. Specifically, the Education Law names sustainability from the preamble, recognizing sustainable development as one of five key focuses of the law, (the others are children's rights, gender equality, personalisation of learning and digital competence).

In Flanders (Belgium) a curriculum reform is in progress. The curricula of the 1st and 2nd grade (ages 12 -16 y) is almost done, the 3th grade will follow from September 2023 on. In the new curricula climate and climate change is more prominent.

4.2 Addressing climate change education

While addressing climate change education in national curricula, three main current needs of climate change education were evident:

1. **Climate change education should be interdisciplinary and transversal;**

In Spain, there are different developments by Autonomous Communities (competences that the Spanish territories have in the field of education), but in general, the curriculum works on the climate emergency in a transversal way. Articles 19 and 121 of the Spanish Education Law specify the

[1] https://www.boe.es/diario_boe/txt.php?lang=en&id=BOE-A-2020-17264

transversal treatment of climate change when working on education for responsible consumption and sustainable development.

In Italy, climate change education is present in among other disciplines in the subject called "Educazione Civica" (Civic Education) that is a compulsory subject, but interdisciplinary: it doesn't have a specific assigned teacher of reference, but it is a shared load among the teaching body. Teachers decide at the beginning of the year what are the objectives and the specific topics that will be covered. Civic Education is then considered an interdisciplinary subject, without fixed rules or fixed hours dedicated to one or another module: it will be decided by the "Collegio dei docenti" (Teachers board) at the beginning of the school year how to share the responsibility of the 33 hours and through which subject.

The Serbian curriculum offers climate change education in the form of an elective course that has to be approached in a project-based way, using the knowledge from various different sources and subjects.

In the Greek and Cypriot curriculum, Environmental Education – Climate Change - can be found in topics of Biology and Geography but the main emphasis on the issue (as well as for the environmental issues and sustainable development) is promoted through an extracurricular programme under the title Unit of Education for the Environment and the Sustainable Development.[2] This extracurricular programme is also project-based and advocates for interdisciplinary approaches.

In the Flemish curriculum geography is seen as one of the STEM subjects (Science, Technology, Engineering & Mathematics). In the curriculum links are made with these subjects, including a more research-based approach of themes like climate change.

2. **Climate change education lacks more precise standards and resources for teaching and learning;**

Upon analysing national curriculum, it is clear that climate change education lacks more precise standards and resources for teaching and learning. In Italy, in the official document from the Ministry of Education, it's stated that Civics Education subject is not a rigidly set up area, but it can be modelled according to needs, but it needs to include the following macro areas using various sources and subject skills:

- Constitution, laws, legality and solidarity;
- Environmental education, sustainable development, environmental and heritage protection;
- Digital education, digital citizenship.

Most of the subjects are theory based and presume teaching from the front. The course books only mention climate change and it is up to teachers to search for additional material and decide whether students should learn it through projects. Nonetheless, there are almost no materials, didactic means or other resources for teachers provided.

[2] https://mepaa.moec.gov.cy/index.php/el/

The Serbian curriculum also lacks resources for teaching and learning. While course books only mention climate change, it is up to teachers to search and present reliable information to students. Nonetheless, there are some assessment standards regarding elective courses that include climate change education, but no specific knowledge is required regarding the specific information on climate change.

In the Greek curriculum, tt the Primary level there is a specific topic “Environmental Education/ Education for Sustainable Development” focused on:

- Reasoning behind the topic
- Basic Constituents/ Axes of the topic
- The Content and the Objectives
- The teaching methodologies and the
- Assessment approaches.

While there are no specific standards and assessment resources, the Greek education system sets the strategic goal to integrate these topics in all the educational levels of the country, through the parallel promotion of central educational actions, as foreseen in the National Strategic Planning, which can contribute to the formation of tomorrow's critically thinking and responsible environmental citizens in the context of the formation of the sustainable school which will function as an agent of environmental and social change.

A number of environmental centres were established in the country. Also actions have been promoted through European programmes, competitions and other activities that are supported either by the Ministry of Education or through other government departments. A very interesting action stems from the Cyprus Energy Agency, which is a non-profit organisation with interest in climate change and which provides ample information for studies and projects on the issue, which enables teachers and students to gather relevant information.

