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Rethinking education in the context of climate change: Leverage points for transformative change

Deborah Nusche,
Marc Fuster Rabella,
Simeon Lauterbach

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Rethinking Education in the Context of Climate Change: Leverage Points for Transformative Change

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By Deborah Nusche, Marc Fuster Rabella and Simeon Lauterbach, OECD

This working paper has been authorised by Andreas Schleicher, Director of the Directorate for Education and Skills, OECD.

Deborah Nusche, Senior Analyst, deborah.nusche@oecd.org.
Marc Fuster Rabella, Analyst, marc.fusterrabella@oecd.org.
Simeon Lauterbach, Intern, simeon.lauterbach@oecd.org.

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Abstract

State-of-the-art scientific evidence shows that our planet is approaching several environmental and climate tipping points faster than previously expected. This means that the international community is facing a rapidly closing window of opportunity to achieve profound transformations across sectors, systems and mindsets to secure a sustainable and liveable future. What is the role of education system in enabling social change at the massive scale and pace needed for climate change mitigation? And what policy levers can they employ to build resilience and adapt to environmental challenges? This paper explores ways to rethink educational approaches in the context of climate change, focussing primarily on school education, while exploring links to other levels of education. It looks specifically at strategies to restructure foundational science education and cross-curricular learning, zooms in on the potential of place-based approaches in empowering learners for action, and concludes by identifying policy levers to increase education system resilience.

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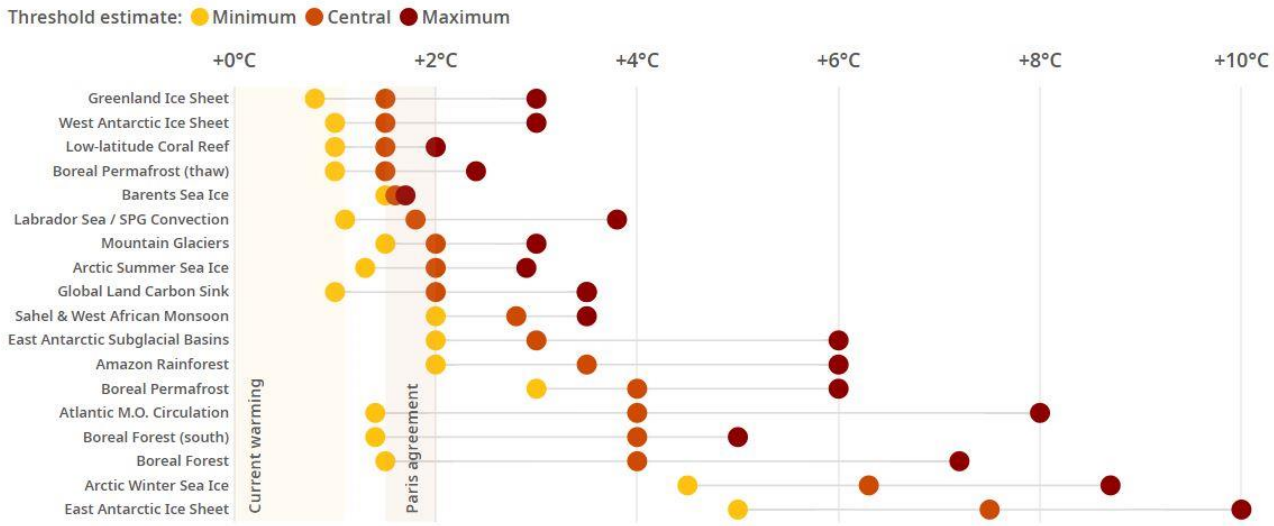
1. Introduction

Education about socio-ecological risks has entered a new era in the 2020s. Recent evidence validated by the international scientific community shows that our planet is approaching several environmental tipping points faster than previously expected (Calvin et al., 2023[1]). In environmental science, tipping points refer to critical thresholds beyond which Earth's systems are likely to reorganise abruptly and/or irreversibly. Examples include higher than expected melt rates of Antarctica and Greenland ice sheets over the last thirty years, loss of Amazon rainforest resilience and the slowdown of important ocean currents (OECD, 2022[2]).

As different environmental tipping points are connected to each other and driven by multiple factors, it is possible that there could be a tipping cascade in the natural world (OECD, 2022[2]) with one sub-system making another sub-system tip like dominoes, resulting in system failure and breakdown. State-of-the-art research indicates that crossing some environmental tipping points is already possible at current levels of warming and will become "likely" at levels of warmings consistent with the Paris Agreement range of 1.5 to 2°C (Figure 1) (OECD, 2022[2]).

Figure 1. Global warming threshold estimates affecting environment elements

By type of effect, in Celsius (°C) relative to pre-industrial levels



Source: (McKay et al., 2022[3]) in OECD (2022) *Climate Tipping Points: Insights for Effective Policy Action*, OECD Publishing, Paris, https://doi.org/10.1787/abc5a69e-en.

This means that the international community is facing a rapidly closing window of opportunity to adapt to the significant environmental changes already underway and achieve profound transformations across sectors, systems, institutions and mindsets to secure a sustainable future. Various models exist to quantify the factors that can contribute to mitigating climate change and other environmental risks (Nordhaus, 2017[4]). These include behavioural changes, technological advances, economic systems and policy interventions.

These factors interact with one another in climate change mitigation strategies, and their respective contributions to reducing emissions are difficult to disentangle. For example, shifts in consumption behaviour can drive businesses to innovate and reduce emissions, and changes in citizenship behaviour such as collective action and voting can influence policy choices and economic incentives. In turn, individual and household behaviours are shaped by existing policies, markets, infrastructures, and technologies (Dubois et al., 2019[5]).

What is the role of education in influencing these complex change dynamics? This paper explores how education systems can go beyond encouraging individual behavioural change to facilitate reflection on collective and system changes, including in the social, economic, political and technological spheres. It considers how education systems can best empower learners to understand, demand and shape the wider transformations that are most effective or most promising in addressing climate change and other environmental risks.

This paper is structured in four sections. This introduction (Section 1) explores the role that education systems can play as drivers of transformative change and identifies potential leverage points for education policy to accelerate such change. The subsequent sections offer more in-depth analysis of the identified policy areas and conclude with a set of pointers for future work:

- Getting the foundations right: rethinking science education and cross-curricular learning (Section 2),
- From individual to collective action: the power of place-based approaches (Section 3),
- From anxiety to adaptation: making school systems climate change–resilient (Section 4).

These thematic priorities were identified as part of a strategic reflection (Annex A) and mapping exercise (Annex B) conducted in the OECD's Directorate for Education and Skills in 2023 to identify areas in which the OECD could offer significant added value and expertise. The identified leverage points are clearly not the only relevant education policy levers to support environmental sustainability in and through education, but they were selected with a view to fill identified gap areas, complement existing international work, and maximise the OECD's comparative strengths.

1.1. Education systems as drivers of transformative change

1.1.1. Education systems as positive tipping elements

As described above, the concept of tipping points has been widely used since the early 2000s to describe climate and other environmental dynamics, offering a sombre outlook on the prospects for our planet's future. But the concept of tipping points is equally useful in describing potential solutions that can match the exponential challenge of climate change. The term has long been used in the social sciences to describe specific forms of social change dynamics (van Nes et al., 2016[6]). In the social sciences, a tipping point is understood as the point when certain behaviours or social norms spread rapidly from minor tendencies to major practices, due to positive feedback loops and self-enforcing progress (Milkoreit et al., 2018[7]; Otto et al., 2020[8]).

The idea of tipping points in social systems implies that small nudges (e.g., timely policies) can lead to rapid social change, potentially accelerating climate change mitigation at relatively low cost and/or effort. However, research indicates that there are preconditions for successful positive tipping, namely that systems need to be 'ready' with other driving factors already in place, and that there needs to be leadership and capacity to sustain change and overcome resistance from vested interests (Otto et al., 2020[8]). Otto at al. (2020[8]) identify education systems as one of six social tipping elements that could be triggered by specific tipping interventions and lead to substantial emissions reductions[1].

Indeed, there are various aspects of education systems that make them well suited to advance social change for climate action. First, the universal reach of education systems makes them a key factor in influencing behaviours, norms and values systems. If solutions-oriented climate change education is prioritised in compulsory school education, this can potentially reach all youngsters at a critical developmental age and lay the foundation for widespread change (Pereira and Freire, 2021[9]; Wynes and Nicholas, 2017[10]). Although young people enrolled in school education have a lower environmental footprint and less decision-making power than adults, education is key to shaping subsequent study and career choices, civic engagement and consumption behaviour. In addition, extending the focus beyond school education and taking a lifelong learning perspective can further enhance the reach of environmental, sustainability and climate change education, offering age-appropriate strategies from early childhood education and care (ECEC) through to higher education and adult education.

Second, the scale of schools, school networks and school districts offer reasonably sized microcosms in which sustainability solutions could be tested and piloted. The multiplying effects of local or school-based initiatives are likely to reach individuals beyond those currently enrolled in education, and touch families, communities and social networks via peer effects, intergenerational exchange and local collaboration. For example, results from the OECD's Programme for International Student Assessment (PISA) indicate that young people's pro-environmental engagement is interrelated with the level of engagement of their parents and peers (OECD, 2022[2]). While the influence of parental values on their children is not surprising, there are indications that this influence can run both ways, with shifts in students' knowledge, attitudes and behaviours also influencing those of their parents (Damerell, Howe and Milner-Gulland, 2013[11]; Lawson et al., 2019[12]).

Third, the broad scope and holistic mission of school education offers unique opportunities to understand the interdisciplinary nature of potential solutions to complex socio-ecological

[1] The other identified social tipping elements are: energy production and storage systems, human settlements, financial markets, norms and values systems and information feedbacks.

challenges. Addressing climate change and environmental degradation requires integration of knowledge from different fields including the natural sciences, social sciences, humanities and arts, as well as local and experiential knowledge (White et al., 2023[13]). Education can bring these different knowledge domains into conversation via cross-curricular and extra-curricular learning, allowing learners to develop agency and self-efficacy and offering unique opportunities for transdisciplinary learning and socialisation.

While some of these effects may unfold only in the medium- and long-term, other impacts of education can materialise much faster. For example, over the last decade, youth-led initiatives have become increasingly visible in the public debate (Pereira and Freire, 2021[9]; Han and Ahn, 2020[14]). These range from environmental activism to institutional representation of young people in climate negotiations and environmental litigation cases presented by young people (OECD, 2023[15]). In addition, holistic education policies that combine the decarbonisation of school infrastructure with learning opportunities for students can make a direct contribution to reducing greenhouse gas emissions in the short term, while influencing mindsets for the long term.

1.1.2. Articulating individual and systemic change

The role of education in climate action is sometimes understood to be mostly in the behavioural domain, i.e. in changing young people's mindsets so that they can live and act in line with sustainability goals. Yet, while there is increasing policy focus on raising students' capacity to act, key questions on what type of actions are more effective than others are not always raised.

The environmental impact of any pro-environmental action will depend not only on its magnitude but also on its "behavioural plasticity", i.e. whether large proportions of society are likely to adopt this action (Dietz et al., 2009[16]; Wynes and Nicholas, 2017[10]). But estimating the effect of an individual action is an important first step to understanding its potential cumulative impact. A large body of literature offers evidence and analysis on the mitigation potential of different individual actions, e.g. related to food, transport, housing and other consumption and lifestyle choices (for a comprehensive meta-review, see Ivanova et al. (2020[17])), but to what extent does this type of evidence inform environmental, sustainability and climate change education?

In the adult population, surveys indicate widespread misconceptions about the impact of different behavioural choices in reducing individual greenhouse gas emissions. In a 2021 international survey of over 21 000 individuals in 30 jurisdictions, more than two-thirds of participants thought that they knew what they needed to do to reduce their environmental footprint, but in fact, the majority of respondents were unable to distinguish high-impact actions from low-impact actions (Ipsos, 2021[18]). For example, 59% of those surveyed believed recycling was among the best ways to reduce their carbon footprint while it was in fact one of the lowest-impact actions proposed in the survey. On average, participants almost consistently ranked low-impact actions such as switching to low-energy lightbulbs as more effective ways to reduce emissions than high-impact actions such as reducing air travel or shifting to a plant-based diet.

No systematic information is available about how pathways for behavioural change are addressed in education across OECD countries, but some studies point to the limited relevance of behavioural changes emphasised in school education. For example, Wynes and Nicholas (2017[10]) analysed high school science textbooks used in seven Canadian provinces to understand how they presented what individuals could do to live in more sustainable ways. They found that the textbooks overwhelmingly focussed on low-impact

behavioural changes that require minimal effort while making little if any reference to high-impact actions.

This might be because some high-impact actions (e.g. living car free) are politically unpopular, controversial or difficult to implement. They may be considered out of reach for most individuals due to structural and institutional barriers (Kollmuss and Agyeman, 2002[19]). Yet, disproportionate focus on low-impact behavioural change risks presenting climate change as a trivial matter and directing attention away from more effective behaviours (Wynes and Nicholas, 2017[10]). Some studies even suggest that disproportionate attention to behaviours might crowd out attention to political action for addressing climate change (Werfel, 2017[20]).

Ivanova et al. (2020[17]) highlight the importance of paying attention to the interactions between individual choices and the broader contexts individuals live in and suggest ways to overcome the various infrastructural, institutional and behavioural lock-ins that may constrain pro-environmental behaviour. In sum, while shifts in individual behaviour play an important role in addressing climate change, these shifts will not happen at the necessary scale unless institutional, policy, market and technology factors are simultaneously activated to facilitate changes in norms and behaviours (Dubois et al., 2019[5]), as well as in institutions and systems. If education systems are to play a role in these complex change processes, it is key that they support people in engaging with complexity and situating potential for action not just in the individual or behavioural sphere.

1.1.3. One size does not fit all: the importance of place and context

Effective educational responses to climate change also require understanding where students are currently at in their learning and attitudes about environmental sustainability.

There are indications that young people generally consider themselves familiar with the challenges of climate change. In the OECD's Programme for International Student Assessment (PISA) 2018, almost 80% of students reported knowing about or being very familiar with climate change and global warming (OECD, 2022[2]). This is not surprising given that headlines on extreme events related to the climate crisis are omnipresent in both mainstream and social media. But it tells us little about the depth of their knowledge, and being aware of climate change does not necessarily mean having a solid scientific understanding of its magnitude, causes and potential solutions.

In addition, surveys also indicate significant variation across different student groups. For example, in the OECD's PISA survey, sustainability outcomes were lower among students who demonstrated lower science performance, those who had less advantaged socio-economic backgrounds and those with less environmentally aware parents. Overall, students from socio-economically disadvantaged backgrounds were less likely to care about the environment and to be aware of environmental issues than students from more advantaged backgrounds (OECD, 2022[2]). This raises questions as to whether environmental, sustainability and climate change education is sufficiently relevant and responsive to the needs of diverse learner groups and communities.

At the same time, other studies indicate that many young people are not only aware, but hyper-aware, of climate change and environmental risks, experiencing feelings of climate-related anxiety and despair (Coffey et al., 2021[21]; Léger-Goodes et al., 2022[22]). Fear may sometimes induce action, but it more likely risks inducing apathy or resignation (Chawla, 2022[23]). A second question therefore is how education systems can teach the reality of climate change in ways that help develop agency, self-efficacy and capacity to act rather than indifference, cynicism or despair.

Finally, there are also large and visible global movements of young people who are both highly informed and actively engaged in demanding climate action, drawing deliberately on scientific research to support their demands. Yet, the choice of "school strikes" as a central way chosen by young people to make their voices heard raises questions on whether education may be sometimes perceived more as an obstacle than an ally for their engagement (Verlie and Flynn, 2022[24]). A third question thus relates to how education systems can achieve a step-change in how they work alongside young people supporting them with tools to contribute constructively to the public debate, while at the same time signalling that their concerns are taken seriously by responsible adults.

Place-based and collaborative approaches have been suggested as ways to address the needs of various different groups and overcome the futility of individual action in the face of massive global challenges. Whole-school approaches and school-community partnerships can consider diverse local needs and perspectives, and facilitate various forms of expression, thereby engaging a broader range of student profiles and families in the local community, including those who are disadvantaged or traditionally marginalised. Such approaches may foster engagement by taking the priorities and needs of their communities seriously and focussing on tangible benefits for those involved, e.g. by increasing access to green spaces, offering career guidance with understanding of the local economy; or supporting household savings through energy-efficient behaviours, while enhancing transformative knowledge and self-efficacy for the long term.

