

Climate Change Education for Carbon Mitigation and Environmental Justice

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TABLE OF CONTENTS

Acknowledgements.....	ii
Table of Contents.....	iii
List of Figures.....	iv
Abstract of Thesis.....	v
Introduction.....	1
Chapter 1: Climate Change Background.....	6
Chapter 2: Environmental Justice Movements.....	14
Chapter 3: Education and Global Sustainability.....	20
Chapter 4: Current State of Climate Change Education.....	24
Chapter 5: Carbon Mitigation Potential of Climate Change Education	33
Chapter 6: Best Practices for Climate Change Education	38
Chapter 7: Education for Environmental Justice	48
Conclusions and Next Steps.....	57
References	61

LIST OF FIGURES

Figure 1.: Observed and projected changes in global surface temperature.....	2
Figure 2.: Attribution of observed physical climate changes to human influence.....	3
Figure 3.: Emissions scenarios for the Representative Concentration Pathways	7
Figure 4.: Projected changes in global average temperature in 2100.....	8
Figure 5.: United Nations Six Sector Solution for carbon mitigation.....	10
Figure 6.: Project Drawdown most effective carbon mitigation solutions.....	11
Figure 7.: United Nations Sustainable Development Goals.....	20
Figure 8.: Industries and organizations involved with modifying national curriculum	30
Figure 9.: Climate change concern levels by country.....	31
Figure 10: Carbon mitigation potential of various carbon reduction technologies	34
Figure 11.: Climate change concern scores of parents before and after intervention	36
Figure 12.: Examples of stakeholder roles and questions in a case study program.....	42
Figure 13.: Framework for environmental justice in exposure science.....	51
Figure 14.: Application of the Environmental Health Literacy Triangle.....	53
Figure 15.: A model for youth-led environmental justice action and positive feedback loops...	55

Abstract of the Thesis

Climate change is the most significant environmental threat to current and future generations, and to mitigate its impacts, a drastic shift is needed in the way energy, materials, and natural resources are used. While advancements in clean energy, energy efficiency, and carbon sequestration will all have a crucial role in climate change mitigation, these sectors do not address the societal shift that is needed for these advancements to be successfully implemented. Climate change education is a powerful tool to accomplish this and is severely lacking in the United States and around the world. This education can have impacts beyond generating public support for climate change policies, including decreasing individual carbon emissions and fostering more pro-environmental attitudes and behaviors. However, the way in which climate change education is implemented and taught will impact the carbon reduction potential it has.

Common themes are identified across successful climate education programs, including variables of ownership, empowerment, and personal relevance that are key to changing behavior and decision-making, as well as engaging teaching methods and project-based learning that prepares students to take action in their communities. Climate change education is also a powerful tool to support environmental justice, particularly grassroots and community-led movements that will lead to improved environmental and human health and reduced emissions, as well as contribute to global environmental justice movements. The interest in climate change education is growing globally, as awareness of climate change impacts and solutions also grows, and research increasingly links climate change education to positive behavior changes. A successful and comprehensive global education model will have cascading impacts on awareness and actions of generations to come, and can drastically improve climate change outcomes.

Introduction

Over 30 years ago at the signing and adoption of the United Nations Framework Convention on Climate Change, or the UNFCCC, in 1992, the global community knew: “Education is an essential element for mounting an adequate global response to climate change,” (UNFCCC, 1992). Despite the acknowledged importance of education in addressing climate change, it often receives little attention in discussions of major climate solutions today. Conversations about addressing climate change typically focus on carbon mitigation and climate adaptation strategies, both of which rely on having a population that is well-informed and educated on these issues (Monroe et al., 2017). Successful transitions to clean energy and more sustainable resource use rely on government action on a global scale, and the decisions made by citizens and governments today and in the coming decades will determine what the global climate will look like far into the future (IPCC, 2023). Government action is essential to accelerate the necessary shifts towards sustainable and climate-resilient development, which must also include equity and justice considerations (Reckien et al., 2017).

Different emissions scenarios show vastly different levels of global temperature change in the future, which will have varying degrees of harm to human and ecosystem health. According to the most recent report from the Intergovernmental Panel on Climate Change (IPCC), without rapid collective action, such as a 45% decrease in global carbon emissions by 2030, climate change will have catastrophic consequences (IPCC, 2023). These consequences include sea level rise of 0.76 meters or more, which will cause devastating loss of land and flooding of island nations, and increased intensity of extreme weather events that will cause trillions of dollars in damage, as well as the loss of human life. The extent of these impacts depends on future emissions scenarios, determined by actions in the near future.

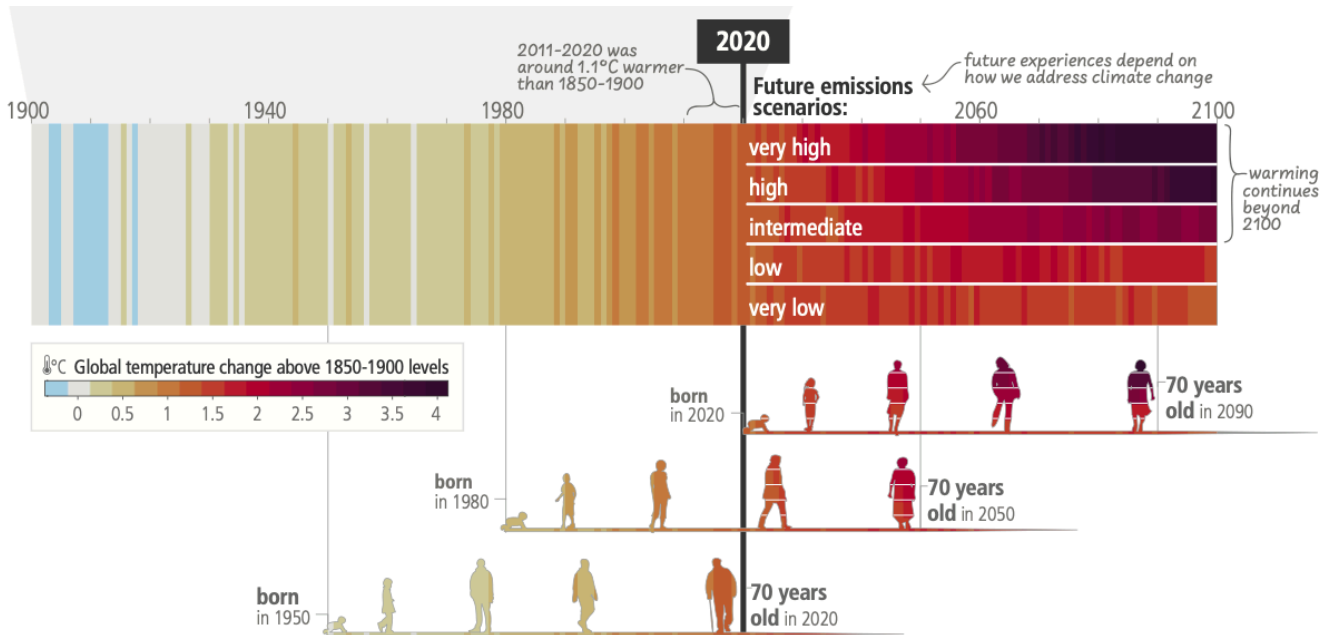


Figure 1. Observed (1900–2020) and projected (2021–2100) changes in global surface temperature (relative to 1850–1900). This shows how the climate has already changed and will change along the lifespan of three representative generations (born in 1950, 1980 and 2020). Future projections (2021–2100) of changes in global surface temperature are shown for very low, low, intermediate, high, and very high GHG emissions scenarios (IPCC Sixth Assessment Report, 2023).