Spanish education system introduces climate change education at a much more reasonable pace:

Spanish education level	CONTENTS
K1-2 (6-8 years) General content related to sustainability	– Sustainable lifestyles and the importance of caring for the planet through scientific knowledge present in everyday life. – Healthy habits related to the physical well-being of human beings: hygiene, varied, balanced and sustainable diet, physical exercise, contact with nature, rest and care of the body as a means to prevent possible diseases. – Eco-social responsibility. Actions for the conservation, improvement and sustainable use of common goods. Animal abuse and its prevention.
K3-4 (8-10 years) The specific treatment of climate change appears	– Climate change. Introduction to the causes and consequences of climate change, and its impact on the Earth's landscapes. Mitigation and adaptation measures.

K5-6 (10-12 years) The specific treatment of climate change appears	– Climate change from local to global: causes and consequences. Mitigation and adaptation measures. – Planetary boundaries and climate change. – Ecosocial responsibility. Eco-dependence, interdependence and interrelation between people, societies and the natural environment.
K7,8 y 9 (12-14 years) Learning and thinking about climate change	– The causes of climate change and its consequences on ecosystems. – Climatic emergence: elements and factors that condition the climate and the impact of human activities. Methods of meteorological data collection and interpretation of graphs. Climate risks and catastrophes in the present, in the past and in the future. Vulnerability, prevention and resilience of the population to natural disasters and the effects of climate change. – Causes and consequences of climate change and environmental degradation: importance of ecosystem conservation through sustainable habits and reflection on the global effects of individual and collective actions.
K12 (17 years) Climate change, consequences and social inequality	– Climate change: its relationship with the carbon cycle, causes and consequences on health, economy, ecology and society. Strategies and tools to face it: mitigation and adaptation. – Economic science and ecology: climate change, sustainable development and circular economy.

Table 2: Source: Royal Decree 217/2022, of March 29, establishing the organisation and minimum teaching requirements for Compulsory Secondary Education. https://www.boe.es/eli/es/rd/2022/03/29/217/con

Also the new curriculum in Flanders (Katholiek Onderwijs Vlaanderen) included as the thrusts of the new curriculum ***Placing the climate within a changing social context:*** Climate change is a consequence of economic and demographic processes and in turn affects those same processes. In second grade, the focus is on the causes and consequences of the enhanced greenhouse effect.
More specific in the new curriculum of the 2nd grade (age 14-16 y) In the new curriculum 2de grade, climate runs like a thread through the curriculum, visualized in this graph