Local initiatives and partnerships also increase opportunities for collaborative learning for adults, both among teachers and leaders within the school but also among outside partners, including from local authorities, higher education institutions, professional learning providers, businesses, civil society actors and other local stakeholders.

1.1.4. A multi-level approach to educational change

National curricula and learning objectives appear as the most obvious way in which education systems can shape at a large scale what people learn. Curricula set the overall framework for schooling and make priorities for schooling explicit.

Traditionally, environmental, sustainability and climate change education have often been anchored in learning objectives for natural science subjects. However, given the intricate relationships between ecological and social systems in climate change, teaching about climate change effectively requires a profound rethinking of teaching approaches within and beyond the natural sciences.

Section 2 offers perspectives for rethinking science education to achieve the complementary goals of ensuring strong scientific literacy for all, while enabling those with relevant interests and talents to pursue further studies and careers in fields that can contribute to scientific and technological breakthroughs. Going further, it reviews how countries may integrate environmental, sustainability and climate change education more broadly across different curriculum areas. Crucially, it considers the importance of embedding these goals with other relevant education policies to avoid that a focus on sustainability leads to curriculum overload or remains merely an intention on paper.

Section 3 investigates further how education systems can go beyond teaching standard content and empower learners to act both individually and collectively. The section zooms in on place-based approaches, which can help bridge the gap between system-level goals mandated by central curricula and the varying contexts and concerns of specific learner groups and communities. It reviews different ways to make environmental, sustainability and climate change education locally relevant and responsive to learners and analyses

enablers and barriers for place-based approaches as social tipping elements for sustainable societies.

Section 4 highlights that while education systems can contribute to enabling transitions towards a sustainable future, they are themselves impacted by climate change. These impacts are real and already disrupting the education of learners around the world. This means that education systems need to build mitigation and adaptation strategies at the same time, avoiding trade-offs and maximising synergies. The section reviews how educational infrastructure and processes may be impacted by climate change and identifies policy levers that systems can employ to become more resilient to climate change and continue to provide education effectively in the face of environmental challenges.

2. Getting the foundations right: rethinking science education and cross-curricular learning

2.1. Introduction

Education systems make different choices in terms of where they embed environmental challenges, climate change and sustainability in curricula – as a cross-curricular priority, as a dedicated subject, or within traditional subjects such as biology, geography, national language, history or civic education. This section looks at different ways in which education systems may include attention to environmental, sustainability and climate issues at the foundational level in primary and secondary education. It starts by looking at ways to rethink teaching and learning approaches in the science, technology, mathematics and engineering (STEM) fields. With respect to environmental sustainability, it highlights the complementary goals of STEM education to 1) ensure climate literacy for all, and 2) enable those with relevant interests and talents to pursue further studies and careers that can contribute to scientific and technological progress.

While acknowledging the foundational importance of STEM competencies, the section also argues that a more holistic, cross-curricular approach is required to achieve the broader social changes necessary for climate change mitigation and adaptation. The section reviews efforts at national and international levels to articulate broader learning goals that cut across subjects and disciplines and encompass knowledge, skills, values, attitudes and behaviours. It explores different ways to embed these competency goals with other relevant education policies, such as teachers' professional learning, assessment and evaluation and whole-school strategies, to avoid that the focus on sustainability leads to curriculum overload or remains merely intentional.

2.2. Rethinking STEM education in the context of environmental challenges

2.2.1. Fostering scientific literacy for all

While impactful environmental, sustainability and climate change education require a comprehensive educational approach, it needs to be anchored in basic scientific literacy. Scientific knowledge and skills offer a foundation for people to understand the complexity of Earth's systems and their interactions with human systems, to critically evaluate different information sources about socio-environmental challenges and solutions, and to make informed choices in their personal, civic, political and professional lives (Young et al., 2006[25]; Monroe et al., 2019[26]). Evidence from the OECD's Programme for International Student Assessment (PISA) indicates that being a top performer in science is

associated with greater awareness of environmental issues, contrary to being a top performer in another domain such as reading (OECD, 2023[27]).

The OECD's environmental science framework "Agency in the Anthropocene" offers a conceptual framework to rethink science education as a cornerstone for understanding and addressing complex socio-ecological challenges such as climate change (White et al., 2023[13]). The framework points to the core mission of science education to foster a baseline of scientific literacy for all learners, including the ability to evaluate different sources of evidence and to understand that scientific knowledge is conditional and constantly evolving. This involves enabling citizens to engage constructively in discussions about science, as well as fostering information, media and digital literacy and offering tools to distinguish high-quality, research-based information from misinformation and disinformation.

The framework also offers reflections on how to enhance solutions-orientated teaching about environmental and climate challenges. It highlights the importance of supporting learners in identifying and critically examining potential solutions to complex real-life problems. It argues that learning about potential solutions is as important as learning about problems. Moving beyond a focus on individual behaviour, understanding solutions that are already being developed and tested around the world can help people situate their own actions within systemic approaches, build their self-efficacy and inspire constructive engagement.

Going further, the framework suggests that encouraging learners to engage with current events and real-life challenges is likely to engage their motivation and interest in science. Applied learning offers opportunities to refine scientific reasoning and critical thinking skills and can foster a sense of self-efficacy and entrepreneurship, for example via school-based approaches where learners investigate local ramifications of global challenges and identify opportunities for action and civic engagement. Real-life applications of scientific knowledge and skills can also be found in new technology landscapes, for example using virtual reality to connect learners with environmental challenges and initiatives across the globe.

Crucially, the framework also proposes a shift from individualism towards collective action and highlights the importance of developing competencies in group problem-solving, deliberation and conflict management as important aspects of addressing collective action problems. This can be achieved in partnership and collaboration with actors beyond the school walls, complementing formal education with extra-curricular opportunities and experiential learning (Section 3).

2.2.2. Raising interest in science studies and careers

Beyond fostering a baseline of scientific literacy among all learners, science education also plays a key role in building foundational skills for future scientists. The importance of science for green innovation is evident, for example, from the large proportion of patent applications in low-carbon technologies that cite scientific literature (Cervantes et al., 2023[28]).

New inventions, technologies and infrastructures are essential to transformations in various sectors, from energy systems to construction, transportation, manufacturing and agriculture. The restructuring of these and other sectors require a future workforce with strong STEM competencies. Such competencies are also essential to deep-tech innovation, namely processes that bring together insights from the natural sciences and digital technologies to provide new and cross-disciplinary solutions to global challenges, such as climate change (OECD, 2023[29]). Attracting and supporting those with related interests and

talents in pursuing further studies is thus an important element in strengthening the future science workforce.

In many countries, however, there are concerns that school science teaching is becoming increasingly outdated and disconnected from real-life science research. While authentic science practice is constantly evolving and now routinely involves collaborative, interdisciplinary, technology- and data-driven approaches, school science teaching has rarely kept up with these changes. Studies from different contexts indicate that the central approaches to school science have remained stable over much of the 20th and 21st century, with a focus on conceptual knowledge, abstract concepts and relatively standard problems taught in the confines of strict disciplinary boundaries (Crawford, 2015[30]; Tytler, 2007[31]).

At the same time, there are examples of initiatives in various countries that aim to support teachers in designing evidence-based pedagogies and reflecting up-to-date scientific and social developments in their classroom teaching (OECD, 2023[15]; OECD, 2023[29]). Tested strategies for connecting school science to authentic science practice include higher education-school partnerships, science communication initiatives and role modelling. In some countries, including the Australia, New Zealand and the United States, a common strategy is to offer "dual enrolment" opportunities, where students can start earning higher education credits as part of upper secondary education (OECD, 2023[29]). In addition, professional learning communities bringing together teachers, researchers, and other actors such as non-governmental organisations (NGOs), associations and industry partners can play a role in connecting schools to ongoing developments in science research and development. Recent OECD studies have reviewed evidence and evaluations on the effectiveness of these approaches, finding some positive impacts, while also pointing to the need for further research (OECD, 2023[29]; OECD, 2023[15]).

Often, however, the focus in school education has centred on the S (science) and M (mathematics), with less attention to integrating the T (technology) and the E (engineering) or other fields such as arts and design (Kelley and Knowles, 2016[32]), which are more applied and could be attractive to learners with different interests and talents (Li et al., 2019[33]). Teaching about climate change and sustainability offers opportunities for education systems to enhance interdisciplinary perspectives, for example via eSTEM (environmental STEM) and STEAM (STEM plus the arts) approaches, and programmes that incorporate insights from the humanities and different knowledge systems. Beyond the potential of attracting different learner profiles to science-related careers, interdisciplinary perspectives are also key to helping future scientists develop systems thinking skills and innovations responding to socio-ecological challenges (Section 2.3).

2.2.3. Fostering diversity in STEM education

Many OECD countries are facing persistent challenges about a lack of diversity in STEM education and careers. The gender gap in STEM fields is well documented, with fewer girls who are high performers in science and mathematics expecting to work in these fields than boys (Encinas-Martín and Cherian, 2023[34]).

There are also concerns about disproportionately low numbers of individuals from disadvantaged socio-economic backgrounds and ethnic minorities going into STEM (Ghazzawi, Pattison and Horn, 2021[35]; Science and Technology Committee, 2023[36]; Bowser and Cid, 2021[37]; OECD, 2023[15]). Bowser and Cid (2021[37]) highlight that this lack of socio-demographic diversity is particularly pronounced in ecology and environmental sciences, contrary to some other science and technology fields where more progress has been made. This lack of diversity risks leading to a narrow range of themes

and approaches identified as relevant for scientific research and exacerbating inequities in who benefits from the green transition.

Education systems around the world have experimented with strategies that link innovations in science teaching (see above) to targeted support for students from underrepresented socio-demographic backgrounds. Such support may include differentiated teaching approaches, role models from diverse socio-demographic backgrounds, coaching and mentorship programmes and financial support (Science and Technology Committee, 2023[36]; Gladstone and Cimpian, 2021[38]; OECD, 2023[15]). Studies from different country contexts indicate that such programmes can help learners from underrepresented backgrounds build confidence, self-efficacy and motivation to continue studying STEM subjects at higher levels (OECD, 2023[15]).

2.2.4. From education to innovation: careers that matter

While STEM competencies will be essential to future scientific research and innovation, many other academic disciplines contribute to shaping green transformations. For example, while careers in the clean energy sector tend to require higher than average levels of scientific knowledge and technical skills, this is not necessarily the case for environmental management occupations (Muro et al., 2019[39]). There are roles in almost any sector and in various types of organisations, including companies, non-profit organisations and governmental agencies that can contribute to sustainability (UNEP, 2021[40]).

For individuals to engage in such roles, their attitudes and dispositions matter, in addition to their specific knowledge and skills (OECD, 2023[27]). While global policies to support low-carbon economies will shift skills requirements across sectors and occupations, an increasing number of studies suggest that skills cannot be "green" per se (OECD, 2023[41]). Indeed, similar skills may be used to contribute to either sustainable or polluting activities, depending on the context in which they are applied (OECD, 2023[27]).

Career advice and guidance can play a key role in helping learners match their personal talents and interests in any field with career pathways where they can make a difference. The United Nations Environment Programme outlines three key elements for effective "green" career guidance: (1) promoting a better understanding of jobs in the sectors that are directly related to sustainability; (2) bringing a green lens to any job; and (3) developing competencies for young people to craft careers that do not exist yet through creativity and innovation (UNEP, 2021[40]).

More broadly, steering students towards careers that can make a difference requires going beyond teaching the scientific facts of climate change and moving towards a focus on specific challenges, solutions and opportunities and challenges across different contexts and sectors. This can be achieved by integrating a focus on sustainability across all curriculum subjects, which will be explored below.

2.3. Fostering cross-curricular perspectives

2.3.1. Defining objectives for environmental, sustainability and climate change education

While scientific literacy is key to understanding climate change and other environmental risks, many other competencies are relevant for addressing these challenges. Beyond subject- or discipline-specific learning areas, overarching curriculum goals can play a key role in setting a vision and directions on what young people learn.

Curriculum goals set the overall framework for schooling and make priorities for schooling explicit. Most countries have central curricula to set the framework for schooling, and different degrees of autonomy for other stakeholders to develop more specific curriculum content. The introduction of new curriculum content, competency frameworks or learning objectives are key moments in which education system stakeholders and other societal actors can reflect on, debate and select what learning is most relevant for the next generation.

Given the complexity of climate change and environmental sustainability, articulating relevant learning objectives can be challenging. While different frameworks exist, there is broad consensus that learning for sustainability involves "heads, hands and hearts" (Sipos, Battisti and Grimm, 2008[42]) and encompasses cognitive, affective, socio-emotional and behavioural dimensions. As these broader competencies cannot be neatly fitted into a single subject area or discipline, most school systems articulate them as cross-curricular themes to be embedded across various subject areas and extra-curricular activities as a joint responsibility for all teachers and the school community as a whole.

At least on paper, the importance of learning about sustainability from various perspectives and within different curriculum fields is well established across school systems. The OECD's Curriculum Content Mapping (CCM), which analysed curriculum goals in 37 countries and jurisdictions, found that environmental sustainability was the most frequently cited transversal theme included in countries' overarching goals for education (OECD, 2020[43]).

Many education systems have developed frameworks or guidelines for developing sustainability competencies across the curriculum (Government of Ireland, 2023[44]; Ministerium für Kultus, 2016[45]) and international organisations such as the United Nations Educational, Scientific and Cultural Organization (UNESCO), the European Commission and the OECD have facilitated international exchange around the definitions of relevant learning outcomes for sustainability (Box 1).

Box 1. International frameworks articulating learning objectives for sustainability

UNESCO's sustainability competencies were developed in the context of its work on Education for Sustainable Development (ESD). UNESCO developed a guide in 2017 (last updated in 2023) that identifies learning objectives, activities and topics for each of the Sustainable Development Goals. Beyond listing specialised competencies for each of the individual SDGs, the guide describes general key competencies for sustainability. These comprise the following:

- systems-thinking competency;
- anticipatory competency;
- normative competency;
- strategic competency;
- collaboration competency;
- critical thinking competency;

- self-awareness competency;
- and integrated problem-solving competence.

The European Commission's GreenComp Framework defines four competence areas and 12 competences for sustainability, applicable to all learners in any setting and age group (Bianchi, Pisiotis and Cabrera Giraldez, 2022[46]). These competences aim to enable learners to understand and address sustainability challenges in a holistic and transformative way. The four competence areas are:

- systems thinking and handling complexity,
- anticipation and visioning,
- critical thinking and analysis,
- and participation and collaboration.

The Environmental Sustainability Competence Toolbox is a framework proposed by the OECD and the European Commission, which extends the GreenComp framework to include additional competence areas that are relevant for sustainability and have been defined and assessed as part of the OECD's Programme for International Student Assessment (PISA). The additional competences are presented as crucial for equipping students with a wide range of cognitive, affective and behavioural capabilities that should allow them to play a positive role in shaping the future of the environment. The four areas are the following:

- environmental awareness: students have a baseline of science proficiency and report knowledge of or familiarity with environmental issues and climate change,
- caring: students agree or strongly agree that looking after the environment is important to them,
- science self-efficacy: students report that they can complete tasks with regard to climate change "easily" or "with a bit of effort",
- environmental behavior: students engage in energy saving or in collective action to protect the environment.

Source: (UNESCO, 2017[47]; Bianchi, Pisiotis and Cabrera Giraldez, 2022[46]; Borgonovi et al., 2022[48]).

The competencies listed in these sustainability competency frameworks typically encompass outcomes that have previously been framed as "key competencies" or "21st century competencies", such as critical and creative thinking, problem-solving and collaboration. In addition to that, sustainability frameworks often include an explicit focus on integrating futures thinking, with an emphasis that understanding sustainability is not only about responding to current problems, but also about being able to deal with risks and uncertainties in a forward-looking manner and to contribute to innovation and social designs for the green transition.

Finally, sustainability competency frameworks typically make reference to values and/or are framed as profiles of future citizens, emphasising students' active participation in local, national and global societies. In various countries, student agency has become a core curriculum goal, as well as a key aspect in sustainability frameworks, promoting space for students to shape their own education, lives and broader environment. Student agency is

also placed at the centre of the OECD's "Learning Compass" which sets out a broad framework of the competencies students need to thrive in the future (OECD, 2019[49]). Although with different nuances across countries, the focus on student agency resonates with a long-standing body of literature on child-centred, constructivist and progressive education theories (McCulloch, 2016[50]).

Hence, although attention to sustainability competencies has surged in recent years, most of these competencies are not new to education systems. Rather, they extend existing formulations of transversal competencies with specific attention to environmental and sustainability issues. As such, the realisation of sustainability competencies shares some of the challenges known for competency-based curricula in general and can be informed by lessons learned from examples of curriculum reform over the past decades.