The youngest generations currently have the least ability to take action or shape climate change policies, yet they will be dealing with the most severe impacts of climate change (Barford et al., 2021). Widespread transitions in the coming years away from fossil fuels and towards clean energy, carbon removal, and preserving natural resources and biodiversity, will determine the health of the planet for future generations (IPCC, 2023). Although it can be difficult to predict exactly how severe future impacts of climate change will be, there is scientific consensus that already observed changes to environments across the globe can be attributed to human influence.

Attribution of observed physical climate changes to human influence:

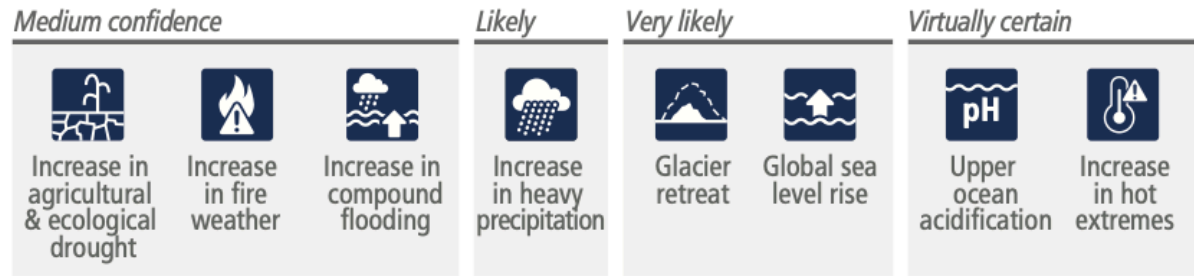


Figure 2. Observed impacts are connected to physical climate changes including may that have been attributed to human influence, as the selected climatic impact-drivers shown. Confidence and likelihood levels reflect the assessment of attribution of the observed climatic impact-driver to human influence. (IPCC Sixth Assessment Report, 2023).

Despite impacts already being seen around the world, government action has yet to catch up to the level of change needed to mitigate the most extreme climate change impacts (UNFCCC, 2022). Governments frequently prioritize short-term economic concerns over long-term environmental issues, especially when there are more pressing issues like war, global pandemics, and poverty. Implementing climate change policies requires large investments in renewable energy and infrastructure updates, and decreasing investments in fossil fuels, which could disrupt key economic industries. Politicians also sometimes fear backlash from voters or powerful industries if they advocate for policies that could potentially harm the economy in the short term. Despite significant impacts already being seen around the world, levels of concern over climate change do not match the severity of future consequences (Lawson et al., 2019). Only 41% of adults in the United States believe that climate change is currently harming people, and only 51% of adults worldwide (Wike, 2016). One contributing factor is that many adults believe there is uncertainty about climate change causes and impacts in the scientific community, or that climate change will not effect them in the future. 28% of adults in the United States believe that the impacts of climate change will only be felt by developing countries (Leiserowitz

et al., 2019). This shows a significant issue with a gap in climate change knowledge and concern, because levels of climate change concern are a very strong predictor of individual and societal climate change action (Hornsey, 2016). In many political environments, like in the United States, climate change can be seen as a political issue, and political ideology can influence perceptions of climate change information (Hamilton, 2011). Additionally, fossil fuel industries and other powerful interest groups lobby governments to prevent climate change action. These industries can fund political campaigns, influence policymakers, and spread misinformation to protect their own financial interests (Basseches et al., 2022). As a result, many elected officials, such as in the United States, can be reluctant to implement policies that could threaten these industries or their support base. Some governments may also fear that taking unilateral action on climate change could put them at a competitive disadvantage economically if other countries do not follow suit (Basseches et al., 2022). To address these obstacles to government action, a widespread societal shift is needed in perceptions and attitudes about climate change to generate more public concern and apply pressure for these changes to be made. Education is one of the most powerful tools available to drive this shift, particularly climate change education that focuses not on just natural science, but ideas of global sustainability and solutions for carbon mitigation (Monroe et al., 2017). Environmental and climate change-specific education is also a powerful catalyst for environmental justice, from increasing awareness of global environmental justice movements to facilitating grassroots movements on the local scale (Kearns, 2014).

Research Goals

Despite the enormous potential of education to facilitate positive environmental change and climate change mitigation, there is a lack of research into the best practices and the outcomes of climate change education interventions. Case studies have outlined different education strategies and their short-term impacts on attitudes and behavior changes, however, many of these examples are anecdotal and do not consider long-term impacts on a larger scale.

Additionally, the majority of research and pilot projects focused on climate change education are from the United States and other wealthy countries, however, this education is even more critical in developing countries that are more vulnerable to climate change impacts. To develop and utilize the full potential of environmental and climate change education to mitigate climate change and support environmental justice worldwide, there is a significant need for further resources invested into this field of research, including more global perspectives and programs that incorporate diverse methods of teaching. Through a comprehensive literature review of existing research and case studies, I identify common themes across existing climate and environmental education programs, as well as the quantifiable benefits of these programs. I outline the current state of climate change education in the United States and around the world based on available information, and highlight the need for and the potential of widespread climate change education. With increased awareness about the positive impacts of climate change education, there will be increased support for these programs through funding and prioritizing future studies, building on established best practices. This research has been conducted with the hope that climate change education will increasingly become part of mainstream discussions of climate change solutions, from the local to the international scale, including incorporation into international climate policy agreements.

Chapter 1: Climate Change Background

According to the Fourth National Climate Assessment, there are different future possibilities of global emissions levels and associated climate change, called Representative Concentration Pathways (RCPs), and the actions taken by governments in the next few decades will determine which pathway is reached in the future (IPCC, 2022). Each pathway represents a different scenario based on levels of policy change and action in areas including renewable energy, transportation, and new carbon capture technologies, as well as uncertainties in how natural systems will respond (Jubb et al., 2013). While there are ranges of uncertainties for natural factors, such as how much global sea level will rise in response to temperature increases, there is much more uncertainty in how human systems will respond. Depending on changes in economic policies, technology, and human lifestyles, projected future emissions can range from very high concentrations of carbon dioxide and other greenhouse gasses in the atmosphere, as in RCP 8.6, to very low concentrations as in RCP 2.6, with the number values representing concentrations in parts per million (Jubb et al., 2013).