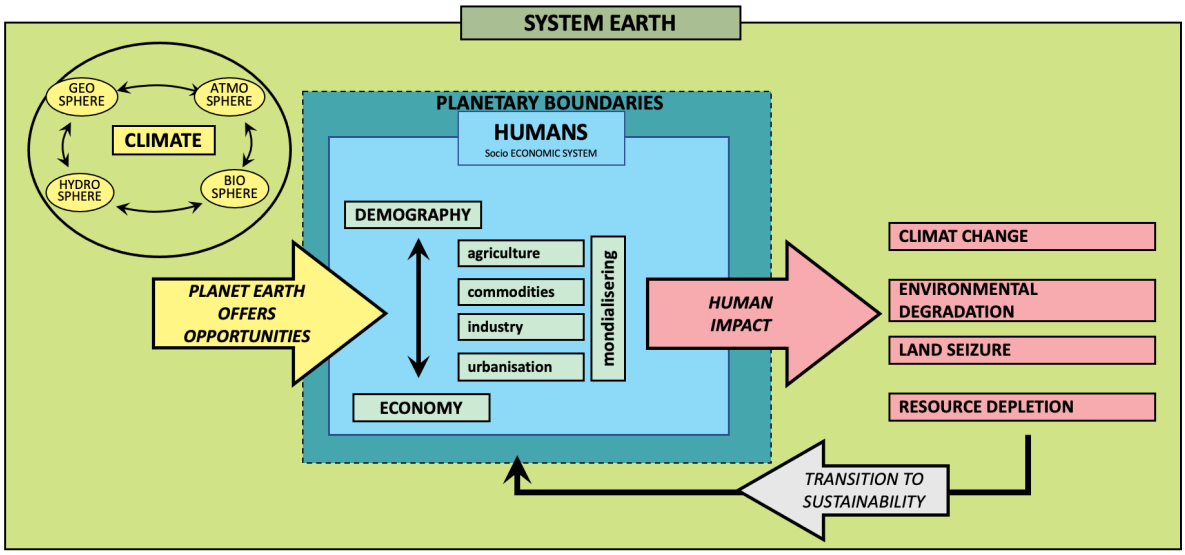

Figure 10 Graphic presentation on the new geography curriculum, Katholiek Onderwijs Vlaanderen, https://pro.katholiekonderwijs.vlaanderen/download/content/837659b7-570e-4acc-b973-8e01dc380a3f/attachments/Leerplan%20II-Aar-d%20(1ste%20leerjaar%202de%20graad%20vanaf%202022-2023).pdf

The curriculum starts (top left) with climate:

- LPD 1: Students explain climate regulation as an interaction between the biosphere, atmosphere, geosphere, hydrosphere. Within this goal, emphasis is placed on the emergence of climate regulation. As a result of the interaction between the 4 spheres, a natural greenhouse effect arises which, together with the carbon cycle, underpins this climate regulation.
- LPD 2: Students relate the physical factors provided by the Earth system to the spatial distribution of humans. Unlike periods with many climate fluctuations, the climate has experienced remarkable stabilisation over the last 10,000 years. This climate stability provides conditions that favour the development of human society. In addition, the development of human society was also highly dependent on the presence of natural resources.

Subsequent goals then address how humans interact with the earth in terms of demographics, agriculture, resource extraction, industry, urbanisation and this in a global context. Planetary boundaries are being crossed and this leads to problems, and one of them is climate change with consequences:

- LPD 12: Students compare the contribution of different anthropogenic sources of greenhouse gases in different regions to the enhanced greenhouse effect.
  The increasing use of fossil fuels massively releases stored fossil C back into the air, throwing the carbon cycle out of balance, resulting in the enhanced greenhouse effect.
  The various anthropogenic sources of greenhouse gases contribute to an enhanced greenhouse effect. You can identify the origins of these gases using some examples. What are the regional differences? Using the global warming potential, you can compare different greenhouse gases in terms of their contribution to warming. What is their effect in space and time (residence time)?
- LPD 13: Students illustrate consequences of the enhanced greenhouse effect using positive and negative feedback mechanisms:

- rise in sea level;
- shifting climates; and ranges of plants, animals and tropical diseases;
- extreme weather phenomena.

Using maps, you can illustrate expected temperature changes, sea level levels, extreme weather phenomena, shifts in climates, ranges of plants, animals and tropical diseases.

Here you can also make it clear that these "maps" are all models or scenarios and thus different from the "normal" maps students work with, which are "factual".

However, you do need to teach students how to deal with this and interpret that there are great uncertainties with these maps. That these maps (especially in media) are often simplistic and do not reflect a possible reality. You can teach students to think critically about such maps.

The solution is a transition to a sustainable world. This uses Raworth's donut model, among others.

3. **Climate change education needs to be more present in the curriculum.**

The review of the national curriculum clearly raises **the need for climate change education implementation from primary to secondary level education in a more formal and organised manner**. While an interdisciplinary approach is certainly the way to introduce climate change education, a better standardisation process and a clearer way to introduce students to this education are needed.

The new Flemish curriculum of Katholiek Onderwijs Vlaanderen understood this, as they state: "*Geography makes students aware of the need to treat planet earth responsibly. More specifically, the new curriculum from in 2de grade also responds to the climate youth's yearning for more attention to climate issues. Geography thus becomes the 'climate subject' par excellence. Thus, geography contributes to citizenship education and sustainable development*."