2.3.2. From objectives to learning

Curriculum design and objective setting is only one aspect of curriculum reform. Whether such documents make a difference to classroom teaching depends on successful curriculum realisation. Experience in different countries has shown that where curriculum development is dominated by a particular sector of society without sufficient democratic debate and stakeholder co-construction, opportunities will be missed to build momentum and shared commitment to change.

If changes are implemented in a top-down manner without meaningful participation of educators, they may have little bearing on teachers' authentic classroom practice (Gouëdard et al., 2020[51]). Hence, understanding school leaders, teachers and students as agents of change at all steps of the process will be key to influencing the lived curriculum. This may be reflected in co-construction of curricula and learning progressions, time and opportunities for professional learning and collaboration, and support and resources for effective assessment.

When transversal learning objectives are introduced, a key challenge can be a lack of clarity on how these objectives can be translated into concrete teaching, learning and assessment activities (OECD, 2013[52]). Sustainability competencies are sometimes stated in a general way for all age groups with little guidance on how learners would be expected to progress through different learning stages. Moreover, the transversal nature of these competencies, which tend to involve several subjects or go beyond school subjects altogether, makes it challenging to determine who is responsible for teaching and assessing them and how to fit them within particular disciplines (OECD, 2013[52]). This is particularly the case where teaching is viewed as a largely individual undertaking that happens behind closed classroom doors and is not yet seen as a collaborative practice informed by joint planning and horizontal accountability (OECD, 2019[53])

2.3.3. Articulating progressions

A key differentiation to make is that a one-size-fits-all approach to environmental, sustainability and climate change education is not likely to fit all age groups in school education. Developing research-informed and age-appropriate progressions for learning about sustainability seems crucial for developing the right angle and focus for learners at different developmental stages but has not received much attention in the sustainability competency literature.

For example, at pre-primary and primary levels of education, building connectedness to nature is widely reported to have benefits for young learners. Engaging young learners in incremental behavioural change, such as recycling and saving energy, can contribute to building a sense of agency, self-efficacy and commitment to protecting the natural world.

At the same time, some studies indicate that young people who take individual environmental action are prone to experiencing low subjective well-being, and that social trust, support and a sense of collective action are key to effective coping strategies (Ojala, 2016[54]).

Various studies suggest that people's interest in and concern about sustainability evolve with age, with levels of connectedness to nature and willingness to act typically declining from childhood to adolescence, and then rising again in young adults (Pereira and Freire, 2021[9]; Chawla, 2022[23]). Perhaps this "adolescent dip" in environmental concern also indicates that learners at this age do not have access to environmental, sustainability and climate change education that is aligned with their needs and interests.

Indeed, developmental psychology points to adolescence as a period in which individuals develop greater future orientation and understanding of long-term impacts of decisions. It is an age at which lifestyle choices may still be more open and malleable than later in life when adults are more deeply settled in specific lifestyles; a time at which young people are seeking increased autonomy and responsibility and starting to make their own decisions in various aspects of their lives such as food, transport and living arrangements (Wynes and Nicholas, 2017[10]). From a cognitive point of view, it seems an ideal age for studying the complex challenges and exploring intricate interactions between various factors in developing adequate solutions (Pereira and Freire, 2021[9]).

Some have criticised that many school systems do not extend learning on climate change beyond material that could be covered at primary school level, and that secondary school students may not be intellectually stimulated by the way the topic is addressed in schools (Pye, 2023[55]). While some countries have articulated sustainability objectives for different ages or stages, there is room for further research and peer learning among countries on how to operationalise learning objectives and understand learning progressions along learners' trajectories in schools and beyond.

2.3.4. Rethinking assessments

Curriculum realisation challenges are often compounded by the existence of narrow evaluation and assessment systems that lag behind countries' future-oriented learning objectives. Such evaluation and assessment frameworks may become a "hidden curriculum", encouraging a narrower approach to teaching and learning, with cross-curricular competencies falling through the cracks (Nusche, 2016[56]).

Evaluation and assessments practices can disincentivise a focus on broader competencies if they are not well aligned with a curriculum focus on competencies. When assessments focus predominantly on the reproduction of pre-defined knowledge, they may overlook the knowledge, skills and dispositions necessary to engage in collaborative action, and fail to signal their importance to stakeholders, notably teachers and students themselves.

By contrast, an emphasis on assessment *for* and *as* learning may help promote more innovative formats of assessment (OECD, 2013[52]) (see some examples in Table 1). While more open and innovative assessment formats are easier to pilot in formative assessment contexts, there are also various ways to rethink standardised assessments to include complex skills like problem-solving, creativity and communication (Foster and Piacentini, 2023[57]).

Table 1. Assessment approaches to measure sustainability competences

Tool	Description
Scaled self-assessment	Students rate their own competence development based on a pre-determined scale.
Reflective writing	Students respond in writing to prompts reflecting on their competence development.
Scenario/case test	Students are presented with a case and asked to respond to competence-requiring prompts.
Focus group/interview	Students respond to prompts, verbally reflecting on their competence development.
Performance observation	Students are evaluated while carrying out course activities in or out of the classroom.
Concept mapping	Students are given a prompt and asked to create a two-dimensional image with nodes and connections (specific to systems-thinking competence).
Conventional text	Students take a test which may include multiple choices or short answers linked to competences.
Regular course work	Students complete regular course work which is analysed for evidence of competences.

Source: European Commission (2022[58]), *Learning for the green transition and sustainable development: Staff working document accompanying the proposal for a Council recommendation on learning for environmental sustainability*, https://data.europa.eu/doi/10.2766/02392.

2.3.5. Embedding sustainability goals with teachers' professional learning

When introducing sustainability competency frameworks, it is key to recognise that formulating educational objectives in terms of more open, transdisciplinary and future-oriented competencies is not a trivial change. It implies a profound paradigm shift for teachers and schools. It fundamentally changes what and how teachers are expected to teach and assess in classrooms, requiring them to experiment with different approaches and resources to make connections between system-wide priorities, relevant local and school objectives, and their own practice and classroom context.

Since any teaching strategy works differently in different contexts, there are no standard recipes for a transversal approach to sustainability that teachers could implement easily in all settings. In addition, scientific knowledge about climate change evolves and so does expertise and experience on approaches to addressing it. This means that curricula, classroom resources and teaching approaches must remain flexible to integrate emerging knowledge as to what works and why and in which contexts (White et al., 2023[13]).

While opportunities for professional development are often highlighted as essential to introducing cross-curricular objectives, whether these offers are well-designed and evidence-informed makes all the difference. There is little evidence that professional development programmes that are punctual, one-off and focussed on knowledge transmission have any impact on changing classroom practice (Boeskens, Nusche and Yurita, 2020[59]). Research shows that teachers do not improve their practice by understanding theory and evidence alone, but through their active engagement with it, for example through observation, demonstration, practice and feedback (Roy et al., 2021[60]).

In addition, teachers' professional learning needs do not just arise from school system aspirations for sustainability and other changing societal goals, but also – crucially – from where they are at in their personal learning and development, as well as the learning needs of their specific students. Effective professional learning therefore requires an active role for teachers, where they can adapt and apply new learning and expertise so that it is relevant and works for their particular context and students (Boeskens, Nusche and Yurita, 2020[59]; Roy et al., 2021[60]).

Finally, the impact of change in teachers' practices will be amplified if it is part of a collaborative effort, both among teachers and leaders within the school but also in partnership with outside partners, including from local authorities, universities, professional learning providers, businesses and civil society actors (Révai, 2020[61]).

External partners can challenge old habits in teaching practice, explain state-of-the-art approaches, help develop theories of action and enable in-depth evaluation (Cordingley et al., 2015[62]). Specific roles in the school, such as co-ordinators responsible for internal collaboration, outreach and external partnerships on sustainability, can facilitate co-ordination but require resources which may only become available through significant restructuring of roles and responsibilities in schools (OECD, 2019[63]).

The OECD has developed an ”ambition loops” framework and tool that can stimulate and guide constructive discussions across multiple stakeholders to create preferred future scenarios relevant to stakeholders in the school community, education community and broader societal actors, to support the work of teachers and facilitate the transformation of education to meet contemporary challenges such as climate change, while focusing on current needs (McGrath, 2023[64]). Such collaborations will be further explored in Section 3 on place-based approaches.

2.4. Conclusion and scope for future work

High-quality foundational STEM education is crucial to foster scientifically literate citizens and well-rounded future scientists. The priority of integrating robust environmental, sustainability and climate change education into school curricula offers new opportunities to rethink science education. Sustainability themes can be a catalyst for innovation in STEM education, allowing to bring authentic science practices into schools, foster interdisciplinary linkages, study solutions to real-life problems and motivate a new generation of learners to pursue studies and careers in these fields. Future work could promote peer learning on how different education systems are turning the climate emergency into an opportunity to revitalise curricular and pedagogical approaches in science education.

But scientific knowledge and technical skills alone do not necessarily lead individuals to make sustainable choices in their lives and careers. The section highlighted that fostering civic and professional engagement in favour of sustainability requires a holistic, cross-curricular focus on the broader competencies needed for solving complex socio-ecological challenges. It also underlined the need to develop age-appropriate approaches to sustainability education, e.g. moving from a focus on connectedness to nature at a young age towards a focus on understanding the systemic factors that can exacerbate or mitigate climate change and reflecting on how equity and acceptability can be achieved in transitions towards sustainability. Future work could focus on studying effective learning progressions for sustainability, analysing different ways in which education can articulate scope for individual action with learning about complex systems, collective action problems and transformative change.

It further emerged from the section that effective approaches to environmental, sustainability and climate change education require a rethinking of teachers’ and students’ agency. To avoid that curriculum objectives for sustainability remain merely intentional, they need to be embedded in system-wide strategies for change that pay attention to curriculum co-construction, teachers’ continuing professional learning, and evaluation and assessment policies that mirror the importance of valued curriculum goals. Local or school-based curriculum development can foster collaboration across subject teachers to agree on the aims, sequence and methods of teaching that best fit the learning needs of their students. Analysis of student assessment and evaluation data can play a key role in identifying these needs. Collaboration around curriculum and assessment can reinvigorate teachers’ intrinsic motivation, supporting them in tailoring subject matters they are passionate about to the specific students that they care for. Future work will benefit from new internationally comparable information on teachers’ current engagement with environmental,

sustainability and climate change education to be collected in the OECD's Teaching and Learning International Survey 2024 (see Annex B) and could link this to comparative analysis of policies and resources best suited to stimulate local and school-based leadership for change.

While student agency is typically among the core goals of sustainability frameworks, an important share of the literature on sustainability education remains focussed on the perceived deficits in students' knowledge, concern or action and their individual environmental responsibilities. This is rarely contextualised or contrasted with the strengths of existing youth movements, whose arguments are often based on scientific evidence and endorsed by the academic community. This ambiguity and the complexity of student agency in sustainability education often remains unaddressed. Although international surveys do show variations in students' sustainability outcomes that need to be addressed, such variations also exist in the general population and might well be more pronounced among adults. Future work could review effective ways for education systems to acknowledge, build on and complement the transdisciplinary knowledge and climate action strategies developed by students in different contexts. This could be linked to analysis of constructive approaches to lifelong learning, intergenerational collaboration and whole-of-society approaches.

3. From individual to collective action: the power of place-based approaches

3.1. Introduction

At a time when environmental concerns are at the forefront of policy agendas globally, the role of education in supporting climate change mitigation is increasingly emphasised. In this context, Place-Based Education (PBE) emerges as an educational approach that immerses students in their local environment and community, deepening their commitment to sustainable practices and equipping them with the tools to act on this commitment.

This section examines PBE, detailing its significance and theoretical underpinnings, and reviewing the evidence supporting its effectiveness. It then turns to discussing key challenges for its implementation, including examples of policy measures that can facilitate its adoption. The section concludes by proposing a framework intended to guide future systematic analysis on how education systems can enhance effective PBE practices and support their adoption at scale.

3.2. What is place-based education and why is it relevant to sustainability education?

Place-based education (PBE) refers to "a pedagogical approach that emphasises the connection between a learning process and the physical place in which teachers and students are located" (Yemini, Engel and Ben Simon, 2023, p. 1[65]). It has become an umbrella term "for any educational approach that is locally driven, community based, or ecologically focused" (p. 2[65]). PBE connects to a variety of educational practices with a long and rich history, such as outdoor, community- and service-learning, in the sense that they all seek to engage students cognitively, emotionally and physically in their learning while fostering a sense of connection between them and their surroundings (Elfer, 2011[66]).

Interest in PBE has grown in recent years as researchers, educators and policymakers place more emphasis on the need to promote individual and collective pro-environmental

behaviours through education (Section 1) (UNESCO, 2020[67]; 2016[68]). While promoting pro-environmental actions has been a key goal of environmental education frameworks, educational practice has often relied on traditional knowledge transmission approaches at the expense of students' deeper learning and the development of action competencies (Rousell and Cutter-Mackenzie-Knowles, 2019[69]). Research has shown that awareness and knowledge, while key, do not automatically translate into transformative action. Other factors such as social norms, personal habits and whether people perceive that their actions can make a difference act as key psychological drivers or barriers (White, Habib and Hardisty, 2019[70]; Kollmuss and Agyeman, 2002[19]).

Changes in mindsets and personal, professional, civic and political choices are more probable when people's awareness of and concern for the environment align with their readiness and capability to take action. By means of locally contextualised and commonly experiential and community-oriented approaches, PBE is seen as well placed to support the development of these multiple facets of 'environmental literacy' (Yemini, Engel and Ben Simon, 2023[65]; Hernandez Gonzalez, 2023[71]). PBE seeks to both leverage and promote positive emotions towards the local context to make students' learning meaningful while fostering in them a sense of stewardship. Furthermore, PBE practice often grounds teaching and learning in authentic contexts. This aims to show students that effective pro-environmental action can be taken and how, supporting them to develop action-oriented knowledge and practical skills (Sobel, 2004[72]; Gruenewald, 2003[73]; Woodhouse and Knapp, 2000[74]; Smith, 2002[75]).

3.2.1. Understanding of and attachment to place

Central to the discourse of PBE is the multifaceted construct of "place", which encapsulates the biophysical characteristics as well as individual psychological associations, sociocultural dynamics, political and economic processes of a place (Ardoin, 2006[76]; Ardoin, Schuh and Gould, 2012[77]). PBE uses the local community and environment as a starting point to teach concepts across the curriculum (Sobel, 2004[72]). Nearby, relatable examples make the abstract tangible: in recognising familiar landmarks, local stories, and community challenges as part of their lessons, in the classroom or beyond, students begin to grasp foundational knowledge and become more engaged with the learning process (Powers, 2004[78]).

Contextualising teaching and learning in the local can be particularly helpful in relation to climate change, which often seems a distant and abstract issue. Climate change manifests differently across regions, and research has shown that individuals typically exhibit greater concern for its nearby impacts, emphasising immediate dangers over far-off ones (Khadka et al., 2020[79]). Environmental education can thus benefit from addressing those aspects of climate change that students more easily observe in their surroundings and care about (Hess, Malilay and Parkinson, 2008[80]). This is not to say that students should not learn about global issues – in fact, children commonly engage with seemingly distant topics, like the universe. To the contrary, a focus on the local is a starting point for students, from which they can move on and build a more comprehensive understanding of how broader natural and human systems work (Schweizer, Davis and Thompson, 2013[81]).

In engaging with the local, PBE often takes the form of pedagogies leveraging active exploration and direct engagement with the environment, such as in experiential, outdoors learning (Hernandez Gonzalez, 2023[71]). Experiential learning builds on the idea that human experience is a central source of learning, and therefore it should be a building block of the education project. Accepting a variety of formulations, including inquiry and student led activities such as projects and community service, pedagogical approaches in this space

combine students' active experimentation with reflective observation and abstract conceptualisation aided by teachers (Paniagua and Istance, 2018[82]).

A central idea in PBE theory is that such a direct experience of places not only facilitates understanding, but also positive emotions like a sense of connectedness, belonging and care towards these places (Schweizer, Davis and Thompson, 2013[81]). People care about things they are personally connected to, and when students engage with their local environment – be it a city park, a nearby forest, or a school garden – they learn about the ecology of these spaces while developing emotional connections to them. Indeed, students do not only bring pre-existing emotions into their learning, which teachers must capture and productively link to learning, but new emotions are formed and shaped as part of the learning process. Feelings of attachment to place are dynamic, not static, and pedagogies tapping into them can make environmental education more effective in promoting sustainable attitudes and behaviours (Semken et al., 2017[83]).