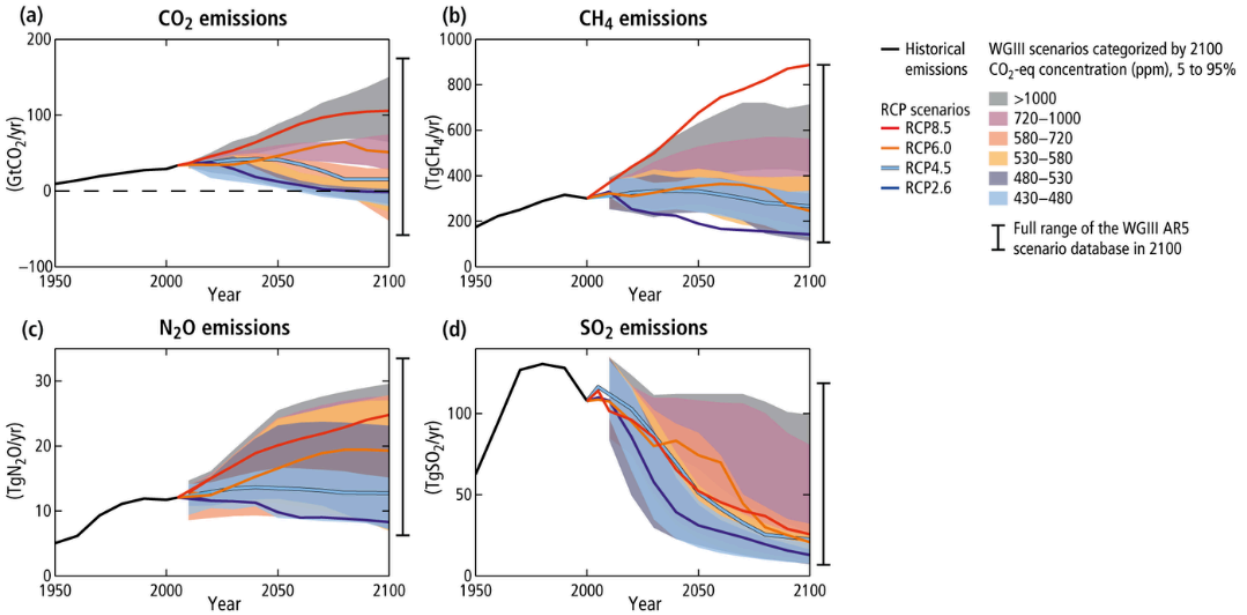


Figure 3. Emissions scenarios and resulting radiative forcing levels for the Representative Concentration Pathways. Panels (a) to (d) show the emissions of carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and sulfur dioxide (SO₂) (IPCC Fifth Assessment Report, 2014).

The majority of these greenhouse gas emissions are happening on the industrial scale, but widespread changes in behavior on a societal scale can impact the production of these industries. For example, replacing 20% of global beef consumption, an industry responsible for a significant amount of methane (CH₄) emissions, with a plant-based alternative, could reduce methane emissions by up to 11%, as well as cut carbon dioxide emissions from livestock-related deforestation in half. (Guglielmi, 2022). If 50% of beef consumption was substituted with plant protein, carbon emissions and associated deforestation would drop by up to 80% (Guglielmi, 2022). It is clear that significant enough changes in the actions of society can have tangible impacts on greenhouse gas emissions, and this may be an essential tool to mitigate climate change while government action is catching up. Even under the most rapid emissions reduction scenario, RCP 2.6, billions of people will be living in an entirely new climate by 2050, and under a business-as-usual emissions scenario, by 2050 over 5 billion people will be exposed to at least

one month of life-threatening heat conditions each year (Kommenda, 2023). This number is currently at 1 billion people, and there have already been devastating losses of life after extreme heat wave events in countries around the world. Each year, more than five million people are estimated to die from extreme heat or cold conditions (Kommenda, 2023). Under a high emissions scenario, high or low temperature events will be even more devastating in the future.

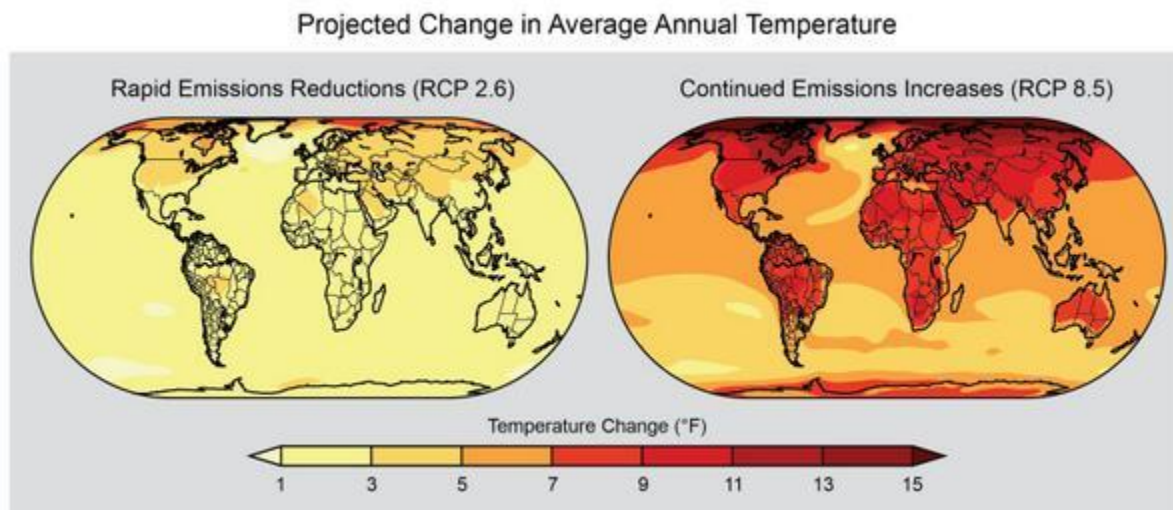


Figure 4. Map of mean results for different greenhouse gas concentration scenarios of annual mean surface temperature change in 2081– 2100. (IPCC Fifth Assessment Report, 2014).

Current data on global emissions, as well as projected future emissions based on countries' commitments to emission reductions, indicate that even under the lowest emissions concentration pathway, RCP 2.6, average global warming is still expected to reach at least 1.5 degrees Celsius (IPCC, 2023). By 2050, billions of people will be living in a new climate. Under the highest emissions scenario, RCP 8.6, warming can reach up to 4.4 degrees Celsius, which would have devastating impacts worldwide. Current observed warming of 1.1 degrees has caused widespread and rapid changes in every natural system, in the atmosphere, oceans, biosphere, and cryosphere (IPCC, 2023). Future increased warming will without a doubt amplify sea level rise, extreme weather including heat waves, droughts, and flooding, and irreversible loss of

biodiversity and vulnerable ecosystems. More than 3.3 billion people currently live in areas that are highly vulnerable to climate change, resulting in food and water insecurity and forced displacement that will only be exacerbated in the future (IPCC, 2023). Over 1 billion people may be displaced by 2050 due to climate change related impacts including natural disasters, droughts, and food shortages (Henley, 2020). Many of the countries at highest risk from climate change threats are also predicted to have large increases in populations in the next 30 years, which will result in higher levels of mass displacement, also posing a threat to global security (Henley, 2020). The current impacts of climate change exacerbating inequality and food and water insecurity will only grow, and make civil unrest and conflict more likely. To protect all forms of life on Earth, urgent action is needed to ensure emissions do not reach higher than a 2 degree increase in temperature (IPCC, 2023).