As climate change is something that affects us all, it is not possible to implement climate change education at a larger scale without making it mandatory and assessed. The national curriculum review has shown that climate change education is present throughout the curriculum in the form of topics and subject elements. While only a handful of countries currently mandate climate change studies in their education systems, barely any countries have included climate education in their formal curriculum. Many projects, agencies, international organisations and NGOs advocate climate change education to become compulsory in schools to better equip children to cope with global warming and other consequences of climate change in the future. This national curriculum review, therefore, addresses the need for this as well.

5. Pedagogical guidelines and approaches

As teachers are the ones that are presenting climate change as a topic, it is essential to lay out some guidelines that can help them do this task the best they can. There are many techniques and resources that can be used in teaching, and most teachers use them regularly, in some instances without training or support. This section reports on the discussions and interviewd held with teachers during the initial stages of the project.

As **climate change is a very complex and diverse topic** that can be approached from different perspectives. The following is a description of the ones considered to be the most suitable and helpful in presenting topics such as climate change, as discussed in the focus groups and interviews carried out with participants. These are just some tools that can be used, and teachers should be encouraged to seek more and adapt them to their own teaching styles. In addition to this, this is supported by research of published articles on teaching approaches.

5.1 Interdisciplinary approach

An interdisciplinary approach presents a crucial tool in teaching and learning, not only when we talk about climate change, but it can and should be applied to as many topics as possible. This approach uses many different disciplines to integrate knowledge and to enrich the class and lesson that is being taught. It gives the opportunity to use multiple disciplines and allows students and teachers to explore the topic from different perspectives and disciplines; allowing students to cling to the ones that are interesting and they feel comfortable in, while also exploring other disciplines. This allows integration and students to be more present during lectures. It also moves teachers and students from the traditional, single-discipline approach, allowing them to see the broader picture.

Figure 11 All fields are integrated in the brain[3]

[3] https://edtosavetheworld.com/tag/interdisciplinary-learning/

The origins of interdisciplinarity can be seen in literature as early as the 1930s through curriculum integration. However, it is noticeable that even today, this approach is far from being used as a utility and to an extent can be used. The interdisciplinary approach has been defined by Executive Director of the Association for Integrated Studies William H. Newell and William Green (1982) as "inquiries which critically draw upon two or more disciplines and which lead to an integration of disciplinary insights" (Haynes, 2002, pg17).

One of the postulates which we need to have in mind is lifelong learning; meaning that school and skills obtained during schooling should support students and help them continue developing skills and gaining knowledge even after they have done with school. Taylor concludes that "Interdisciplinary work by both educators and students may broaden students' knowledge of history and diverse cultures. Including the arts in social studies instruction may have pedagogical benefits as well because the inclusion would facilitate differentiated instruction" (Taylor, 2008). Statistical reports and further research has shown better levels of understanding, longer retention of knowledge and better test scores compared to groups which did not learn through the mentioned approach.

Over the years the number of research articles on interdisciplinarity in teaching STEM especially has increased, and as can be seen on Figure 2, the number of available articles increased significantly. This can also be attributed to more teachers being willing to try the approach, but also interest from those in Universities seeing the importance of including other subjects in teaching and researching different topics.