In sum, grounding teaching and learning in place facilitates understanding, raises student engagement with learning and promotes a sense of connection and care towards the environment and community.

3.2.2. From knowledge to action: Education as place-making

Engaging student emotions is, however, not free of risk. As students deepen their connection to and understanding of the challenges facing their local environment, they also gain a more realistic appreciation of the magnitude of climate change and its impacts. Greater awareness and concern can trigger pessimism, and even negative impacts on mental health (Section 4), which result in feelings of helplessness and paralysis (Jensen, 2002[84]). The challenge for education is to build a sense of hope that decreases fear by empowering students to take effective actions to protect the environment and realise that they can make a difference. Given sufficient space and support, challenging emotions can be channelled constructively towards a heightened sense of responsibility and motivation to look out for solutions (Chawla, 2022[23]; Lehtonen, Salonen and Cantell, 2018[85]).

But how does this work? A stream of psychological research has explored how people's dispositions to engage in altruistic behaviour are formed. Norm activation theory (Schwartz, 1977[86]) posits that such dispositions are activated when people 1) are aware of that a given problem exists; 2) feel a sense of responsibility towards addressing that problem; 3) perceive that viable solutions are possible; and 4) consider that they can contribute to those solutions. Connecting these variables to what education can do is the idea that teaching and learning should focus on promoting different forms of knowledge, in addition to a deep understanding of the science behind climate change (Section 2). Such knowledge includes an understanding of which solutions are possible for the issues at stake (action knowledge), and an understanding of how effective such solutions are (effectiveness knowledge) (Roczen et al., 2013[87]).

PBE interventions are deliberately conceived to foster these varied forms of knowledge – for example, when students engage in environmental protection, or develop a community-oriented awareness campaign for reducing energy consumption. Importantly, a focus on the local can connect to teaching about the social and political factors that enable or constrain the scope for local action, the factors that shape places, make them more or less worth living, or threaten their existence. Several scholars have emphasised the civic and political profile of PBE, where the value of education lies in inviting students to think critically about the communities they inhabit, how these places came to be as they are now and how could be transformed for the better (Gruenewald, 2003[73]; Schild, 2015[88]).

Different initiatives spanning both formal and non-formal learning programmes are structured in this spirit, supporting the development of transformative competencies as students engage in researching, crafting and implementing solutions to actual societal and ecological challenges. In these programmes, the role of the community is key, both as object of and context for learning. On the one hand, the community becomes the object of study as students investigate and problematise social norms, common practices and regulations driving or deterring sustainable behaviour. On the other hand, it is the space where learning happens, affording a variety of experiences, from gardening in the schoolyard to testing the waters of a nearby river and volunteering in a local organisation (Smith, 2002[75]).

However, some scholars studying the social and political aspects of PBE warn against overemphasising local issues in teaching (Nespor, 2008[89]; McInerney, Smyth and Down, 2011[90]). In an interconnected, globalised world, there is often a "disjuncture between the geographic scale(s) at which a problem is experienced, and the scale(s) at which it can politically be addressed" (Kurtz, 2003[91]). These perspectives stress once again that local places and communities should be taken as a starting point in the curriculum, directing student attention to an evaluation of how local actions fit into a wider scheme of systemic, political solutions and studying how and where the latter are being implemented. Given the open and complex nature of the problems at stake, discussing such topics may prove controversial at times. But controversy can be productive if well managed, for instance by teaching students how to engage with scientific evidence and how to use it to inform deliberation and debate (Monroe et al., 2017[92]; Hess, 2009[93]).

3.3. Does place-based education work?

Powers' (2004[78]) evaluation of four PBE programmes provides an interesting point to begin to think about the evidence base supporting PBE practices. As she notes, research specifically investigating the effectiveness of PBE interventions is limited, although a large body of education research in various fields of the "learning sciences" can be instrumental in empirically assessing its value. This section starts by briefly discussing both specific PBE evaluations and more general studies on human learning. It then turns to the lessons learnt from research of effective environmental education practices to discuss how these relate to PBE and the extent to which they support its tenets.

3.3.1. Research on effective human learning and experiential pedagogy

First, it must be noted that some evaluations of place-based programmes do exist and show promising results with regards to its capacity to enhance students' environmental literacy. For instance, a qualitative assessment of ten programmes representing over 100 schools in the United States concluded that "place-based education fosters students' connection to place and creates vibrant partnerships between schools and communities. It boosts student achievement and improves environmental, social, and economic vitality" (Place-based Education Evaluation Collaborative, 2010[94]).

In addition to these evaluations, PBE theory finds support in the wider literature on human development and learning. Among other aspects, key lessons from this literature include the need for teachers to help learners connect new information to what they already know, since people typically start building their mental representations of how things work from discrete examples (National Academies of Sciences, Engineering, and Medicine, 2018[95]). Achieving this successfully involves educators who craft tasks that tackle real-world problems, which are pertinent and thought-provoking, and combine direct explanations of fundamental ideas with well-planned investigative activities. In doing so, teachers may use

various methods, where the key is to connect teaching and learning with children's innate curiosity about their everyday surroundings (Darling-Hammond et al., 2019[96]; Paniagua and Istance, 2018[82]).

Ample evidence from empirical studies of experiential learning supports this view. Investigations into outdoor, nature-based interventions have underscored the importance of direct experiences and time spent in the natural world. Experiences of nature are not just about acquiring knowledge (Kuo, Barnes and Jordan, 2019[97]; Williams and Dixon, 2013[98]); they are deeply emotional and play a role in cognitive development in addition to enhancing physical and mental health outcomes. Positive experiences in nature, such as feelings of wonder, joy, and curiosity, have been found integral to forming a bond with the environment and contributing to individuals' willingness to engage in actions to protect it (Chawla, 2022[23]).

Research on community-based learning, in particular evaluations of service-learning programmes, is also informative of PBE's potential. Service-learning is an experiential learning pedagogy in which education is delivered by engaging students in community service that is integrated with the learning objectives of core academic curricula (Furco, 2010[99]). Quantitative and qualitative reviews of service-learning programmes have reported large gains in student motivation, academic learning across disciplines and greater application of knowledge. Research on service-learning stresses that, when well-articulated and appropriately guided by teachers, such programmes contribute to the development of civic and pro-social skills, dispositions and behaviours as students build new social networks and come to realise that they can make a difference in tackling real-life issues (Yorio and Ye, 2012[100]; Celio, Durlak and Dymnicki, 2011[101]).

3.3.2. Evidence on effective environmental education practices

An extensive body of research has evaluated the outcomes of environmental education programmes specifically – or programmes using similar labels, like climate change and sustainability education (Ardoin et al., 2017[102]). In recent years, different systematic reviews have surveyed existing studies in this space to identify the pedagogical practices that are most impactful. Their conclusions align with the general literature on human learning and pedagogies discussed earlier, suggesting that PBE theory holds empirical ground. For instance, in their systematic review of the literature, Monroe et al. (2017[92]) concluded that considering climate change information that is personally relevant and meaningful for learners, and incorporating activities designed to engage learners practically, like in project- and inquiry-based teaching are the two key components of successful programmes. Along similar lines, a review by Rousell and Cutter-Mackenzie-Knowles (2019[69]) stressed the effectiveness of engaging participatory, interdisciplinary, creative, and affect-driven approaches in climate change education.

Both studies resonate with the findings of an earlier review by Stern and colleagues (2013[103]), which noted the importance of active pedagogies for environmental education programmes. The review analysed 66 evaluations conducted between 1999 and 2010, uncovering positive correlational evidence between environmental education programmes and a spectrum of student outcomes – from knowledge and awareness to skills, attitudes, intentions, behaviour, and enjoyment. Notably, the most effective interventions were those that featured active and experiential engagement in real-world problems, included co-operative group work and involved intergenerational communication with teachers and other community members taking on the role of inspiring role models.

Building on this body of reviews, other scholars have employed meta-analytical techniques to address potential biases in the literature. In a recent study, van de Wetering et al. (2022[104]) examined 512 effect sizes from 169 studies across 43 countries. Considering all

types of programmes, they found a positive impact of environmental education on student environmental literacy outcomes, particularly knowledge, but did not find clear evidence regarding most effective pedagogical designs at the meta-analytical level. Interestingly, however, they noted positive behavioural outcomes as well, which led them to articulate two possible interpretations: firstly, that environmental education effectively addresses psychological barriers in youth, empowering them with actionable knowledge and skills. By contrast, the alternative explanation is that education programmes focus on low-impact behaviours that young people already deem relatively straightforward, while paying less attention to actions and engagement that are more likely to be impactful (see also Section 1).

Aside from these findings, several reviews highlight methodological challenges in environmental education research (Stern, Powell and Hill, 2013[103]; van de Wetering et al., 2022[104]; Williams and Dixon, 2013[98]; Ardoin et al., 2017[102]). Many studies offer limited details about the programmes they evaluate, making it difficult to replicate or compare them. A significant portion of evaluations focuses on individual programmes, and without control or comparison groups, it is hard to draw strong conclusions about what aspects of the programme work and for whom. Additionally, when studies do not find any significant results, they often do not report these "null findings". This lack of reporting can make it challenging for comprehensive reviews to identify consistent patterns across studies.

Moreover, while knowledge is often the primary outcome measured in evaluations, its use as a reliable indicator of behavioural change is increasingly questioned (Ardoin et al., 2017[102]). Additional issues with behaviour measurement include an overreliance on self-reported outcomes, despite their known biases, as opposed to direct measures, and a tendency to target simpler, individual behaviours, neglecting more complex, higher impact actions – the latter including collective actions in the public sphere, such as supporting environmental organisations, with potential for delivering broader societal change (Chawla and Cushing, 2007[105]).

3.4. Barriers and enablers of place-based sustainability education

Place-based education offers a promising avenue to fostering the kinds of declarative and action-oriented knowledge individuals need to protect the environment. Evidence from evaluated interventions suggests that, by anchoring teaching and learning in local context, PBE not only makes abstract concepts more accessible, but nurtures a sense of connection and stewardship in students with respect to their local environment and community. All the same, the integration of PBE into education systems presents challenges. Inherent structures and views of schooling can either support or impede the adoption of innovative approaches and, as noted by Yemini et al. (2023[65]), growing recognition of PBE brings to light its divergence from mainstream educational practices.

Education stakeholders often have their views of education moulded by conventional wisdom rooted in established schooling cultures. Perceptions in such contexts may narrowly define "effective" education with the kinds of pedagogical practices that stakeholders are familiar with, rather than those informed by research and evidence (Burns and Köster, 2016[106]). In contexts where the prevailing view of education leans towards highly structured, teacher-led and discipline-specific learning activities; where the education of students is seen as the sole responsibility of schools and indeed, something that can only happen within the confines of schools, embracing PBE principles can prove challenging. This section explores these questions, delving into the complexities surrounding effective PBE practice.

3.4.1. Integrating PBE in current schooling systems: A shift for educators

At the centre of incorporating PBE in schooling are teachers who, in a PBE setting, become orchestrators of a richer, interconnected learning experiences. They use local places and resources, champion interdisciplinary teaching, and collaborate extensively with peers for curricular planning and delivery (Powers, 2004[78]). This collaboration often extends beyond the school, involving different partners in designing and implementing community service and other types of projects with a variety of sources and resources for teachers and learners to tap into. PBE sees teachers not just as knowledge providers, but as guides, mediators, and facilitators. Teachers bridge the community and school, encourage students towards critical reflection, and often lead in curriculum development and programme leadership (Yemini, Engel and Ben Simon, 2023[65]).

PBE presents an innovative approach to reshaping the learning experience of school students in many contexts. When education is centred on resolving community challenges, it naturally becomes an interdisciplinary endeavour. Take a project that examines local air quality, determines pollution sources, devises strategies to mitigate these causes and develops an awareness-raising campaign, for instance; this can compel students to integrate their competencies in STEM subjects, social studies, civic education, and language. But shifting current views of teachers and teaching in this way is not straightforward. The ease with which teachers engage interdisciplinary work is determined by several factors, including the methods of curricular design, student assessment, teacher professional training and school management (Section 2).

A lack of systemic leadership and guidance means teachers have to pioneer PBE curricula design with little to no support, a particularly daunting task in the absence of clear frameworks. Students may experience difficulties in integrating key ideas and methods when working across disciplines, and teachers may lack familiarity with the content and standards of the subjects that they do not commonly teach. The traditional curriculum structure, focused on distinct disciplines and reinforced by rigid school timetables and departmental silos, creates further obstacles to interdisciplinary learning. It is regularly recognised that teachers feel constrained by a lack of time, incentives, and support when seeking to experiment with new teaching methods, notably due to pressures linked to overloaded curricula and the need to prepare students for high-stakes examinations (OECD, 2013[52]; 2020[43]). Testing and accountability systems that reward traditional teaching, along with a deficit in collaborative and co-teaching environments, can stifle teachers' attempts to effectively orchestrate and assess interdisciplinary student projects.

As noted by Smith (2007[107]), consolidated cases of PBE practice have taken place *despite* such pressures, favouring the incorporation of only some aspects of the local context into mainstream programmes. Indeed, PBE activities can be observed in a continuum ranging from simple uses of local artefacts in relatively conventional lessons (e.g. illustrating an idea discussed in a textbook with a related local example) to a fully transdisciplinary curriculum where students' inquiry about place and its attributes becomes the foundation on which all teaching and learning is structured, as in service-learning (Semken et al., 2017[83]).

Simpler forms of integrating PBE elements into the curriculum can be valuable to the extent that they enhance student learning. In fact, given the relevance of local, relatable examples for student learning, many teachers already incorporate such elements in their practice even when they do not deliberately seek to incorporate PBE principles into their teaching. Simpler forms of PBE can be more easily adopted within existent curriculum and school structures. They can also constitute a foundation to ease the adoption of more innovative practices, where teachers start by making place-based aspects already present in current

learning designs more explicit, and progressively move from planning content-focused activities to activities drawing on learners' experience and skills (Smith, 2007[107]; Paniagua and Istance, 2018[82]).

Scaling up and sustaining such change in teaching practices, however, requires broad community support and a structured way to showcase their efficacy (Gruenewald, 2005[108]). Moving on to more sophisticated transdisciplinary practices calls for the establishment of wider support systems for teachers and schools, including co-construction of curriculum goals; curricular guidelines and exemplars; incentives and recognition for teachers who are willing to experiment with new methods, paired with professional learning opportunities for them to do so; and mechanisms to promote high-quality research production and use (OECD, 2022[109]; OECD, 2023[110]; OECD, 2023[29]).

3.4.2. Making place-based education age-appropriate and inclusive

Case studies exemplify that PBE can positively impact cognitive, emotional, and environmental outcomes across education levels when tailored to students' developmental stages (Hernandez Gonzalez, 2023[71]). As noted in Section 1, individuals' connection to nature fluctuates with age, peaking in childhood and young adulthood and declining in adolescence. But adolescence is also a moment when students can begin to comprehend the functioning of complex systems, understand the long-term impacts of current decisions on climate, and begin to actively contribute solutions. A key question is developing learning progressions that translate this knowledge of child development into age-appropriate practices.

Lausselet and Zosso (2022[111]) illustrate how an age-appropriate learning progression could look like. Their framework, reflected in Table 2, displays an evolution from early childhood, emphasising foundational bonds with nature and feelings of safety, to more intricate engagements in later stages. In primary education, students are encouraged towards guided exploration, strengthening connection with the environment. In secondary school, the focus shifts to independent exploration and deepening commitment to environmental concerns, with students beginning to think about the systemic nature of environmental challenges. By upper secondary, the curriculum advocates for a more reflexive approach, pushing students to apply their knowledge as they reach out to and act in their communities, communicate about environmental concerns and network with various actors. The outlined bonds, ranging from inclusive to performative, signify the depth and nature of the student-environment relationship at each stage.

Table 2. Age-appropriate outdoor environmental education

Learning progression for outdoor environmental education in early childhood, primary and secondary education

Early childhood (4-8 year-olds)	**Primary** (8-12 year-olds)	**Lower secondary** (12-15 year-olds)	**Upper secondary** (over 15 years old)
Sense of belonging	Exploration (guided)	Exploration (autonomous)	Reflexivity
Feeling safe within the environment	Adaptation (place <-> self)	Adaptation (place <-> self) and commitment	Commitment
Sense of well-being in the environment	Sense of well-being in the environment	Thinking the environment and myself in it	Communication to and with others about environment
Awakening to the complexity and richness of the environment	Caring for the environment	Caring for the environment	Networking with societal actors for the environment
Curiosity (about the living world)	Curiosity (about biodiversity) and understanding	Prospective curiosity (about possible transformations of the environment)	Action and agency
Inclusive bond	**Adaptive bond**	**Transformative bond**	**Performative bond**

Source: Lausselet and Zosso (2022[111]), "Bonding with the world: A pedagogical approach", https://doi.org/10.1007/978-3-031-04108-2_15.