There are many different industries and pathways to climate change mitigation and adaptation. Mitigation involves actions that work to directly reduce the amount of greenhouse gasses in the atmosphere, either through reducing emissions through policy changes and improvements in technology, or directly removing carbon from the atmosphere with natural or engineered methods (Zimmerman & Farris, 2017). There are many options for carbon mitigation that are becoming increasingly cost-effective and politically feasible. These options include solar and wind energy, electrification of transportation and other energy systems, increased energy efficiency, and improved management of forests, as well as agricultural and food industries (IPCC, 2023). The United Nations has proposed a roadmap to limiting emissions with a six-sector solution that would reduce carbon emissions by the necessary 30 gigatons to limit warming below 1.5 degrees Celsius, involving implementing already existing technology across six different industry sectors including energy and industrial energy use, improving agricultural

land management and supporting nature-based solutions, and creating greener buildings, cities, and forms of transportation (United Nations Environmental Programme, 2023).

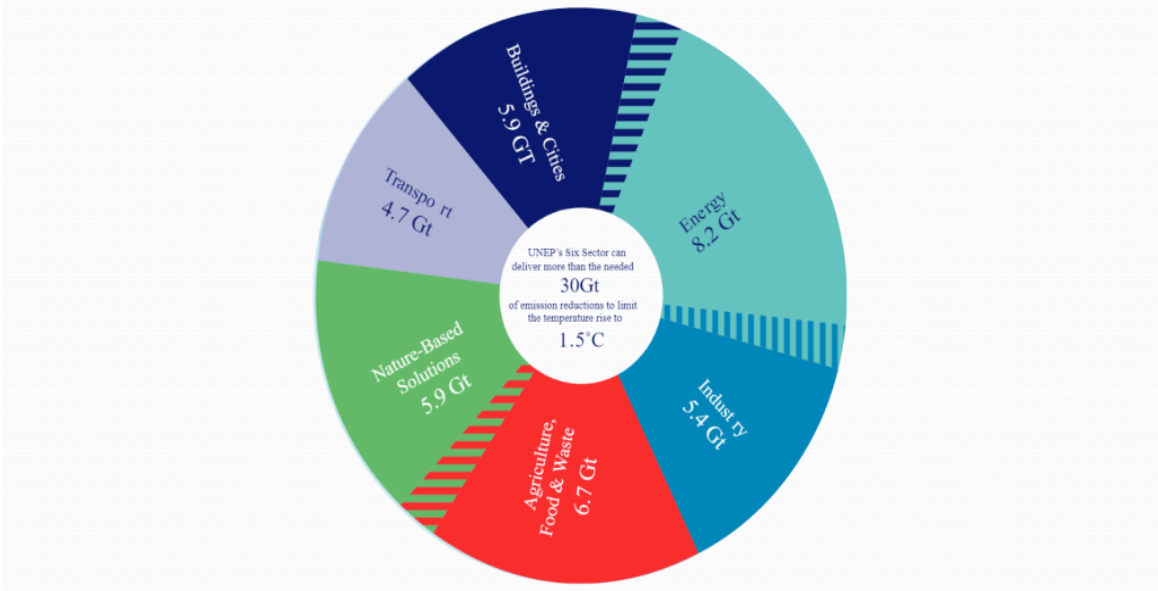


Figure 5. The six-sector solution proposed by the United Nations based on data from the 2023 IPCC Synthesis Report shows projected carbon reductions by industry (UNEP, 2023).

In the last decade, there have been significant improvements in many of these mitigation strategies, such as an 85% decrease in the per-unit cost of solar energy, a 55% decrease in the cost of wind energy, and an increase in the deployment of electric vehicles by a factor of almost one hundred (IPCC, 2023). There have been numerous policy tools that facilitate the improvement of these mitigation pathways, including increased government funding for research and development, and subsidies for purchasing electric vehicles or making energy-efficiency improvements, and these tools should continue to be implemented on a larger scale. Expanding on this, Project Drawdown has identified more than 80 technologies and practices that will be the most effective solutions to reduce carbon emissions and mitigate climate change (Hawken 2018).

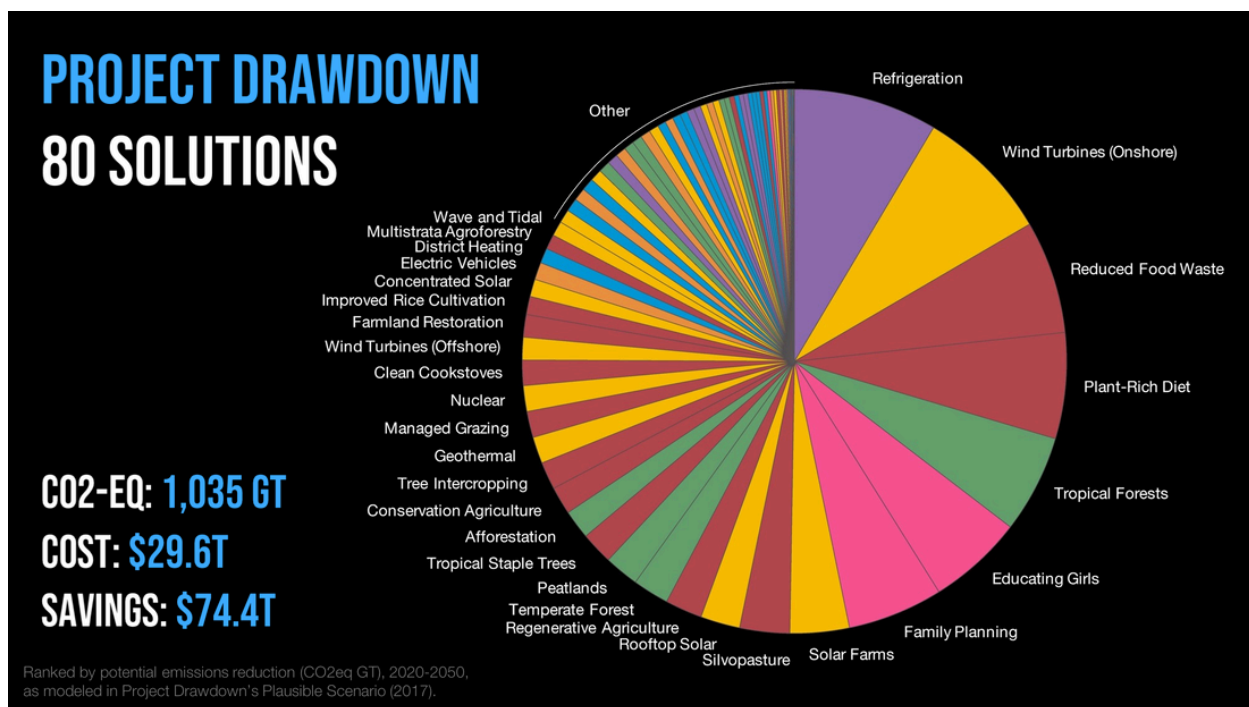


Figure 6. The 80 most effective carbon emissions reduction and sequestration solutions, ranked by carbon dioxide reduction potential (Hawken, 2018).