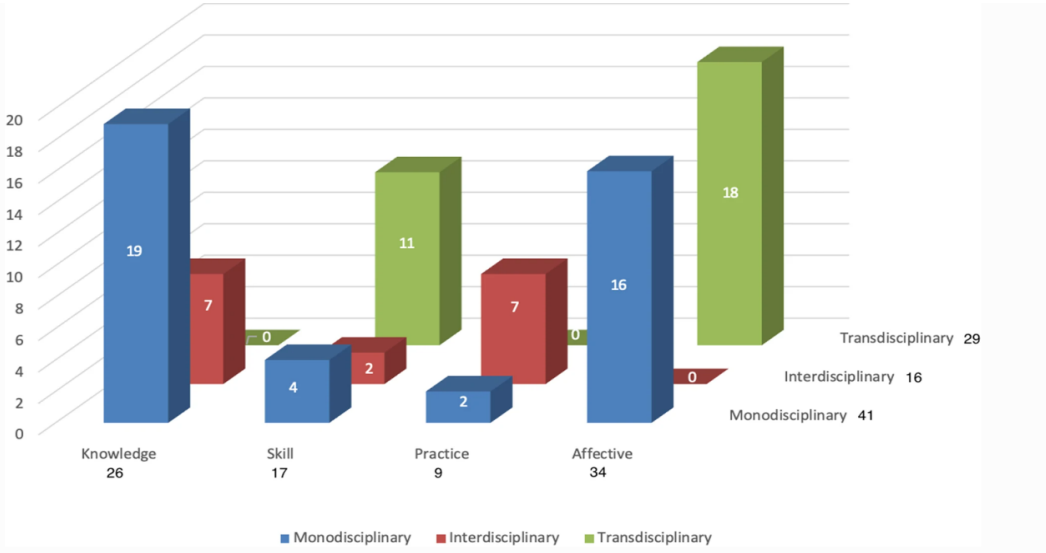

Figure 12 Distribution of different article categories[4]

By using this method more than one perspective may be shown to students, and students with different and varied interests may become more engaged in the lesson. In practice, this approach has shown that the retention of knowledge is significantly higher as well as engagement of students, even the ones that have lower marks. In addition, students may share knowledge amongst themselves and

[4] Gao, X., Li, P., Shen, J., & Sun, H. (2020). Reviewing assessment of student learning in interdisciplinary STEM education. *International Journal of STEM Education*, *7*(1), 1-14. https://doi.org/10.1186/s40594-020-00225-4

by reinforcing transgenerational learning and peer tutoring we can see higher marks on the assessments and tests, as well as better overall in-class participation. Not only do students learn to collaborate in the group, but they also have an example of collaboration between the teachers of different subjects allowing them to see through the example how cooperation is important.

This approach, however, involves more than one teacher and planning such lessons can be and is time-consuming for teachers who have busy schedules. Planning these kinds of lessons may be tricky since there are syllabi requirements in all subjects that need to be met, so carefully designing a plan for the lesson may be more time-consuming if the teacher has time to spare. In addition, sometimes schedules may not be met, and not big enough space can be found. These obstacles are not deal breakers, since in this case, students do gain more usable knowledge.

5.2 Project-based learning

This approach usually relies on teachers to introduce and design projects for students to do in groups or on their own and solve an issue or answer the question. It is known in the pedagogical community and among teachers, but many teachers do not use them regularly since it takes a lot of time to plan and later on evaluate the results students come up with. It is essential to mention that through project-based learning students are involved from the start to the end of the project and they have complete freedom to execute it as long as they are following given guidelines and answering the question they need to or they are solving a given problem.

When constructing these kinds of projects teachers may make them last as long as they want to or see fit, incorporating them with different tasks provided by the syllabus. It is essential to maintain the interdisciplinary approach and include other teachers in order to expand the reach of the project as well as to make sure students are more interested and engaged in the project that is being planned.

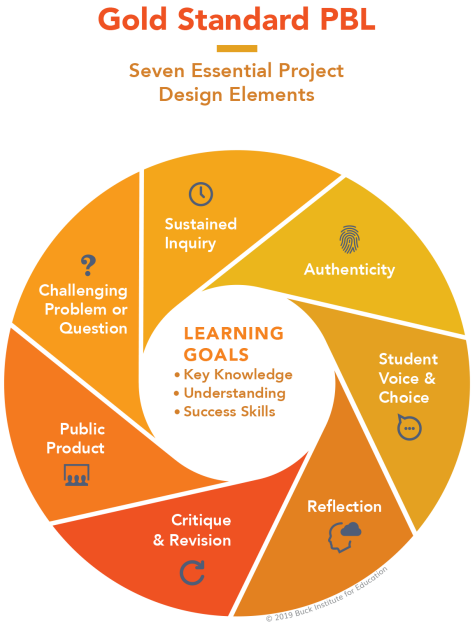

Figure 13. Gold standard in making project-based lessons[5]

[5] https://www.pblworks.org/what-is-pbl/gold-standard-project-design

Planning these activities is not always easy, by following a few guidelines it can be easier. Figure 3, shown above, represents the so-called gold standard. All these elements are important and by having them all in the project, it can make them long lasting, repetitive and have better impact and knowledge retention. It is always good to start with the question or problem to be solved, and move forward in making sure students can do them on their own, making it personalized, but also open for reflection and revision once done. In the end the project needs to contain some kind of product in the end, and this circles the entire process.