In addition to matching educational goals and students' developmental stages, an effective curriculum must also be culturally relevant to the students it serves. Research on human learning has recognised that learning in schools "may be facilitated if the out-of-school cultural practices of students are viewed as resources, tools, or assets" (National Academies of Sciences, Engineering, and Medicine, 2018, p. 140[95]). In grounding instruction in local phenomena, PBE can incorporate students' unique perspectives into the curriculum and show one way in which culturally responsive instruction can be accomplished. All the same, given the diverse experiences that students bring into the classroom, their perceptions of a place and community can vary, which also poses challenges for instructional design.

Some scholars point out that a potential issue arises when the idea of place is subject to restrictive interpretations (McInerney, Smyth and Down, 2011[90]; Nespor, 2008[89]). There is a risk that PBE programmes present places as static and clearly defined, overlooking their dynamic and interconnected nature. As discussed earlier, places are multifaceted. They are shaped by factors such as politics, race, gender, and class, which influence the relation individuals establish with them. Challenges appear when an idealised view of places neglects the challenging realities faced by those in less scenic or socially divided areas. In line with views stressing the civic and political aspects of PBE, the perspectives expressed here highlight the need to critically assess the physical, social, and cultural aspects of places, acknowledging student identities in the process.

Giving students voice in defining the themes and projects they will work on is one way to do this. The point is not for teachers to let students do what they want but negotiating the articulation of the programme with them, making them feel comfortable and motivated while ensuring the learning plan connects to the intended curriculum. Research shows that students in service-learning programmes are often given the opportunity to select the activity that best suits them, and that matching students' preferences in this way can increase the benefits of the intervention (Moely, Furco and Reed, 2008[112]; Furco, 2010[99]).

Student agency has been recognised as essential to high-quality education in the 21st century (OECD, n.d.[113]). In environmental matters, agency is key for realising the tipping potential of education to accelerating the transition to sustainable societies. System-level policies can play an important role in this. For example, national policy in France mandates the election of "eco-delegates" in secondary education schools to drive and advocate for

sustainability initiatives. These student representatives are elected by their peers and must respect gender parity. The elected delegates lead environmental projects, raising awareness and rallying their peers to participate (European Commission, 2022[58]). Electing student representatives is one way of fostering entrepreneurial and leadership skills in some students, an approach that can be reinforced and further extended to all students if other forms of participatory and co-operative classroom and school management are adopted more generally (see, for instance, Freiberg (1996[114]) on classroom management, and Gottschalk and Borhan (2023[115]) for a more general overview of education policies and practices supporting child participation in decision making).

While national policies provide an overarching framework, implementation is subject to local conditions, including socio-economic factors, cultural attitudes, and existing infrastructures. Territorial approaches like PBE, by their very nature, run the risk of exacerbating existing inequalities. Regions with better resources and stronger institutional support are likely to implement these programmes more effectively, potentially widening the educational gap between different territories. Ensuring equitable access to quality education is a critical goal for any government, and systems must therefore play an active role in monitoring and mitigating capacity disparities (Burns, Köster and Fuster, 2016[116]).

3.4.3. Challenges to taking learning outdoors

One of the reasons why PBE approaches have received increased attention in recent years is the growing concern that children do not have enough opportunities to engage in free, unstructured time, including time spent in nature (Brussoni, 2020[117]). Several trends contribute to this issue, including rising urbanisation and the resulting limited access to open, green spaces; parental concerns over their children's safety and success in later life, which are associated to children spending more time indoors, and the translation of such concerns to educational institutions in the form of strict safety regulations and more structured, academic approaches to learning early on in children's education (OECD, 2019[118]).

Meanwhile, field-based and other forms of outdoor experiential learning face a number of additional challenges. Foremost among these are funding limitations, liability issues, and physical inaccessibility. Travel to field sites, especially remote ones, can be costly and time-consuming for both participants and instructors. Teachers often grapple with supervising learners outdoors and the additional preparation and paperwork involved. Weather conditions can deter institutions from organising trips and some sites may be generally inaccessible or pose challenges for students with special needs (European Commission, 2022[58]; Klippel et al., 2019[119]).

Limitations to outdoor learning and nature experience can come at the cost of lost learning opportunities for students. For instance, in a study covering over 300 field trip programmes for middle-school-aged students (grades 5-8) in the United States, Dale and colleagues (2020[120]) concluded that both the naturalness and uniqueness of places visited in such programmes enhanced cognitive, attitudinal and behavioural student outcomes.

One way to addressing existing concerns is ensuring that children have access to meaningful outdoor learning opportunities within the confines of school, greening playgrounds and giving children access to school gardens (Williams and Dixon, 2013[98]). Working with local partners like natural museums, farms and public parks, as suggested by the notion of "learning cities" (UNESCO, n.d.[121]), can also be a way to ensure that children access outdoor learning opportunities in safe and unexpensive ways.

More generally, system-level policies can also promote the articulation of outdoor, including out-of-school, structured learning activities. For instance, across the OECD,

central education authorities have increasingly adopted policies permitting, promoting and in some cases mandating community service as part of the requirements for secondary school graduation. This is the case of Ontario (Canada), which established a 40-hour community involvement requirement for secondary school students in 1999. A different yet complimentary approach is the promotion of extra-curricular activities offering students' access to outdoor experiences. Non-formal learning opportunities are not necessarily offered extensively nor for free, but there are examples of federal/national interventions showing that it is possible to widen access to them by leveraging local partnerships and school time regulations, as in Germany (Bundesministerium für Bildung und Forschung, n.d.[122]) and Portugal (Direção-Geral da Educação, n.d.[123]).

There is also increasing attention to the role that digital technologies can play in supporting students' understanding and connection to nature. Digital technologies increasingly afford immersive, interactive, and affordable ways for students to connect with relevant learning experiences. These tools increase accessibility, allowing more students to experience field-like studies. They offer flexibility, with students exploring at their pace from any location, and safety is enhanced as students virtually explore challenging terrains without risk. Additionally, these platforms encourage a deeper understanding by enabling shifts in perspective, like travelling back in time to observe the historical evolution of places. Research on virtual field trips suggests that these advantages can be achieved by using the technological equipment that is already available in most schools across the OECD, such as desk-top computer simulations (Klippel et al., 2019[119]). Across OECD education systems, digital resources have also been a way to help ministries deliver enrichment and career activities (including practical experiences) related to green jobs. Using online learning for enrichment and work-readiness activities and to foster collaboration between schools across distances is among policy efforts used by countries to provide active learning experiences to students in schools in disadvantaged, rural or remote areas in a number of OECD countries (OECD, 2023[15]).

Using digital technology in this way also raises concerns, such as technologies posing a distraction for learning and acting as a barrier rather than an enabler for learners to engage with the outdoor environment (Hills and Thomas, 2019[124]). The task for place-based educators lies in harnessing these technologies to incorporate multi-disciplinary and multisensory components, aiming to cultivate a sense of place like analogue PBE does (Semken et al., 2017[83]), where combining virtual and outdoor experiences, and leveraging technology for learning in the latter, appear as sensible ways forward.

3.4.4. Creating a conducive institutional context

School institutions, positioned between the practice of individual teachers and the broad directives of systemic policy, have a key role to play in supporting PBE practices. As institutions, schools can offer a clear vision and related structures for embedding sustainable learning and action throughout all aspects of school life. They can facilitate the co-ordinated action of educators and other stakeholders towards expanding opportunities for learners to engage in reflective action.

This idea is often encapsulated by the term "whole-school" or "whole-institution approach" to sustainability (European Commission, 2022[125]). It represents a collective endeavour to extend beyond isolated 'islands of good practice' within individual classrooms. By integrating sustainability into the school's operations and infrastructure, and linking these actions to student learning, a more holistic educational experience is cultivated.

A whole-school approach necessitates the establishment of mission statements and policies that explicitly endorse sustainability, positioning it as a foundational element of the school's identity. This approach seeks to impact student learning beyond the formal

curriculum, targeting the social norms and values involved in the everyday interactions of the school community.

Because schools are large consumers of goods and services, "greening" school operations, such as in reducing their energy consumption, is a positive step in and of itself (OECD, 2021[126]). Going further, making students an active part of this process provides them with authentic learning experiences to apply their knowledge (Okada and Gray, 2023[127]). Students may, for instance, study and organise food procurement and serving in school canteens, assess the social and environmental impact of different purchase options, effectively making decisions on what to buy together with the school's staff, and strengthening food waste management.

Countries can combine approaches to reduce emissions from educational infrastructure with opportunities for learning. New Zealand's Carbon Neutral Government Programme (CNGP) exemplifies how such a view can be promoted. The CNGP requires public organisations, including schools, to annually measure and report emissions, align targets with the 1.5-degree global warming goal, and implement reduction plans, aiming to offset remaining emissions by 2025. The Ministry of Education manages school emissions reporting and identifies key emission sources such as transport and construction for targeted strategies. Schools contribute by adopting measures like waste reduction and cleaner energy. Ongoing pilot programmes in schools aim to establish realistic targets and broaden sector-wide reductions. Connecting to the curriculum, this initiative offers real-world learning opportunities to foster student engagement and agency in sustainability (Te Tāhuhu o te Mātauranga - Ministry of Education, 2023[128]).

Collaboration is central to the whole-school approach. It encourages teachers across various grades and subjects to unite under a shared vision, breaking down the silos that are often embedded in school structures and culture. This collaborative spirit is not confined within the school walls but extends to the wider community. Schools forge partnerships with local organisations and businesses, bringing real-world context to students' learning and optimising the impact of school initiatives by co-ordinating them with broader community efforts (Nilsson Brodén, 2022[129]; OECD, 2017[130]).

In Portugal, for example, a National Network of Live Science Clubs at School (CCVnE) has been set up to offer learners open spaces for contact with science and technology. The clubs are based on partnerships with scientific and higher education institutions, local authorities, live science centres, companies with a research and development focus, museums and other cultural institutions. The objective is to promote science education activities and experimental teaching in collaboration with different knowledge areas that are part of the curriculum and that are linked to the Profile of Students Leaving Compulsory Schooling. Many of the projects developed in these spaces relate to sustainability and climate change, with a focus on multi-disciplinary and contextualised learning. In 2023, the network was made up of 897 clubs distributed across 718 schools engaging 3 968 partner entities (Direção-Geral da Educação, n.d.[131]).

The widespread adoption of whole-school approaches requires synergies between the leadership at the school and community levels and the strategic policy frameworks enacted by governments. School leaders play a pivotal role in rallying educators to adopt a collaborative spirit and in forging partnerships that extend the school's initiatives into the community. They are responsible for generating the formal and informal institutional structures that support these endeavours. Additionally, local actors such as school district officials and municipal education offices can provide resources and facilitate connections with other community stakeholders. They can assist schools in the creation of partnerships by helping them to define the roles and expectations of each party within clear collaboration frameworks. Austria's ÖKOLOG network, bringing together schools, regional teams,

universities and public authorities is an example of an initiative that connects international and national strategies on sustainability education to local action (ÖKOLOG, n.d.[132]).

Additionally, system-level policies are essential in providing the frameworks, resources, and incentives for schools to prioritise place-based action. For example, policies may mandate student involvement in school decision-making processes. In Portugal, schools are required to implement a participatory budgeting process, empowering students to engage in and advocate for environmentally conscious projects within their institutions (Abrantes, 2023[133]).

On the side of incentives, granting recognition to schools that incorporate sustainability considerations in all aspects of their operations, such as in "green" labelling programmes like Eco-schools (Foundation for Environmental Education, n.d.[134]), can be an effective form of external pressure to raise students' environmental literacy (Boeve-de Pauw and Van Petegem, 2017[135]; Byrne et al., 2023[136]; Cincera and Krajhanzl, 2013[137]). In France, for example, since 2013, the E3D label has been awarded to 12 500 schools (20% of institutions) when they teach sustainability while also implementing concrete actions like waste reduction or biodiversity protection. Similarly, in Iceland, programmes like Eco-schools Iceland, the United Nations International Children's Emergency Fund (UNICEF) rights-respecting schools, and health-promoting schools have supported sustainability initiatives for over a decade.

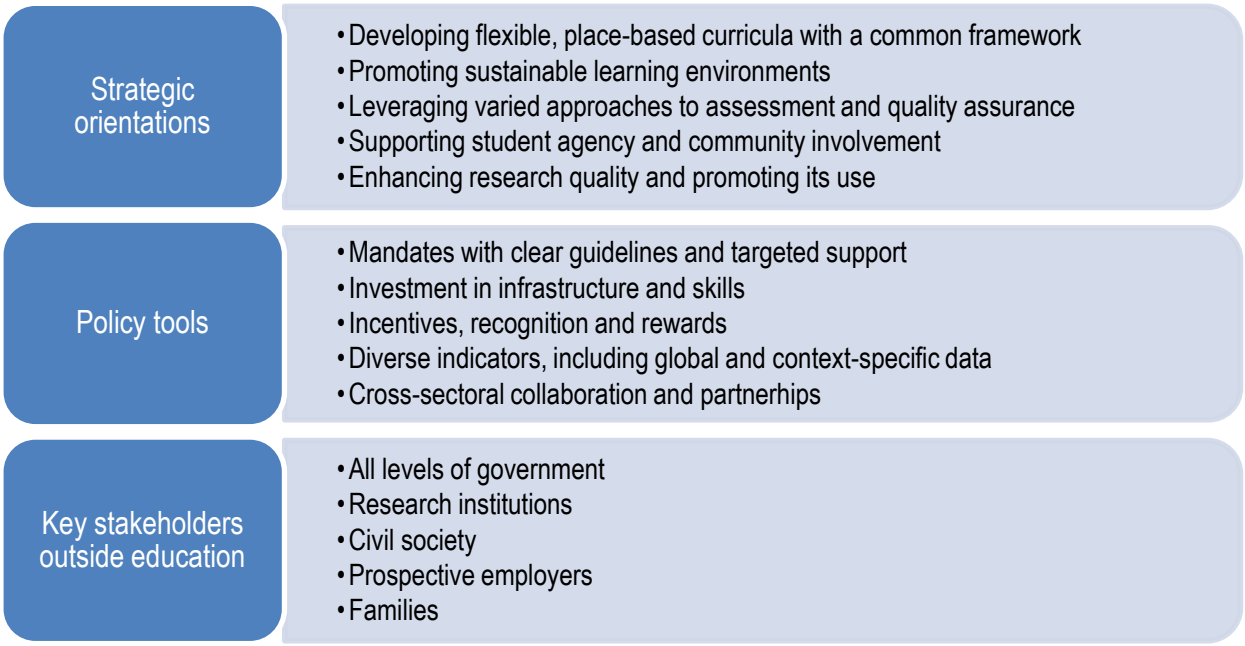
Action to build capacity at the system level can include self-evaluation guidelines for schools to systematically review their initiatives and measure progress. The 'Whole school and community approach to learning for sustainability' guide in Scotland (United Kingdom) illustrates this option (Education Scotland, n.d.[138]). Equally important is the allocation of targeted resources for enhancing school infrastructure in environmentally sustainable ways, alongside support for engagement activities with community partners. Support can extend to funding and developing career structures that acknowledge and incentivise school staff who lead the co-ordination of these activities, as it is the case in France with the role of the ESD co-ordinator, a member of the staff in each school that promotes and supports sustainability projects (OECD, 2019[63]; OECD, 2023[15]).

3.5. Conclusion and scope for future work

With a better understanding of the enablers and barriers facing PBE practices, it is possible to begin to think about how policy can promote and scale up the uptake of such practices for the education system at large. Figure 2 sketches out a framework that could steer future analytical work in this area. Drawing inspiration from the OECD's work on territorial approaches to the Sustainable Development Goals, the framework is conceived as a tool to systematically explore key strategic objectives, assess current policy alignments, and propose necessary shifts to support and scale up PBE practices in school systems.

The analytical framework proposes three main areas for system-level education policy attention. The first area, *strategic orientations*, involves considering the necessary shifts in current policies to support and promote further adoption of PBE practices in schools. The second area, *policy tools*, constitutes the inventory of instruments or the 'toolbox' that policymakers can utilise to realise strategic objectives. The third area focuses on the *key stakeholders outside education* involved in policy definition and operationalisation, stressing that they can play a key part in supporting policy implementation, albeit each bringing unique contributions.