While reducing carbon emissions can decrease the severity of future climate change impacts, there is another, equally necessary shift to prepare for future climate change scenarios. Adaptation involves changing infrastructure and systems so they are more resilient to climate change impacts and projected future impacts such as sea level rise, extreme weather events, and temperature shifts (Dolsak & Prakash, 2019). Global government action to reduce emissions or institute other climate change mitigation policies will determine what future impact scenarios societies will have to adapt to, including the loss of human life and biodiversity, so it is essential to use every tool available to mitigate these losses.

There has been significant progress on international climate change action in recent decades. In response to growing awareness of climate change, the United Nations Framework Convention on Climate Change was adopted in 1992, which provided a framework for countries to reduce their greenhouse gas emissions (Kuyper et al., 2018). This was followed by the Kyoto

Protocol in 1997, which required quantification and reduction of greenhouse gas emissions in developed countries. In 2015, the Paris Agreement was adopted, which provides a framework for countries to submit nationally determined contributions (NDCs) to reducing greenhouse gas emissions, as well as facilitates international cooperation on climate change mitigation and adaptation (Kuyper et al., 2018). Each year, the UNFCCC organizes the Conference of Parties, or COP, for the 196 member countries to discuss and negotiate climate policies, monitor progress on greenhouse gas reduction and other climate actions, and make decisions on how to address climate change collectively .

However, climate change action is expensive and often politically charged, and without broad public support the policies that are necessary can be politically infeasible to implement in individual countries. According to a 2020 survey by the Pew Research Center, 65% of Americans believe the federal government is not doing enough to address climate change, and 79% say that the country's priority in terms of energy supply should be generating alternative and renewable sources of energy (Tyson and Kennedy, 2023). This growing public concern and political support can be credited for many recent improvements in U.S. climate policy, such as the recent Inflation Reduction Act of 2022, that will devote more than 368 billion dollars of funding towards clean energy development (Waldholz, 2023). Without widespread public understanding of climate change risks and support of climate action, funding like this would be widely politically unpopular and therefore more infeasible (Dolsak & Prakash, 2019). While this is a groundbreaking step for the second-largest greenhouse gas emitting country, further government action, and therefore further public awareness and pressure, will be required for a sustainable future.

Education surrounding climate change and climate policy is necessary to achieving this awareness and pressure. According to a 2023 survey conducted by the International Monetary Fund, of almost 30,000 people in 28 countries, providing small amounts of information about climate change policies and their benefits creates more support for these policies (Li et al., 2023). Policies such as carbon taxes, or cap and trade, can be very effective at limiting emissions , though are often politically unpopular. Education focused on climate change impacts and the costs of inaction such as decreased health from pollution, and increased extreme weather events, is an effective way to increase public support for these unpopular policies (Anderson, 2012). Increased education and awareness surrounding climate change and its impacts is critical not just for government action, but also for necessary widespread societal shifts in behaviors, resource use, and attitudes towards climate change and the environment. While governments and industries are responsible for the majority of carbon emissions, individual sustainable actions can have significant impacts similar to the carbon mitigation impacts of technologies like electric vehicles and offshore wind energy (Cordero et al., 2020). Widespread climate change education is one of the most powerful and most cost effective tools to reduce carbon emissions and protect future generations, and raising awareness of smaller-scale environmental issues has been proven to facilitate reductions in emissions and positive environmental and social change for decades (Monroe et al., 2017).

Chapter 2: Environmental Justice Movements

Throughout history there are countless examples of public advocacy or community campaigns that were successful in raising awareness and pressuring governments or companies for positive environmental change, with the most well known examples in the United States coinciding with mainstream environmental movements in the 1960s and 1970s (Wilson, 2010). Bringing education on environmental issues to the public has generated increasing awareness and concern about protecting natural resources like healthy air and water, since these concerns began to grow on a national scale. For example, Rachel Carson's 1962 book *Silent Spring*, raised awareness about how pesticides were damaging wildlife and bringing ecosystems to the brink of collapse (Wilson, 2010). This book was a bestseller and led to the complete banning of the most harmful pesticides like DDT in 1972, and is also credited with sparking a larger movement of environmentalism and the eventual creation of the U.S. Environmental Protection Agency in 1970 in response to growing public concern (Kabasenche & Skinner, 2014).

This environmentalism continued to grow and shift into concern about environmental justice. Environmental justice seeks to address disparities in environmental burdens and benefits, also known as environmental 'goods' and 'bads', so that vulnerable communities do not experience a disproportionate amount of environmental 'bads' such as polluted air or water (Mihaylov & Perkins, 2015). Environmental justice also involves equal access to and meaningful involvement with the development and implementation of environmental regulations and policies, to mitigate the unequal distribution of environmental harm.

In 1982, civil rights activists and environmentalists mobilized a sit-in protest against a landfill for toxic substances, polychlorinated biphenyls or PCBs, in Warren County, North Carolina (Wilson, 2010). The protest was unsuccessful in stopping construction of the landfill,

but this event is often referred to as the catalyst for the environmental justice movement in the United States. Starting in 1983, numerous studies were published documenting the link between Black communities and the locations chosen for toxic waste sites and waste incinerators, both of which pollute air, soil, and water with harmful chemicals that negatively impact health.

In 1987, a comprehensive national study conducted by the United Church of Christ Commission on Racial Justice, or the UCC, found a high statistical relationship between the location of hazardous waste sites and the racial and economic makeup of the communities in which they were found (EPA, 2023). At the time, over 15 million African Americans, 8 million Hispanic people, and more than half of the entire population of Asian and Pacific Islanders and Native Americans, lived in communities with at least one toxic waste site (EPA, 2023). This study was the first to raise broad public awareness of the environmental injustices that are connected to marginalized communities, with race being the most significant correlation to the location of toxic waste sites (Mihaylov & Perkins, 2015).

After this landmark study, growing awareness led to numerous other grassroots environmental justice movements, like that of Love Canal in the 1980s and '90s. Residents in this Niagara Falls, New York neighborhood experienced noxious pollution of their air and groundwater, as well as physical symptoms like high rates of asthma, miscarriages, cancers, and other illnesses, as they were unknowingly living on top of a chemical waste disposal site contained around 21,000 tons of toxic wastes (Gill & Mix, 2020). Residents began raising awareness and pressuring the state government for help with relocation and mitigating the environmental damage, resulting in the eventual establishment of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 which included the Superfund Program (Gill & Mix, 2020). This national program to protect communities exposed

to toxic hazards was sparked by a grassroots movement in one small neighborhood. With growing environmental awareness and activism since the 1960's, there are numerous current examples of grassroots-level environmental movements around the world that successfully promote environmental justice or conserve important natural resources (Wilson, 2010). These movements have been growing not just in the United States, but around the world for centuries, since environmental harms started being introduced and inflicted on communities. Indigenous groups have been fighting for environmental justice since the beginning of their forced displacement by colonizers in areas around the world. These groups have been subjected to genocide and forced off their ancestral lands, often for the use or exploitation of these lands by governments or corporations. Today, many are still fighting to maintain or restore their place within these ecosystems under an idea of conservation that removes all human influence from a natural environment and therefore excludes them from their own land (Mihaylov & Perkins, 2015), often with a negative environmental cost. Tribes like the Southern Sierra Miwuk Nation developed forest management practices like traditional burning over their thousands of years living in Yosemite Valley, and when the U.S. government outlawed any burning in the valley, over centuries this has created forests much more vulnerable to wildfires and resulted in devastating fires like the Oak Fire in 2022, which burned around 20,000 acres around Yosemite National Park (Veltman, 2023).