Projects may be a good tool for teachers to have up their sleeves and many organizations such as UNICEF may offer some examples of projects which involve climate change. This can be a good start in planning and many projects may be changed by teachers' and students' individual needs. Adapting may be time-consuming and some teachers may struggle with this aspect, but once made, they can be reused and upgraded as time goes on. Since these projects may include other subjects, it requires collaboration between departments and different subject teachers, expanding the project reach and giving students more perspectives to look at the problem form. Since not all students have the same interests, by introducing interdisciplinary projects, teachers can target more students and make them engaged. This also allows the students to learn how to cooperate and work as a team, and to make long-term connections between different subjects. Students may assist one another in completing tasks and learning from one another resulting in higher scores and better retention of knowledge.

Service learning can be described as a form of problem-based learning that concerns meeting the needs of the community. It is a pedagogy integrating academically relevant service activities that address human and community needs into a course. Students connect knowledge and theory to practice by combining service with reflection in a structured learning environment. The problems are normally established by the students with the community and the teacher merely plays a supporting role in the design of the activities.

5.3 Research, critical thinking and development of these skills

Schools may have different syllabi but it is evident that developing research skills of the students is increasingly important in this day and age. In some programmes, there are subjects designed to help students learn how to do their own, independent research, how to distinguish reliable sources from the ones that are not reliable and even how to interpret data; in other programmes, these skills are meant to be thought through STEM subjects, even though, not only in these you may use this particular set of skills.

There is a lot of fake news and clickbait on the internet, and it is important to advise students from an early stage on how to recognise the sources they can trust and the ones they cannot and why. This not only assists in proceeding with school-related tasks but it enables students to be more diligent in gaining information.

Research has been carried out on graduates and it has shown that skills of research are essential for completing their studies and preparing them for future jobs and continuation of schooling. Since the research is based on self-reporting, it is good to remember these skills are functional and usable in all spheres of life and beyond schooling.

Many teachers struggle to find a way to help students develop these skills and it can be very time-consuming to organise lessons around this, especially if students lack mathematical skills as well. What can be helpful is combining the development of these skills with an interdisciplinary approach and projects, and letting students figure it out on their own with the guidance of teachers as well as their peers.

Peer tutoring can be an important asset in developing these skills, and through carefully planned tasks, students can learn and improve their critical thinking, and learn how to do the research on their own.

Figure 14. Importance of critical thinking [6]

Critical thinking is essential for lifelong learning and it provides a set of opportunities for the ones that have highly developed levels of these skills. In the first place, it helps gain better problem-solving skills and improve decision making which is essential in all aspects of life. In addition to that, it provokes curiosity and creativity, leading to better responses in different situations, but most importantly refines research skills essential for teaching and learning about climate change, amongst other topics.

Through the development of their skills, especially critical thinking and independent research teachers build capacities, and empower students with more than just book knowledge which is important for problem-solving. Here, as mentioned, different activities may help.

5.4 Planning hands-on activities

No matter which curricula they follow, and how old students are, any kind of activity which involves them making something and providing a specific outcome can be very time-consuming for teachers to

[6] https://tscfm.org/blogs/the-benefits-of-critical-thinking-for-students/

plan any sort of activity, especially if we take into consideration that there are specific time frames that need to be followed.

Including activities which make students move physically can have many benefits. This also includes field visits where different tasks including measurements that can be done in nature. Research has shown that having field trips in which students and teachers do their own research and measurements, increases not only interest but also retention of knowledge. Especially as climate change in this case becomes more “real” and students can see the impact on the environment.

These kinds of activities may and should include more than one subject and rely on the interdisciplinary approach when planning so engagement may be increased. By using this method students learn more about collaboration and connections between different sciences, especially the connection between the scientific and anthropogenic parts of climate change. Constructing activities is not an easy task, due to the fact that it is time-consuming, data needs to be completed after activities, and teachers need to find common ground in making sure all needs of the syllabus have been met. Carefully planned investigation may improve students' research and critical thinking skills, as well as lead to better retention of knowledge.