Figure 2. Analytical framework for a territorial approach climate change education



Source: Adapted from OECD (2020[139]), *A Territorial Approach to the Sustainable Development Goals: Synthesis report*, OECD Urban Policy Reviews, https://doi.org/10.1787/e86fa715-en.

Blending desk-based research with data analysis and case studies of territorial approaches, future work could highlight both effective examples of PBE and challenges to their broader adoption. Considering the importance of cross-sectoral approaches, the focus could be on territorial approaches that have a key focus on local school systems but also involve other local sectors to build impactful local collaboration. The work could build on the OECD's wider expertise on territorial approaches, generating actionable insights for education policy makers. This could support the strategic expansion of PBE in education systems and offer significant contributions to understanding education as a positive tipping element in building sustainable economies and societies.

4. From anxiety to adaptation: making school systems climate change–resilient

4.1. Introduction

Despite international ambitions to reduce the effects of climate change, a recent report from the United Nations warns that the global community is still failing to meet the COP21-Paris targets and that there is no realistic pathway to limit global warming to 1.5°C. With the current policies in place temperatures are expected to raise by 2.8°C by the end of the century, while only an urgent and system-wide transformation can prevent a climate catastrophe (UNEP, 2022[140]). As outlined in Section 1, even with effective mitigation policies in place, the likelihood of critical tipping points being exceeded within the 1.5 to 2°C temperature increase range remains significant (OECD, 2022[141]). This implies, among other considerations, an elevated risk of more frequent occurrences of extreme weather events.

This section puts its primary emphasis on the adaptation of education systems with regards to extreme weather events, but it also addresses the broader consequences of climate change on students, in terms of their physical and mental health and educational experiences. The section starts by delving into the impact of extreme weather events on school infrastructure and students and then analyses different strategies for education systems to address risks, adapt to changing environmental contexts and build resilience. It concludes by looking into how risk analysis, monitoring and foresight can best inform these strategies and proposes areas for future work.

4.2. Global context

Extreme weather events can be defined as short-term localised phenomena that deviate from the normal weather conditions, such as heat waves, floods, droughts, storms and wildfire. Climate change refers to the long-term changes in the average climate of the Earth, such as temperature, precipitation, wind patterns, and ocean currents. These long-term changes, in turn, influence the intensity and sometimes the frequency of extreme weather events (Van Oldenborgh et al., 2022[142]; IPCC, 2023[143]; Zachariah et al., 2023[144]; Hansen et al., 2013[145]).

Available evidence suggests that the number of climate-related disasters has increased significantly during the last two decades. According to the United Nations Office for Disaster Risk Reduction, 6 681 climate-related events occurred between 2000 and 2019 compared to 3 656 events between 1980 and 1999 (UNDRR, 2020[146]). Most extreme weather events are floods and storms, while recently droughts, wildfires and extreme temperatures also became more frequent and severe.

While low-income countries are more impacted by extreme weather events, climate risks are also increasing in high-income countries. In 2018, for example, advanced industrialised nations experienced some of the most severe impacts of heatwaves and droughts worldwide (Eckstein et al., 2020[147]). Moreover, in Europe, the incidence of extreme heatwaves has increased to a degree that is now up to 100 times more probable when compared to a century ago. The Intergovernmental Panel on Climate Change (IPCC) also anticipates that, as a consequence of global warming, the frequency and intensity of tropical cyclones and the severity of agricultural droughts will continue to rise in North America, Australia, and Europe (IPCC, 2023[143]).

The increase in extreme weather events will also make climate-induced displacement more likely. In 2022, approximately 3.3 to 3.6 billion people were living in contexts highly vulnerable to climate change and extreme weather events (OECD, 2023[148]). The global

population exposed to river floods, for example, will increase by 120% if global warming increases by 2°C, and estimates suggest that such floods already account for 10 million internal displacements each year. While most of the displacement occurs in low-income countries, it is also likely that high-income countries may experience more climate-related displacement, whether it be internal or cross-border, in the future. Therefore, education systems around the world must anticipate and adapt to these potential changes.

4.3. The effects of climate change on education systems

Extreme weather events have far-reaching implications that affect human lives, well-being, infrastructure and property. By extension, they pose a significant threat to school buildings, accessibility, and the educational experience overall. Extreme weather events can require students' relocation to alternative areas, lead to the closure of schools, hinder the learning of students, and increase the poverty and vulnerability of students and their families.

At present, it is estimated that extreme weather events disrupt the education of approximately 40 million children worldwide and this number is only expected to increase in the near future (Theirworld, 2023[149]; UNESCO, 2023[150]). Subsequently, it is important for governments to make their education systems more resilient against extreme weather events and the consequences of climate change in general. (OECD, 2023[151]) describes resilience as comprising four key stages: awareness, assessment, action, and adaptation:

- Awareness refers to enhancing understanding of the potential impacts of climate change on different sectors, regions, and communities.
- Assessment involves measuring the exposure, sensitivity, and adaptive capacity of different systems to climate change.
- Action involves the implementation of the most appropriate and effective responses.
- Adaptation applies to a set of actions that reduce the vulnerability of individuals and societies to the impacts of climate change. This includes building safe and flexible learning spaces, the provision of water, sanitation and hygiene services and protecting students' and teachers' health and well-being.

The discussion that follows focuses on the effects of climate change on school infrastructure and students. Effects on school infrastructure are defined as damages or losses caused by extreme weather or gradual changes in climate that affect the physical facilities, structures and equipment of schools. For the effects on students, this paper mainly considers the impacts of extreme weather events on the physical and mental health of students, as well as on learning outcomes. The section also addresses concerns and anxieties that students may have regarding climate change as a global phenomenon, even if not personally affected.

4.3.1. Effects on school infrastructure

There is a wide range of extreme weather events that can impact on the infrastructure of schools, including floods, storms, water scarcity, pollution and extreme temperatures.

Floods and storms pose a serious threat to school buildings. They often occur simultaneously and reinforce each other. By damaging school buildings, equipment and material, floods and storms make classrooms unsafe and unusable. Floods may also contaminate water sources and distribution systems leading to unsafe water for drinking and hygiene. Moreover, floods and storms cannot only harm the school infrastructure, but

also the nearby roads or railroads. As a consequence, students may lose the ability to access their schools.

A recent example is the winter storm that hit northern parts of Mexico, the United States, and Canada in February 2023. The storm disrupted electricity supplies and forced the closure of hundreds of schools (O'Brien, 2023[152]). In the same year, London was forced to shut down schools due to heavy rainfalls and an increase in the water level of the Thames (Greater London Authority, 2023[153]). The region of Emilia Romagna, Italy, also had to evacuate schools due to heavy rainfalls and the risk of landslides in May 2023 (Climate Foundation, 2023[154]). Other examples are the flood disaster in the Ahrtahl, Germany, where floods destroyed more than 20 schools during the summer 2022 (Kuhn, 2022[155]), and more recent floods in Slovenia that destroyed 12 kindergartens, 19 primary schools and five high schools in August 2023 (Slovenia Times, 2023[156]). Additionally, the floods affected the surrounding infrastructure, which prevented some students to access their educational facilities.

On the other extreme, water scarcity disrupts water supply systems and hinders the maintenance of sinks, showers, toilets and handwashing stations in schools (Development Bank of Southern Africa, 2023[157]). Water scarcity also reduces the quantity of water allocated for the maintenance and cooling of school premises and equipment, as well as for the irrigation of school gardens and farms. South Africa, for example, frequently experiences severe drought crises (Booysen and Gerber, 2021[158]). Schools in Pretoria and Gauteng were compelled to close due to a water outage and non-functional school facilities in 2023 (Pheto. Belinda, 2023[159]). In early 2024, Catalonia (Spain) declared a state of emergency due to the worst drought on record (Hedgecoe, 2024[160]).

Extreme temperatures pose another significant threat to school infrastructure. They can cause overheating and direct damage to school's infrastructure, even though directly observable impacts from heatwaves rarely exist (OECD, 2021[161]). In addition, heatwaves lead to frequent school closures, when temperatures reach levels unsuitable for teaching and learning. The European Environment Agency (EEA) indicates that approximately 43% of schools in European cities are in so called urban heat islands (European Environment Agency, 2023[162]) [2]. This implies that with rising temperatures school closures could occur more often in Europe. For instance, France had to close more than 4 000 schools due to extreme heatwaves in 2019 (The Local, 2019[163]).

Wildfires can damage schools and make them inaccessible. The related air pollution puts teachers' and students' health at risk. For example, in the 2018/19 school year, California in the United States had to close more than 1 911 schools due to wildfire and bad air quality, which affected more than 1.1 million students (Miller and Hui, 2022[164]). In early September 2023, New South Wales in Australia had to close more than 21 schools due to fire warnings (The Guardian, 2023[165]).

Beyond the impact that extreme weather events are already having on school infrastructure in many countries, the fact that these events are predicted to further increase in frequency is of particular concern. These events risk further jeopardizing school infrastructure and disrupting education at a large scale unless proactive adaptation measures are taken. As an illustration, in California, the incidence of school closures caused by wildfires has surged by nearly 100% in recent years. Between 2002 and 2015, schools were already forced to close for a cumulative total of 10 700 days due to wildfire (each closure day equals one lost day of instruction at a single public school site). However, between 2015 and 2019, this

[2] Urban heat islands are areas in cities that are normally much warmer than the surrounding countryside due to human activities (European Environment Agency, 2023[162]).

figure doubled to 21 000 days of school closures. Overall, California was forced to close schools for a total of 34 000 days between 2002 and 2019 due to extreme weather events (Cal Matters, 2019[166]).

4.3.2. Effects on students

Physical and mental health

While the preceding section has highlighted the profound impact that extreme weather events can have on the infrastructure of schools, it is equally important to assess the repercussions of such events on various aspects of students' life. Table 3 gives an overview how extreme weather events, such as pollution or extreme temperatures, may affect the physical health of students.

Table 3. Effects of extreme weather events on student health

Extreme weather events	Physical health
Pollution	Asthma, reduction in cognitive abilities, lung cancer, heart disease, strokes and high blood pressure (Manisalidis et al., 2020[167]; Prunicki et al., 2021[168]; Horvath and Borgonovi, 2022[169]).
Extreme temperatures	Heat stroke, heat exhaustion, hypothermia, cardiovascular and respiratory problems (WHO, 2023[170]; Horvath and Borgonovi, 2022[169]).
Droughts	Dehydration, malnutrition, infections and diseases. Problems with growth and delayed puberty (Twiddy, Trump and Ramsden, 2022[171]; Agabiirwe et al., 2022[172]).
Floods	Water pollutions causing diarrhoea, dysentery, cholera. Hydration and nutrition problems (Paterson, Wright and Harris, 2018[173]).
Wildfire, storms	Exposure to physical hazards, such as heat, cold, fire, lightning, wind or falling objects. Respiratory and cardiovascular problems. Skin problems, allergies, infections, eye problems (Silveira et al., 2021[174]).

Extreme weather events can influence not only the physical health of students, but their mental well-being as well. Often, these impacts on physical and mental health are interconnected, potentially intensifying each other (Hayes et al., 2018[175]). The mental health impacts of one extreme weather event can range from mild stress and insomnia to more severe conditions like depression, anxiety, and post-traumatic stress disorder. In some cases, individuals may even experience suicidal thoughts (American Psychiatric Association, 2023[176]; Silveira et al., 2021[174]).

For example, both floods and extended periods of drought have been linked to mental health issues such as increased anxiety, depression, suicide, and post-traumatic stress disorder. Floods may damage schools or make them inaccessible, leading to further upheaval in children's educational routines. For example, the 2022 flood disaster in Ahrtahl, Germany destroyed 29 schools. As a consequence, students were redistributed across schools and in extreme cases students had to travel up to 2 hours per day to their new schools putting additional stress on their mental health and academic performance. In addition, this also stretched the capacity in the receiving schools (Kuhn, 2022[155]).

Children are often more severely affected by disasters compared to adults, with enduring trauma-related symptoms (WHO, 2023[170]). Disruptions in their daily routine, being distanced from their caregivers due to necessary evacuations or displacement, and post-disaster stress experienced by their parents all add to the distress of children. While children often display a remarkable ability to recover and the immediate effects of disasters may diminish over time, it remains important to monitor them for any potential long-lasting effects that could be a result of prolonged stress (Osofsky et al., 2015[177]).

Increasingly, extreme weather events as a result of climate change are likely to lead to significant population displacements. It is estimated that climate change could force up to 216 million people across six world regions to move within their country by 2050 (World Bank, 2021[178]). The upheaval, trauma, and loss associated with such displacement can further contribute to reduced well-being and mental health among students.

There is also evidence that young people's mental health may be impacted by climate change even if they have not directly experienced its consequences. The mere thought of climate change and its potential for causing extreme weather events in the future can lead to climate anxiety, which in turn may increase feelings of fear, sadness, and depression (Whitmore-Williams et al., 2017[179]).

Learning outcomes

The implications of physical and mental health issues, compounded by the potential closure of schools due to extreme events, can have a profound impact on students' learning outcomes. Extreme temperatures can lead to a decrease in attention span and learning abilities, making it challenging to concentrate and learn (Horvath and Borgonovi, 2022[169]). High temperatures can have a direct impact on test scores (Zivin, Hsiang and Neidell, 2015[180]). For example, research has shown that high school students in New York City are 12.3% more likely to fail an exam, when the temperature is about 32°C as compared to when it is about 22°C (Park et al., 2020[181]).

There is an extensive literature examining the impact of school closures on students' academic performance. The disruption of regular learning processes leads to significant educational setbacks for students and can even have an impact on their future earnings (Glewwe et al., 2013[182]; Hanushek and Woessmann, 2020[183]; Hammerstein et al., 2021[184]; Patrinos, Vegas and Carter-Rau, 2022[185]).

These effects are often more pronounced for students with lower socio-economic backgrounds. One study conducted in the United States demonstrates that the effect of school closures on educational outcomes is highly unequal, with high school students from poor neighbourhoods suffering large and persistent learning losses after school closures, whereas learning outcomes of children in wealthier neighbourhoods were barely impacted (Agostinelli et al., 2020[186]).

More broadly, there is evidence that the effects of climate change disproportionately affect students with lower socio-economic backgrounds, minority backgrounds, or at risk of marginalisation. A study by (Park et al., 2020[181]) shows that extreme heat affects learning, especially in schools without air conditioning. The study finds that students in hotter classrooms performed worse on standardised tests, and that the effect was more pronounced for Black and Hispanic students in the United States. Indeed, minority communities are more likely to reside in areas with higher temperatures and poorer air quality in the United States. Despite this, many schools and communities in less well-off regions do not have enough resources to make their educational infrastructure resilient to climate change impacts and this may amplify existing inequalities in the long run (Bank, 2016[187]; Horvath and Borgonovi, 2022[169]).

4.4. Strategies to make education systems more resilient

The previous section has shown that extreme weather events and climate change negatively impact school infrastructure, students' physical and mental health, as well as academic performance and equity. This section offers an overview of policies and practices for schools to adapt to increasing risks and build resilience. As climate risks vary across

countries and localities, there is no one-size-fits-all approach. Nevertheless, some common principles emerge that are summarised below.

4.4.1. Resilient school infrastructure

As shown by analysis in the previous section, building or upgrading school buildings in ways that make them resistant to extreme weather events is key to protecting educational infrastructure and also serves to improve indoor comfort and reduce energy consumption. Infrastructure adaptations also offer opportunities to improve students' learning. For instance, studies have shown that the installation of air filters and air conditioning can raise mathematics scores by 15 to 20% of a standard deviation at an annual cost of only USD 1 000 per class in the United States (Gilraine, 2020[188]; Neilson and Zimmerman, 2014[189]).

In holistic approaches to sustainability education, such infrastructure adaptations could be planned in conjunction with related learning opportunities for students (Section 3). For example, as new energy systems are installed, schools could use this as an opportunity for designing cross-curricular projects where students investigate how renewable technologies function and how they support climate action. This may involve experimenting with the energy output and efficiency of different renewable energy systems and comparing them with fossil fuel systems.

Some countries have education-specific strategies to adapt buildings and infrastructure. France and Germany, for example, have policies in place to incentivise the installation of heating, cooling and ventilation systems. France's "*Plan de Rénovation Énergétique Des Écoles*" aims to renovate 40 000 primary schools by 2034. The plan includes measures to improve energy performance and to install systems to regulate temperature and to provide clean energy. To receive funding, schools need to actively apply for the different funding schemes (Le ministère de l'Éducation nationale, 2023[190]; French Government, 2023[191]). Germany's "Federal funding for efficient buildings" programme offers a 15% subsidy for municipalities to install room cooling technology or energy-efficient lighting systems in public schools (Bundesministerium für Wirtschaft und Klimaschutz: BMWK, 2023[192]).