In many natural areas, returning land stewardship and management to indigenous groups with centuries of cultural knowledge is the best way to preserve these ecosystems and mitigate losses of biodiversity brought on by climate change impacts. Although indigenous people make up less than 5% of the world's population, they are responsible for protecting 80% of the world's biodiversity (Raygorodetsky, 2018).

Efforts by the indigenous peoples of the Amazon have led to the preservation of species-rich forests and rivers that are made healthier by the stewardship of tribes. This stewardship is at risk around the world, with countries wanting to develop indigenous land for natural resources like oil development or lumber or mineral extraction. Protecting the role of indigenous peoples worldwide is critical to protecting ecosystems and mitigating climate change impacts (Raygorodetsky, 2018). Indigenous communities are also leading resistance of development of natural areas worldwide. For example, in the United States and Canada, leaders of the Gwich'in Nation have been fighting to protect the Arctic National Wildlife Refuge from oil drilling since the 1980s, turning the debate from a purely conservation one to one focused on environmental justice and their human rights (Dunaway, 2021). Indigenous peoples here led education campaigns to raise public awareness and pressure on Congress to protect these lands, organized assemblies and protests, and their efforts eventually resulted in the protection of these lands and cancellation of oil leases in 2023. Without their stewardship, activism, and education, this flourishing ecosystem and critical carbon sink would become an oil drilling expanse, further exacerbating the climate crisis (Bustillo, 2023). Around the world where ecosystems are being degraded and natural resources are extracted, there is almost always a human cost as well, to the livelihoods and cultures that rely on these natural areas. For example, the Ogoni people's movement in Nigeria is a prominent example of environmental activism in response to oil extraction in the 1990's-present day, which has directly caused human rights abuses and severe degradation of the environment in the Niger Delta region (Bodo, 2018). While many prominent figures in this environmental justice movement, like Ogoni leader Ken Saro-Wiwa, were killed, their activism has generated international attention and pressure on the oil giant Shell to halt their oil extraction operations and mitigate the great harm they have caused. This conflict is still

ongoing, but there are many examples of resource extraction that have been altogether halted due to environmental activism and international attention.

The Yasuni initiative in Ecuador has been a decades-long conflict regarding the extraction of large oil reserves in Yasuni National Park, a sensitive ecological area among the most biodiverse on the planet, that is also home to numerous indigenous communities (Vallejo et al., 2015). The Yasuni ITT initiative was established in 2007 to create an area that was off limits to drilling, on the condition that the international community would compensate Ecuador for the lost revenue from these oil resources. The plan ultimately failed, but in 2023 citizens of Ecuador voted to halt all future oil drilling operations here, winning by a majority of more than 1.5 million (Dominguez-Gaibo et al., 2023).. This not only protects this incredible diverse natural area and leaves billions of barrels of oil in the ground, keeping carbon emissions out of our atmosphere, but it also protects the isolation and livelihoods of the hundreds of indigenous people living in this region (Vallejo et al., 2015). It is clear that awareness sparked by communities' advocacy, and education on their natural land stewardship and protection, are important tools for future environmental protection.

There are also examples of more urban communities like Love Canal around the world, where they are facing high levels of pollution and environmental harm due to industries in their area, that are causing significant health issues like higher rates of cancer and respiratory illnesses. In China, there are communities located near industrial zones or highly polluted areas known as "Cancer Villages" due to the disproportionately high rates of cancer and other diseases in these populations (Sing et al., 2023). Residents in these communities have suffered through decades of contaminated air and water, and in the early 2000's awareness of these villages began growing due to advocacy of residents there, working with local NGOs and environmental

organizations. After years of increasing media attention, the Chinese government first acknowledged the existence of these communities in 2013, followed by the first amendments to China's environmental protection laws in 25 years, in 2014 (Sing et al., 2023). These amendments included greater power for environmental regulation authorities and harsher fines and punishments for polluters. There is still a disconnect between these government policies and their implementation, however this is a sign of progress that resulted directly from community advocacy and the international media interest and pressure their advocacy generated.

In Buenos Aires, Argentina, there is an area known as Villa Inflamable, which is an informal settlement near a highly industrialized region, highly impacted by pollution from nearby plants and oil refineries (DeCesare & Auyero, 2017). This community has experienced higher than average rates of cancer, respiratory diseases, and more health issues attributed to their exposure to toxic chemicals. Residents of Villa Inflamable have been working to raise awareness through protests and legal action, and in 2008 the Supreme Court of Argentina ordered the government to enact policies that would reduce pollution and improve the quality of life in this area. While this remediation is still ongoing, the government has invested \$5.2 billion USD in the clean up so far, with the World Bank committed to investing \$850 million USD in improving the public water and sanitation services in this area (Pellettieri, 2017). This is not an immediate solution that mediates the decades of environmental injustices in this area, but it does represent positive progress and significant financial investments that would not have happened without the advocacy of this community, and the other organizations that helped them spread awareness. It is clear that grassroots environmental justice movements can raise awareness and pressure governments towards pollution remediation and pro-environmental policies.

Chapter 3: Education and Global Sustainability

The United Nations 2030 Agenda for Sustainable Development provides a blueprint for a sustainable and equitable future, and focuses on 17 Sustainable Development goals to improve both public and environmental health.



Figure 7. The 17 sustainable development goals identified by the United Nations in the 2030 Agenda for Sustainable Development (United Nations, 2018).

After the first three goals of No Poverty, Zero Hunger, and Good Health and Well Being, the fourth goal to ensure sustainable development is quality education; to “Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all” (United Nations, 2018). However, the number of young people who lack access to quality education is growing; by 2030 over 300 million students will lack basic numeracy and literacy skills, and only one in six countries will achieve secondary school completion targets (United Nations, 2018). In the area of education alone, this is a huge issue that furthers poverty and inequality worldwide.

These 17 goals can all be connected to education, and providing access to education worldwide

can advance each one of them by reducing poverty, improving food and water systems, addressing gender inequality, and preparing future generations for careers in each of the fields corresponding with the sustainable development goals.