The NASA website (Figure 5) has a large number of educational resources and it offers a number of pupil activities. Sites such as this may be used as a resource and can be a good start for further planning. The teachers can mould the activities in the way they see fit, applying them through their own syllabus, as well as using as much time as they have to conduct the activities. Once established, they can be incorporated and repeated year after year, establishing good practice and creating a wide variety of learning tasks.

Figure 15. Screenshot from NASA website of activities[7]

One of the obstacles to planning may be funding, and there are schools which cannot grant funds for students to travel long distances and be on the spot, such as forest, river, lake etc; however this is where teachers' creativity comes into action, and there could be suitable replacement for on site

[7] https://climatekids.nasa.gov/menu/make/

activities. A walk to the city park, or even in the front yard of the school, and observing the behavior of students may be a good starting point in making students aware of the impact on climate change.

Activities may include data retrieval and statistical analysis of temperatures, humidity and PM particles in the air; considerable amounts of data Is available, so students can create charts, diagrams and compare data in the way they could not do beforehand. The usage of existing documentary resources may include historical research of diaries, records and events. The aim is for teachers to conduct as many relevant activities as possible and engage students in teaching and learning processes that are different from ex-cathedra.

5.5 Metacognition

Metacognition is commonly defined as thinking about thinking. This concept has been well known in psychology since the start of the 80s and it is very hard to actually define it since the science behind it holds a lot of details. The term "metacognition" is most often associated with John Flavell, (1979). According to Flavell (1979, 1987), metacognition consists of both metacognitive knowledge and metacognitive experiences or regulation. The importance of this method is to become aware of the higher cognitive processes which are happening in the brain while thinking and learning about the specific topic. In science education it is essential to be aware of processes occurring, since mechanisms may be too complex to comprehend, so thinking about the process of comprehension and teaching students to do so may unlock skills which are essential to overcome obstacles in learning.

Considering the biology of the whole process. Figure 6 represents how metacognition works in the brain. There is input coming from the surroundings, which is placed in so-called sensory memory; this is due to the fact that all stimuli comes through specific sensors in the body, and travels via sensory neurons into the specific lobes in the brain as sensory input. As early as 1974, Baddeley and Hitch suggested the term working memory, which describes cognitive processes occurring in the brain while one is actively processing information coming from the sensory parts of the brain. Processes occurring are very fast and do happen in up to 30 seconds, after which other brain parts take over the processes and place them into the long term memory if the information does not dissipate.

Figure 16. Visualisation of metacognitive processes. Illustration courtesy of iDoRecall [8]

Awareness of the cognitive processes that occur and recognition of the time needed for specific tasks to be done is important and can help in time management skills. This also allows students to plan their time in accordance with tasks, but not only to students, but teachers as well. Thinking about the task and being aware of all subtasks to be done makes sure that students and teachers are more productive and use their time effectively. Metacognitive experiences involve the use of metacognitive strategies or metacognitive regulation (Brown, 1987).

This method is essential in learning about climate change, as well as in learning new skills, gaining new knowledge and also polishing skills that already exist. Teachers and students in most cases use this method but they are not aware of it. Increasing awareness of processes happening inside one's mind, enables one to become more aware of the processes around oneself, and it can assist in recognising patterns which may in different occasions be missed. This is essential in recognising parts of mechanisms which are very complex and involve multiple steps and perspectives.

Seeking support

Last but not least, seeking help is important in tackling topics such as climate change. As this topic is very broad it can be overwhelming to dive into it, so help is needed. Teachers may cooperate with one another, use interdisciplinary approaches to polish the skills and make lessons which can explain desired topics. In addition, help from the authorities, NGOs, Ministry and University is essential, since they can provide teachers with data that is up to date.

Online resources may be of help in planning activities and learning more about the topics. But also in building competences through training and workshops.

[8] https://www.learningscientists.org/blog/2020/4/2-1

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