Also, California (United States), provides grants and subsidies for public schools to improve their heating, cooling, and ventilation systems through the "California Schools Healthy Air, Plumbing, and Efficiency Program – CalSHAPE" (California Energy Commission, 2023[193]). Moreover, the Federal Inflation Reduction Act offers tax incentives for schools to install renewable energy systems like solar panels, which can cover up to 30% of the costs (White House, 2022[194]). This approach enables schools to use clean and affordable electricity generated from their own sources to power their energy systems. In addition, the government of Türkiye is adopting a comprehensive sustainability approach in education, focusing on constructing resilient school infrastructure. According to regulation from the Ministry of Environment, Urbanization, and Climate Change, newly constructed buildings within the Ministry of National Education (MoNE) are targeted to achieve an Energy Performance Class of B or higher (Government of Türkiye, 2023[195]).

Other countries have cross-sectoral strategies to adapt public infrastructure, with educational infrastructure being one among other priorities. Japan, for example, a leader in disaster strategies and risk management, launched a five-year plan in December 2021 to boost its disaster preparedness. The plan, worth USD 144.4 billion, focuses on reducing the risks of earthquakes, storms, and floods. It includes improving infrastructure such as roads, schools, and airports, and using advanced seismic engineering and artificial intelligence. Japan also changed its laws and building codes to make its environment safer and more resilient to disasters (Katanuma, 2021[196]).

National or state guidelines can also offer important information for sub-national construction and adaptation strategies. For example, in 2020, California introduced Assembly Bill 3074, which directs the California Department of Forestry and Fire Protection (CAL FIRE) to devise guidelines for enhancing fire safety and resilience in schools situated in high-risk fire areas (California Legislative Information, 2020[197]). The guidelines encompass building standards, defensible space requirements, and measures such as the use of less flammable construction materials. Similarly, Canada's Fire Smart Program aims to mitigate wildfire risks for communities and their infrastructure (FireSmart Canada, 2023[198]). The programme assists in establishing defensible zones around homes and state infrastructure and encourages collaboration among governments, communities, and industry to enforce wildfire-resilient infrastructure standards. These standards include the use of fire-resistant building materials and strategic land use planning.

Finally, as part of strategies for infrastructure adaptation, some countries have explored the use of school buildings as shelters for disaster situations. This approach focuses on designing and building school facilities to function as secure and comfortable shelters for individuals in the aftermath of natural disasters. For example, the Federal Emergency Management Agency (FEMA) in the United States funds and gives guidance for the installation of safe rooms in schools. Using school buildings as shelters offers advantages such as their community familiarity and accessibility, their capacity to accommodate educational and other activities, and their potential to minimize the expenses and environmental consequences associated with constructing separate shelter facilities.

Nevertheless, it is essential to note that this strategy may not be appropriate for all types of disasters, could disrupt the regular operation of schools, and often necessitates additional funding and co-ordination among various stakeholders. Following the large earthquake in 2011, schools in Japan have been reconstructed to serve as evacuation centres and shelters for floods, storms and earthquakes (Ministry of Education, 2023[199]). These shelters, however, also face problems such as overcrowding, lack of privacy and psychological stress (University of Cambridge, 2012[200]).

While whole-of-government approaches have the potential to pool significant resources for bolstering infrastructure resilience across public sectors including education, a challenge is that these approaches may bring complex co-ordination, constraints on available resources and conflicts of interest, and/or risk that education-specific perspectives are not sufficiently considered.

4.4.2. Nature-based solutions for schools

Governments are increasingly considering the adaptation of school environments as a viable strategy. This often encompasses the implementation of nature-based solutions, which are interventions aimed at the protection, sustainable management, and restoration of natural and modified ecosystems. These solutions are designed to address societal challenges in an effective and adaptive manner, providing mutual benefits for both humans and nature. Such interventions may include the cultivation of drought-resistant plants, the provision of shaded play areas, the construction of fountains, and the unsealing of areas to facilitate rainwater infiltration and recovery. However, this approach is not without its challenges. Issues related to the financing of nature-based solutions, water availability, land use, and pest management can pose significant obstacles. Therefore, careful planning and management are essential to ensure the successful implementation of nature-based solutions in schools.

Beyond their role in nature conservation, these measures have the potential to enhance student well-being, improve learning outcomes, foster environmental consciousness and offer opportunities for outdoor learning. As shown in Section 3, learning about plants,

biodiversity or the ecosystem in general in green gardens of schools allows students to develop a deeper connection with nature (Burns and Gottschalk, 2020[201]). For instance, the Openness, Adaptation, Sensitisation, Innovation and Social Ties (OASIS) initiative in Paris, France, has "greened" over 130 schools through the introduction of trees, gardens, and water installations since 2017. These interventions have contributed to a cooler school environment, decreased air pollution, and enhanced biodiversity (Ville de Paris, 2023[202]; European Environment Agency, 2023[162]). Comparable initiatives have been undertaken in cities such as Barcelona, Brussels, and Rotterdam (COOLSCHOOLS, 2023[203]).

In the United Kingdom, the Climate Change Risk Assessment (CCRA), a component of the United Kingdom's Climate Change Act 2008, mandates that new schools in the United Kingdom must prioritise nature-based solutions by 2025. This encompasses the implementation of sustainable drainage systems such as rain gardens and natural shading for outdoor areas, which not only offer protection from flooding and overheating, but also optimise the use of outdoor space. These stipulations are required to be integrated into the guidelines and standards adhered to by contractors involved in the construction or refurbishment of schools (United Kingdom - Department for Education, 2023[204]).

Other systems embed nature-based solutions for schools in broader territorial approaches. For example, Hong Kong, China, which experiences an average annual rainfall of 2 400mm and is susceptible to tropical cyclones, has a city-wide strategy to enhance resilience. As part of this, nature-based drainage systems are being constructed across the entire city to enhance flood resilience and to improve the use of public spaces (OECD, 2018[205]).

4.4.3. Adapting school calendars and operations

While infrastructure adaptations aim to actively enhance the resilience of educational infrastructure to withstand climate-related hazards, other strategies aim to cope with the consequences of climate change on increasingly inadequate schooling infrastructure and/or rethink learning programmes to work around climate-related risks.

Several countries have used strategic adjustment of school operating hours and the modification of learning models to minimise exposure to extreme weather events. This can include altering school starting and ending times, rescheduling summer vacations, or even transitioning to online learning during periods of heatwaves, floods, or storms. Potential risks with such approaches include disruptions to the continuity of learning, insufficient co-ordination with various stakeholders such as parents and transportation services, and an increase in educational inequities. Potential benefits include enhancing students' comfort, attendance, and academic performance while ensuring their safety.

For example, Malawi changed the school calendar in 2020 to avoid that students need to attend school during the colder dry season, as most schools do not have any heating installations, while the Philippines are considering to change the school calendar to avoid learning during the hottest months within the next five years (CNN, 2023[206]; Niwe, 2021[207]). In India, increased heat waves have led some schools to reschedule summer vacations or switch to online learning (Akhtar, 2022[208]).

In addition to government policies designed at the national level, regional and local governments often have their own strategies in place. For example, federal states in Australia have established different guidelines on how to deal with extreme heat. The state of Victoria does not close schools for extreme weather, but may shorten breaks, while Western Australia adjusts programmes as needed (Thorne and Stein, 2017[209]).

When implementing changes to school calendars and operations, it is key to integrate strategies to avoid disrupting the continuity of learning, ensure adequate co-ordination with

various stakeholders such as parents and transportation services, and monitor impacts on educational equity.

Changes in school calendars and school operating hours aim to minimise disruptions in student learning and optimise the conditions for learning in schools. However, extreme weather events may still force schools to close temporarily, and ensuring learning continuity in these cases is essential.

4.4.4. Remote learning

There is a wealth of experience and lessons learned from around the world on the benefits and drawbacks of various remote learning strategies tested during the COVID-19 pandemic (OECD, 2021[210]; OECD, 2020[211]). Having policies in place for remote learning increases the accessibility and flexibility of education without being limited by geographical or temporal constraints. However, remote learning also needs to consider that not all students have the same learning opportunities and support, as some students may have unfavourable learning conditions at home or limited access to online platforms due to their socio-economic status, digital literacy, or special needs. Remote learning also requires a high level of self-discipline, which some students may struggle with. In addition, a lot of time and money is required to train teachers adequately and to set up digital learning platforms (Burns, 2023[212]; EDHEC, 2021[213]).

Finland has a national strategy for digital education that aims to enhance the quality, accessibility, and competencies for teachers and students, promoting online learning environments and platforms and supporting flexible and personalised learning paths. During the COVID-19 pandemic Finland was able to smoothly switch to remote teaching thanks to its existing digital infrastructure (Kyyrö, 2023[214]). Also, Singapore has a comprehensive framework for e-learning, called the "Singapore Student Learning Space" (SLS), which is an online platform providing curriculum-aligned resources, interactive tools, and learning activities for student and teachers. Singapore has also invested in professional development programs for teaches to enhance their digital skills and pedagogies (Ministry of Education Singapore, 2023[215]). Türkiye has made significant strides in digital education, particularly through the Education Information Network (EBA) (Presidency of the Republic of Türkiye, 2023[216]). EBA is a national initiative that fosters a more digitalised learning environment and has currently over 18 million registered students. It was particularly important during the COVID-19 pandemic. It fosters accessible and effective education, bridging gaps and ensuring a robust learning environment for millions of students. There is also a Teacher Information Network (ÖBA), which supports teachers in adapting to the digital landscape (Ministry of National Education, 2023[217]). It has over one million registered teachers.

Lessons learned from remote learning during the COVID-19 pandemic can inform teaching strategies in the event of natural and other disasters. Slovenia, for example, implemented a hybrid teaching model after having experienced the floods in August 2023. This innovative approach allowed students who could not physically attend classes to access study materials online, ensuring continuity in their education (Slovenia Times, 2023[156])

4.4.5. Addressing climate-related health and well-being issues

As discussed above, resilience is not only about adapting school grounds, infrastructure and operations, but also about responding to the impacts of climate change on students' health and well-being. In addition, adaptation strategies offer opportunities to engage young people in reflections about adequate responses to climate change. Given local

variations in how climate change and extreme events are being experienced by students, there needs to be flexibility in how these strategies are being developed and implemented.

Emergency response plans are key for coping with the direct impacts of extreme events, including elements such as evacuation procedures, shelter-in-place instructions, and first aid resources. These plans should be regularly updated and communicated to students, staff, and parents to ensure everyone's safety during extreme weather events related to climate change. Furthermore, schools may collaborate with local government and community organisations to enhance their preparedness and resilience in the face of extreme weather events.

For example, the government of Mexico has established a National Strategy on Climate Change including measures to protect health and education from climate impact. The strategy supports schools in developing climate change awareness campaigns, strengthening emergency preparedness and response, and improving water and sanitation facilities in schools (Federal Government of Mexico, 2013[218]). To give a more targeted example, the state of Victoria, Australia, has a Bushfire Safety Policy in place requiring schools to have emergency plans and to assist with evacuations before and during a wildfire (EMV, 2018[219])

In addition, there are various strategies that can be helpful for education systems to proactively address climate-related mental health and well-being issues. Establishing a nurturing and secure learning environment in schools, where students are encouraged to openly express their emotions and concerns, is a first step to devising adequate responses. Where there is open discussion and recognition of effects of climate change on students, these concerns can be better integrated into curricula, pedagogical approaches, pastoral care and administrative strategies. These approaches may empower students with relevant knowledge and skills to cope with different impacts related to climate change (Herr, 2021[220]).

For example, Italy has mandated the inclusion of sustainability and climate crisis education in their curriculum. Starting from September 2020, government schools have been required to allocate approximately 33 hours each school year to discuss topics such as global warming, the human impact on the environment, and climate anxiety (UNESCO, 2023[221]; Hodal, 2019[222]). Similarly, New Zealand implemented changes to their curriculum in 2020 to educate students about the climate crisis, activism, and climate anxiety. The focus is on equipping students with the necessary tools to manage their feelings of climate anxiety. The changes in the curriculum apply to all students aged 11 to 15 (Graham-McLay, 2020[223]).

Psychological, well-being and mental health services may also be required to support students experiencing climate anxiety (Burns and Gottschalk, 2019[224]). Collaboration with psychologists and other professionals, including counselling and psychological support can help schools to identify and assist students experiencing stress, fear, anger or hopelessness, in particular during and after extreme weather (Harper, Cunsolo and Clayton, 2022[225]).

For example, the Philippines after being severely affected by Typhoon Haiyan in 2013, has issued a policy on the provision of psychosocial support services for learners and personnel affected by disasters and emergencies including those caused by climate change. The policy aims to promote the mental health and well-being of learners and personnel, and to ensure their access to appropriate and timely psychosocial interventions. Moreover, the policy outlines the roles and responsibilities of various stakeholders, such as school heads, teachers, guidance counsellors, social workers, and health personnel, in providing psychological support services (WHO, 2022[226]). Also in Australia, during the 2019-20 wildfires, the federal government provided mental health counselling free of charge and

extended opening hours for mental health services to young students (Harper, Cunsolo and Clayton, 2022[225]).

Overall, while efforts to adapt to the impacts of climate change have increased in order to safeguard the safety and well-being of students, it is important to note that adaptation responses have not been evenly distributed globally and are not projected to keep pace with the changing climate (IPCC, 2023[143]). They are predominantly in the planning stages and have not seen widespread implementation. In particular, given increasing evidence of climate-related mental health and well-being challenges, adaptation efforts require further attention and co-ordination among key stakeholders and governments.

4.5. Monitoring, forecasting and foresight of climate risks

4.5.1. Monitoring and forecasting of climate risks

Strategic approaches to adaptation and resilience of education systems require robust monitoring and forecasting of climate risks. Monitoring can be defined as an ongoing process of observing and tracking changes over time. In the context of climate change, this involves the continuous observation and measurement of environmental variables to detect and understand changes in climate patterns (Noltze et al., 2021[227]). On the other hand, forecasting makes predictions about future events based on current and historical data. In practice, monitoring and forecasting of climate risks often occur simultaneously. They support decision making and assist countries in formulating climate adaptation strategies to safeguard their societies, including education systems, and to enable countries to reduce disaster losses from extreme weather events.

For instance, France has set up the National Centre for Meteorological Research, which is a joint research unit between the French National Centre for Scientific Research and Météo France (CNRM, 2023[228]). The centre models risks of climate change events and provides technical advice for climate change adaptation. A similar institution is the Centre for Climate Change adaptation in Japan (CCCA, 2023[229]). The institution promotes the development of platforms for information related to the impacts of and adaptation to climate change. It also provides technical advice for adaptation planning.

However, little information is available on the extent to which education policy is integrating these monitoring approaches into the process of adapting their education systems. An interesting example comes from the United Kingdom. Since 2023, the National Adaptation Programme (NAP) has mandated the Department for Education to perform yearly evaluations of climate-related risks. The objective of these assessments is to identify school settings that are most vulnerable to climate risks and subsequently to provide guidance on climate risk mitigation strategies. Schools also need to develop Climate Action Plans to protect learners from climate risk (Greater London Authority, 2023[153]).

Furthermore, education systems can rely on various international resources to analyse climate-related risks and build resilience. Several international organisations have focused on identifying and addressing risks for education systems. Table 4 offers an overview of a range of available resources. By prioritising disaster risk reduction, safety measures and capacity building, various international organisations are working towards ensuring a sustainable and secure future for education in the face of an evolving climate. Most programmes offer policy guidance and provide information on different adaptation strategies.

Table 4. Examples of international approaches to risk assessment and mitigation

Institution	Details	Key tasks
UNESCO	UNESCO International Institute for Educational Planning (UNESCO-IIEP) (UNESCO, 2023[230]).	• Crisis sensitive planning (CSP) to identify and analyse the risks posed by conflict and natural hazards to education. • Policy briefs, reports, technical assistance and capacity development programs.
	Chair on intersectoral safety for disaster risk reduction (University of Udine) (UNESCO, 2023[230]).	• Policies for effective risk management. • Multi-hazard assessments and capacity building.
	Chair on Disaster Risk Reduction & Resilience Engineering (University College London) (UNESCO, 2023[230]).	• Methods to assess and mitigate the risk of damage posed by natural hazards.
UNICEF	Worldwide Initiative for Safe Schools (WISS).	• Global partnership seeking to secure political commitment and to foster the implementation of a comprehensive school safety framework.
UNFCCC	United Nations Framework Convention on Climate Change (UNFCCC, 2023[231]).	• Information on climate adaptation measurements implemented by different stakeholders.
IANNEE	Inter-Agency Network for Education in Emergencies (Inter-agency Network for Education in Emergencies, 2023[232]).	• Educational assistance to children and youth affected by climate-induced disasters and conflict.
World Bank	Global Program for Safer Schools (GPSS).	• Knowledge and tools for large-scale investments into safer schools' infrastructure. • Provision of technical advice to countries developing school infrastructure.