Education also has implications for sustainable development and climate change action. Worldwide, almost 130 million girls do not have access to education (United Nations, 2023). According to Project Drawdown, a climate solution resource that ranks 75 key strategies to reduce carbon dioxide emissions, educating women and girls has a carbon mitigation potential of 85.42 gigatons of carbon by 2050 (Hawken, 2018). Education can increase actions like family planning to promote sustainable population growth, and improve quality of life, economic productivity, and public health. Climate-related hazards disproportionately affect women and girls, and exacerbate gender disparities in areas including reproductive health, women's rights, education, gender based violence, and socioeconomic status (Patterson et al., 2021). Climate change impacts disrupt girls education, increase their time in poverty, and increase the risk of forced child marriage (Kwuak, 2021). Climate stressors such as droughts often increase gendered responsibilities for girls, such as retrieving water or fuel, and ensuring support and access to education can combat these unequal impacts.

Climate change focused education can work to reduce climate change vulnerability in the areas this is needed most (Hawken, 2018). A study of climate change education and vulnerability in low-income settlements in El Salvador and Brazil found that average levels of education were lower for households at high risk to climate change impacts, partially due to environmental stressors they are already experiencing, and how these stressors limit their access to education (Wamsler et al., 2012). However, because education is the most impactful way to increase household and community resilience to climate change impacts and ability to adapt, further

stressors and climate change impacts are creating a cycle of decreasing capacity to act, which needs to be addressed with improving access to and quality of environmental education (Wamsler et al., 2012).

Environmental education can also increase agricultural yields and promote sustainable practices (Hawken, 2018). An analysis in five sub-Saharan African countries found that closing the gender gap of access to education could increase crop production by up to 19% by providing women with resources and technical knowledge (Fang & Akram-Lodhi, 2019). Education increases the likelihood of farmers to adopt sustainable agricultural practices that are also an opportunity for climate mitigation. In Ethiopia, for example, with each year of additional education, the likelihood of adopting two or more sustainable agriculture practices increased by 12% (Fang & Akram-Lodhi, 2019). Educated women are better able to protect themselves, their families, and their livelihoods from environmental stressors like floods and droughts, and better able to recover after disasters (Hawken, 2018).

According to Project Drawdown, education, and female education in particular, is the “single most important socioeconomic factor associated with a reduction in vulnerability to natural disasters” (Patterson et al., 2021). Additionally, women’s political empowerment is strongly linked to better environmental outcomes, including protected land areas, environmental treaties, and smaller climate footprints (Kwauk, 2021). The future of climate change is likely to bring an increased reliance on and demand for STEM fields, and this shift threatens to exacerbate the gender gap in employment without adequate STEM education for girls .

The United Nations Framework Convention on Climate Change (UNFCCC) included the responsibility of participating countries to implement education and public awareness campaigns focused on climate change (UNFCCC, 1992). UNESCO’s Climate Change Education for

Sustainable Development program aims to increase climate change literacy among youth in particular, often the most likely to take action. It is also critical to prepare the future generations that will be most affected by climate change, with education about how to adapt to future impacts. Understanding the science and facts behind climate change can help combat the fear and uncertainty that is often a barrier to taking action (Ojala, 2012). Despite the numerous well-documented benefits of educating women and girls, in the context of climate change, there is a huge lack of prioritization and commitment to education in climate change policies, and a lack of climate change education included in mainstream curriculum.

Chapter 4: Current State of Climate Change Education

Environmental education in the United States largely sprung from the environmental movement that took place in the 1960's and 70's, after awareness grew of environmental injustices like Love Canal, and of the environmental impacts of harmful substances like DDT (Fang, 2022). One of the first definitions offered of environmental education came from a University of Michigan professor in 1969:

“Environmental education is aimed at producing a citizenry that is knowledgeable concerning the biophysical environment and its associated problems, aware of how to help solve these problems, and motivated to work toward their solution.” (Hungerford et al., 1998).

This definition of environmental education was expanded on in 1980, to fully emphasize the last part about motivating work on solutions.

“... to aid citizens in becoming environmentally knowledgeable, and, above all, skilled and dedicated citizens who are willing to work, individually and collectively, toward achieving and/or maintaining a dynamic equilibrium between quality of life and quality of the environment.” (Hungerford et al., 1998).

However, today, environmental education is largely science based, issue focused, and neglects the other side focused on ability and pathways to create change, and actually inspiring students to affect that change (Monroe, 2017).

As one of the global leaders in climate change technology and renewable energy, climate change education is still not a priority in the United States, despite strong public support. According to a 2019 study, more than 80% of parents in the U.S. support climate change being taught in classrooms (Kamenetz, 2019). Teacher support was even higher, with 86% of teachers believing climate change should be included in curriculum. This support even spans political divides, with the majority of both Republicans and Democrats agreeing. However, this is not reflected in classrooms, or at home. Only 42% of K-12 teachers say they've discussed climate change with their classes, and only 45% of parents reported talking about the issue with their children (Kamenetz, 2019). This means the majority of American students are receiving no information about climate change, other than catastrophic headlines and news stories that only increase anxiety about the topic.

Of the teachers who don't teach about climate change, the dominant reason why is that it is not part of their curriculum for the subject they teach, for 65% of teachers. 20% reasoned that their students are too young to learn about it, while 17% said they don't know enough about it, and 17% also said they don't have the materials needed to teach this subject (Kamenetz, 2019). This is not surprising, as the majority of current teachers also received no education or curriculum training on climate change, and there is no climate change curriculum provided or included in most state standards. There are online resources available, such as the Climate Literacy and Energy Awareness Network (CLEAN), which comprises more than 600 climate change education resources reviewed by science and educators, or national training programs like Project Learning Tree that are designed to help teachers bring climate change education into their classrooms (Armstrong et al., 2018). However, without a climate change curriculum and

guidelines, educators may be unaware of these resources or unsure of how or if they can use them in their classrooms.

Of the 42% of teachers who do talk about climate change, they spend an average of 1-2 hours per year on the subject (Kamenetz, 2019). 4% of teachers said their school does not allow it, and over 30% of teachers were worried about parent complaints if they talked about climate change in school. This evidences the need for state curriculum requirements so that teachers are able to talk about it in their classrooms without fear of repercussions. There is overwhelming support for this from both Republican and Democratic parents (Kamenetz, 2019), but still hesitation from teachers to include outside content in their classrooms without requirements. Some states are already making advancements in this, and in 2020, New Jersey became the first state to require all public schools to adopt climate change education into their curriculums (Mosley, 2021). The standards included in these curriculum requirements were developed by the New Jersey Department of Education with input from teachers, school administrators and districts, non-profit organizations, and higher education institutions, to include aspects of community based climate education, and environmental justice, a critical part of education to facilitate environmental action. A main priority of this new curriculum is taking a balanced approach to teaching climate change, intentionally choosing lessons not to overwhelm students with the scale of the problem but rather to help them understand and be empowered with solutions (Mosley, 2021).