Other international resources offer tools for localised risk analysis. For instance, the Intergovernmental Panel on Climate Change (IPCC) publishes an "Interactive Atlas" that allows users to analyse the observed and projected climate change implications on different regions in the world, such as temperature or sea-level rise. A strand of work from UNICEF examines the current and future climate risks for children in different countries (UNICEF, 2021[233]). Based on this, UNICEF developed a Children's Climate RISK Index (CCRI), a comprehensive tool that reveals how climate and environmental shocks, such as cyclones and heatwaves, affect children's vulnerability across different countries.

A recent OECD report analyses urgent issues of climate-related losses and damages and explores how climate change may play out in different geographies, over time, and focuses on slow-onset changes such as sea-level rise or extreme events including heatwaves, extreme rainfall, and drought (OECD, 2021[161]). The report explores approaches to reduce and manage risks with a focus on policy action, finance and the role of technology in supporting effective risk governance processes. Another report from the OECD investigates climate risks faced by non-OECD countries, such as India, Indonesia or Saudi Arabia (Maes et al., 2022[234]). The report specifically attempts to comprehend the potential impact of climate-related natural hazards by assessing the exposure of people and assets to these hazards.

In addition, the OECD's Centre for Entrepreneurship, SMEs, Regions, and Cities has collected data on climate hazards faced by countries and regions. This data contains information about climate risks related to coastal flooding, drought, extreme precipitation, extreme temperature, wildfire, and river flooding. It is usually provided at the regional level for each country, allowing to compare regions within a country and across countries. The data spans the time period from 2000 to 2022 (OECD, 2023[235]).

Nonetheless, challenges remain in drawing from these various monitoring and forecasting systems to understand localised risks and to integrate these into sectoral education policy

planning to implement adaptation strategies. Further research linking climate risk assessments to education planning would be helpful in strengthening the international knowledge base on effective approaches to making education systems more climate resilient.

4.5.2. Foresight of climate risks and education systems

Engaging in strategic foresight is as important as the monitoring and forecasting of climate risks. Strategic foresight involves the structured consideration of ideas about the future to identify ways to make better decisions in the present (OECD, 2020[236]). The main idea behind strategic foresight is that our ability to predict the future is limited, but nevertheless it is possible to make wise policy decisions by imaging and using multiple future scenarios to test our assumptions and future-proof existing plans (ibid.).

In this sense, strategic foresight does not aim to predict a single, most likely future. Instead, it facilitates the exploration of a spectrum of possible futures. This approach facilitates the anticipation of risks and the exploration of related policy challenges and opportunities. Foresight serves as a bridge connecting different policy domains, fostering public awareness and encouraging participation. In essence, it is a tool for preparing today's strategies to cope with the long-term uncertainties of tomorrow.

Strategic foresight offers several tools. These include scanning the horizon for emerging signals of change in current trends and constructing visions of a desired future to trace back the steps that would be required to realise them. Discussing multiple scenarios can reveal desirable futures, but also potential shocks and surprises societies are currently not prepared for, both of which can be used to act in the present to stress-test current strategies and to plan for potential contingencies (OECD, 2020[236]).

Strategic foresight sets itself apart from the conventional methods of monitoring and forecasting climate risks. It is unique in its ability to anticipate future uncertainties, particularly those that are highly unlikely to surface when relying solely on trying to predict what is most likely to happen (OECD, Forthcoming 2024[237]). Rather than merely extending current trends, foresight challenges decision-makers to contemplate their adaptation strategies for potential drastic shifts and their cascading effects on social systems.

Several governments across the OECD have invested in developing a foresight infrastructure to inform policy making. For example, the government of the United Kingdom has commissioned a project known as the “Net Zero Society” (Government Office for Science, 2023[238]). This project investigates how societal transformations could influence the country’s journey towards achieving net zero emissions by 2050. The report presents four scenarios, each depicting a different version of the British society in 2050, and examines their potential impacts on energy demand, costs and the benefits of achieving net zero emissions. The four scenarios differ with regard to economic growth and institutional trust. The report does not provide specific policy recommendations, but instead offers insights and tools that policymakers and other stakeholders can use to plan for these various potential futures.

In Canada, Policy Horizons Canada, the Government of Canada’s centre of excellence in foresight, supports the federal government in developing stronger policies and programmes in the face of an uncertain future (Government of Canada, 2023[239]). The organisation has the mandate to develop robust and resilient future-oriented policies, also with regard to disruptive climate change. Policy Horizons Canada publishes a variety of reports discussing potential future scenarios, for example relating to the future of work, the future of generative artificial intelligence or global existential threats.

In addition, Finland has implemented several foresight measures to prepare for the uncertainties the future may bring (Prime Ministers Office, 2023[240]). The foresight activities aim to support decision making by creating a shared understanding of the changes that lie ahead. One of the key initiatives is the "Government Report on the Future", that is submitted to the Parliament during each electoral term. The report identifies future issues that require particular attention by policymakers. For instance, the report presents three distinct scenarios how the future may unfold with regard to climate change. The scenarios differ with regard to climate policies being implemented, extreme weather events and social justice.

The OECD supports member countries with their strategic foresight in several ways. The Strategic Foresight Unit, situated within the Office of the Secretary-General, collaborates with governments and organisations worldwide to address diverse strategic challenges. Efforts include supporting governments, enhancing OECD initiatives and preparing the organisation for the future. For example, in the context of the OECD's Horizontal Project on Climate and Economic Resilience (Net Zero+), the Strategic Foresight Unit created a toolkit assisting users to develop and stress-test public policy goals across various potential futures. The toolkit offers a practical methodology to bolster policy resilience in the face of future uncertainties and a set of scenarios, many of which focus on possible environmental developments (OECD, Forthcoming 2024[237]).

Meanwhile, the OECD's Centre for Educational Research and Innovation (CERI) has long supported strategic thinking in education through foresight methods. Since 2008, its "Trends Shaping Education" report has provided key data and analysis on global trends and their potential impact on education (OECD, 2022[241]). The series has further offered suggestions on how current trends could shift based on emerging evidence or "weak signals" of change, and consistently asked "big picture" questions with respect to what education can do to address trends such as environmental degradation. Complementing this work, CERI released four scenarios for the future of schooling in 2020. This set of speculative futures invites education stakeholders to consider fundamental transformations to what society currently expects of education, and to reflect on the potential effects that such changes would have on the organisational structures of schooling, the teaching workforce and education governance more generally (OECD, 2020[236]).

Overall, it is yet to be determined to what degree education stakeholders integrate foresight into their long-term strategic planning. Nevertheless, this section underscored the increasing significance of doing so to prepare education systems for addressing the ramifications of various climate scenarios.

4.6. Conclusion and scope for future work

Given the extent to which climate change is already impacting on students' learning experiences and will increasingly do so, it is key to include an explicit focus on adaptation and resilience in environmental, sustainability and climate change education approaches. This is not a matter of choosing between climate change mitigation and adaptation. Previous OECD work suggests that there is no dichotomy between actions to enable transitions and those to address climate risks and build resilience, but that policies can be designed to recognise mitigation-adaptation linkages, leverage synergies, and minimise trade-offs (OECD, 2022[141]). Nature-based solutions, which are described above, are a case in point, as they can contribute both to mitigating climate change and adapting to climate hazards. As highlighted in this section, they also offer benefits for student health, well-being and learning.

Future work could focus on exploring how education systems can move towards adaptation and resilience strategies without reducing attention to addressing the causes of climate change. Results from the OECD's 2024 Teaching and Learning International Survey (TALIS) will offer relevant data allowing to analyse the interplay of school-level adaptation policies and pedagogical strategies. This will include data on the knowledge of teachers and school principals about climate change and digital teaching, as well as the extent to which school principals shape the school's environmental sustainability practices and ecological footprint, e.g. by installing cooling systems or conserving energy and water. This will allow for cross-country and cross-regional analysis of the degree to which schools are adapting their infrastructure as well as their teaching approaches in the context of climate change.

In terms of education system resilience, future work could help mobilise OECD climate monitoring, forecasting and foresight expertise for education policy making. For example, OECD data on the climate risks faced by different countries and regions can be used to group countries and regions facing similar risks, review evidence on the effectiveness of different adaptation policies and promote peer learning among countries facing similar challenges. In addition, scenarios developed by the OECD and other organisations, as well as the OECD's work on the future of schooling (OECD, 2022[241]; OECD, 2020[236]), can be brought together and be adapted to inform strategic thinking in countries on the implications of various possible futures on education systems and explore effective responses.

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Annex A. Scoping OECD work on education and climate change

In their Declaration on Building Equitable Societies Through Education in 2022, OECD Education Ministers called on the OECD's Education Policy Committee (EDPC) and other OECD Committees to support countries in "fostering environmental sustainability through education" and in "building a new vision for skills development that supports the transition of societies to net-zero carbon emissions". In response to this request, in 2023, The OECD's Directorate for Education and Skills organised a set of horizontal workshops bringing together analysts from different OECD Directorates to:

- take stock of findings on education and climate change from across different projects in the Directorate for Education and Skills,
- integrate multi-disciplinary research from different sectors and Directorates to rethink the role of education in reaching climate goals, and
- mobilise foresight expertise to explore potential future disruptions and the challenges and opportunities these may present for future work in this area.

Annex B offers an overview of completed, ongoing and upcoming projects in the Directorate for Education and Skills that consider themes relevant to environmental, climate change and sustainability education. Taken together, the findings from these projects offer a good knowledge base and starting point for strategic work on education and climate change.

The first multi-disciplinary workshop in June 2023 aimed to develop a holistic picture of the various behavioural, technological and socio-economic spheres in which education can contribute to impactful social change. It explored state-of-the-art research on climate tipping points, needed adaptation measures and promising approaches to climate change mitigation, including in the social, economic and technological spheres. Building on input from the Environment Directorate (ENV) on climate tipping points, from the Directorate for Science, Technology and Innovation (STI) on the role of science in addressing climate change, and from the Centre for Entrepreneurship, SMEs, Regions and Cities (CFE) on the power of territorial approaches in climate action strategies, participants from the Education Directorate engaged in interactive discussions to reflect on the implications of these developments for education, and identify ways in which the Directorate can support countries' efforts in enhancing education strategies for a sustainable future.

The second workshop in September 2023 focussed on strategic foresight and aimed to stress-test potential education system approaches to addressing climate change and consider ways to anticipate, prepare for, and adapt to changes over the years and decades ahead. While climate change is certainly the most daunting of the challenges facing societies in the 21st century, the climate crisis is not happening in isolation. It interacts in often unexpected ways with other megatrends such as advancements in Artificial Intelligence (AI) and unforeseen geopolitical dynamics. The workshop therefore engaged participants in exploring several possible disruptions that could radically alter the environmental, economic and education policy landscape in the coming decades, and discussing the possible action steps education systems could take to be better prepared for these possible futures. The workshop was structured around the OECD's Strategic Foresight Toolkit (OECD, Forthcoming 2024[237]), which presents twenty-five possible disruptions that could drastically change the ability of governments and organisations to meet their current climate and environmental commitments. Eight of these disruptions were chosen for the workshop to stimulate reflection about possible education futures. In

collaboration with colleagues from the OECD's Strategic Foresight Unit (SFU), the scenarios were adapted to include key questions for education systems to consider. The objective of the exercise was not to try and predict the future but to help explore a wide range of possible futures and sharpen the assumptions underlying current strategies, anticipating how these might be exposed by various disruptions.

Annex B. Existing work of the OECD's Directorate for Education and Skills related to education and climate change

Completed

- **Curriculum mapping.** In 2019, the OECD's Future of Education and Skills 2030 project collected information from 37 countries on whether literacy for sustainable development was included as a cross-curriculum theme in intended curricula at the jurisdiction level. It also collected more in-depth information from 15 jurisdictions on how the theme was embedded into the curricula various school subjects. The results from the curriculum analysis were included in a 2020 report (OECD, 2020[43]).
- **Student learning outcomes in science and global competence.** In its 2006 and 2015 assessment rounds, the OECD's Programme for International Student Assessment (PISA) focused on science as its major domain. The results from these assessments include insights into students' proficiency in environmental science and student attitudes towards environmental issues. In addition, in PISA 2018, 26 countries and economies (of which 12 OECD countries) participated in an optional "global competence" assessment, which included measures of students' global sustainability competence. The results from these assessments were brought together in a 2022 report on students' readiness to take on environmental challenges (OECD, 2022[2]).
- **Video examples and lesson plans for teachers.** In 2021, OECD, UNESCO and Education International ran the Teaching for Climate Action Initiative, which gathered videos from teachers around the world on the approaches they used to help students act and lead on climate matters. Overall, about 850 teachers from 157 countries shared their climate initiatives and participated in five global dialogues on teaching for climate action together with their peers, teacher educators, school leaders, organisations and climate experts. In addition, the OECD-CERI project Fostering and Assessing Creativity and Critical Thinking Skills in Education developed a bank of lesson plans with a focus on creativity and critical thinking in different subjects areas, including a set of lesson plans for climate change education as part of science teaching.

Ongoing 2023/24

- **Policy frameworks.** The OECD Education Policy Outlook is an analytical observatory that monitors the evolution of education policy priorities and developments. Its 2023 edition analyses data collected on countries' policy landscapes, including how sustainability compares to other priorities for education ministries over the short and mid-term (OECD, 2023[15]). The report also investigates education systems' frameworks for sustainability, and the extent to which they provide all learners with experiences to shape the green economy; translate learners' environmental awareness into action; and position education as a critical sector for a sustainable society.
- **The role of higher education.** The OECD has joined efforts with the European Commission (EC) to develop an Education and Innovation Practice Community (EIPC). The project aims to understand better how higher education institutions (HEIs) can contribute to developing competencies for innovation, with a specific

focus on the competencies needed to shape and adapt to the digital and green transitions. It examines how HEIs can help develop such competencies at a foundational level school education (e.g. through curriculum design and support for teachers and school leaders) as well as in mainstream higher education and upskilling and reskilling. It has also reflected with governments on system-level support for strengthening higher education school partnerships, and examines how higher education institutions can integrate competencies for innovation into their curricula.

- **Teacher professionalism and cross-sectoral partnerships.** The ongoing multi-national stakeholder study on New Professionalism and the Future of Teaching aims to anticipate the medium- and long-term in teacher professionalism and empowerment. One of its focus areas is on building partnerships with the broader society, including sustainability actors. The project developed an ambition loops framework in which schools are conceptualised as possible anchor institutions to connect different parts of a community to achieve social benefits.
- **Career guidance.** A working paper is being developed by the OECD Directorate for Education and Skills' career guidance team on career guidance for the green economy, with publication scheduled for 2024.

Forthcoming 2025/26

- **Teaching and Learning International Survey.** The OECD's Teaching and Learning International Survey (TALIS) 2024 will collect a rich set of internationally comparable indicators on teachers' engagement with environmental and sustainability education and climate change education. This will offer information on different aspects of teachers' engagement with these topics, including their attitudes towards sustainability and climate education, their attitudes towards climate change itself (such as their level of concern), their professional opportunities to learn about climate change, and the barriers they experience to teaching about climate change. TALIS also includes a principal questionnaire and collects information on actions taken by principals to adapting school infrastructure in the context of climate change. Once collected, the data will allow policymakers to evaluate different characteristics of teachers and teaching related to climate change and sustainability. The initial report from TALIS 2024 will be released in October 2025 and a dedicated report on teachers' engagement with environmental, sustainability and climate change education will follow in 2026.
- **Programme for International Student Assessment.** The 2025 round of the OECD's Programme for International Student Assessment (PISA) will again focus on science as its major domain. The PISA 2025 Science Framework (White et al., 2023[13]), which was published in June 2023, includes an ambitious environmental science framework to measure students' Agency in the Anthropocene, which comprises: their ability to explain the impact of human interactions with Earth's systems; their capacity to make informed decisions to act based on evaluation of diverse sources of evidence; and creative and system thinking. The Science Framework overall focusses not just on foundational competencies for future science careers but also on broader student competencies to navigate and play an active role in tackling societal challenges, such as climate change. The initial report from PISA 2025 will be released in 2026.