One common reason parents may be resistant to climate change education is concern about the mental health impacts on young students learning about this very serious and complicated topic. Climate anxiety is anxiety associated with ideas about climate change, even if those experiencing it have not directly experience any impacts (Hickman et al., 2021). Anyone

who experiences natural disasters or other climate related impacts experience increased levels of PTSD, depression, anxiety, and even substance abuse, and children are most vulnerable to this. However, even for those not directly affected, anxiety about the future of their environment, grief about places and species that will be lost, and concern for their future, all negatively impact mental health (Hickman et al., 2021). More specific terms have been coined, such as “ecoanxiety”, or even “eco paralysis”, an inability to take any actions against climate change due to the belief that nothing can be done against this existential threat (Moser, 2007). A 2016 study of more 10,000 young people in 10 countries found that over half of those surveyed felt anxiety, sadness, anger, or guilt about climate change, and 45% reported that their feelings about climate change negatively impacted their daily lives (Hickman et al., 2021). This is another reason why resources must be invested into researching and developing an effective climate change curriculum that provides teachers with guidance on how to talk about this challenging subject in a way that empowers students.

While climate change and environmental education can be a powerful tool for positive environmental change, there are documented racial disparities within the United States in environmental education, as well as racial and socioeconomic disparities in access to and contact with nature (Klompaker et al., 2023). According to a 2013 study, high populations of minority students at middle schools across North Carolina were negatively correlated with environmental education programs and environmental literacy rates at each school (Stevenson, 2013). Because environmental injustices such as pollution and climate change impact minority and low socioeconomic status communities disproportionately, this means that those students who are most affected by these issues often have the least education about them, and voice in them (Kearns, 2014). In these communities, access to environmental education and nature is

even more important and impactful. Often the environmental education that exists today in schools can be inaccessible or less personally relevant to students in urban areas of environmental injustice. Low income households and neighborhoods have unequal access to nature compared to high income populations, even more so in communities with unhealthy environments from industry emissions and pollution (Klompaker et al., 2023). There is a need to include a revised, more comprehensive form of environmental education in all schools, but especially in urban settings and areas most impacted by environmental injustices.

Climate Change Education Globally

Despite a lack of research or inclusion in international climate agreements, many countries are already implementing climate change education into national curriculum requirements. As a notable example, in 2019, the Italian government announced that starting in 2020, students in every grade would be required to study climate change and sustainability, and public schools would include a minimum of 33 hours a year in their curriculum that is devoted to these topics (Mezzofiore, 2019). However, with the onset of COVID-19 in 2020, governments and schools were left struggling to adapt to online learning, much less able to introduce new subjects into their curriculum. This global pandemic has set back plans for climate change education around the world, but as education returns to business as usual, there is a significant opportunity to include climate change education.

According to a 2021 report by the United Nations Education, Scientific, and Cultural Organization, only 53% of national curriculum from 100 countries surveyed incorporated climate change at any place in their curriculum (UNESCO, 2021). 45% of national curricula made little to no reference to any environmental-related themes, including climate change, sustainability, and natural resources, and only 19% made any reference to biodiversity. In addition to this, only 40% of teachers surveyed felt confident in explaining the severity of climate change, and fewer than 30% felt they were able to explain the local impacts of climate change in their region (UNESCO, 2021). This is not at the fault of teachers, as more than a third of teachers surveyed reported their teacher training programs did not include any information about environmental themes, so even if they were allowed to include them in curricula, they do not have the background necessary. In fact, 95% of teachers surveyed felt it is essential to teach about climate change in schools (UNESCO, 2021). The difficulty of making changes to national or regional education curriculum varies, but it is never a simple task. For example, the below figure shows

the numerous government and other institutions that would need to be involved in efforts to modify curriculum and introduce themes of climate change education.

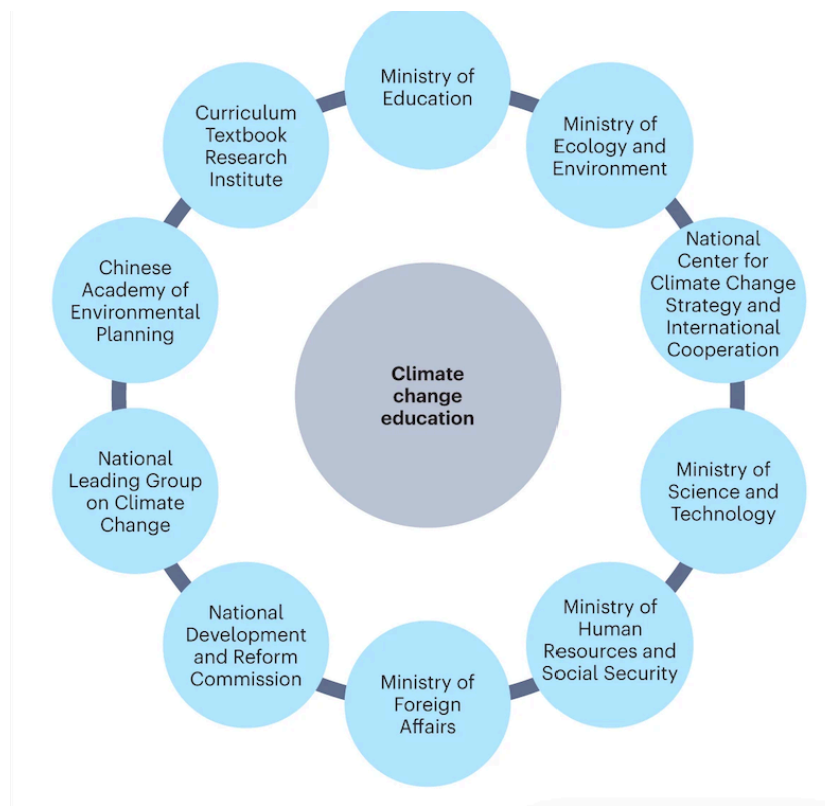


Figure 8. In China, modifying national curriculum frameworks and implementing CCE policies and projects involve collective efforts of multiple ministries and sectors. (Ma & Chen, 2023).

It is clear that in order to utilize the carbon mitigation potential of climate change education, a large-scale collaboration is needed between governments, academics, policy-makers, and other organizations. Increasing access to education as a whole is the first step in achieving higher rates of climate change education and literacy.

Analysis from Africa’s largest representative public opinion survey shows that climate change literacy rates range from 23 to 66% of the population across 33 countries, with the strongest positive predictor of climate literacy being education (Simpson et al., 2021). Climate change literacy increased significantly with rates of secondary and tertiary education. Climate

change literacy in this survey is defined as having heard of climate change, and understanding that climate change is in part caused by human activity. Poverty rates are negatively correlated with climate change literacy, and literacy rates are on average 12.8% lower for women than for men (Simpson et al., 2021). These findings are especially concerning, as Africa is projected to experience some of the most severe impacts of climate change, and women are frequently more vulnerable to climate change impacts than men (Rao et al., 2019).

The disparity between the severity and perception of climate change in less vulnerable countries like the United States is also concerning. A 2016 Pew Research international survey about climate change attitudes found that individuals from countries with the highest per-capita emissions, also including Canada, Australia, and Russia, reported the lowest levels of concern about climate change, while those from lower-emitting countries in Africa, South America and Asia, reported higher levels of concern (Wike, 2016).

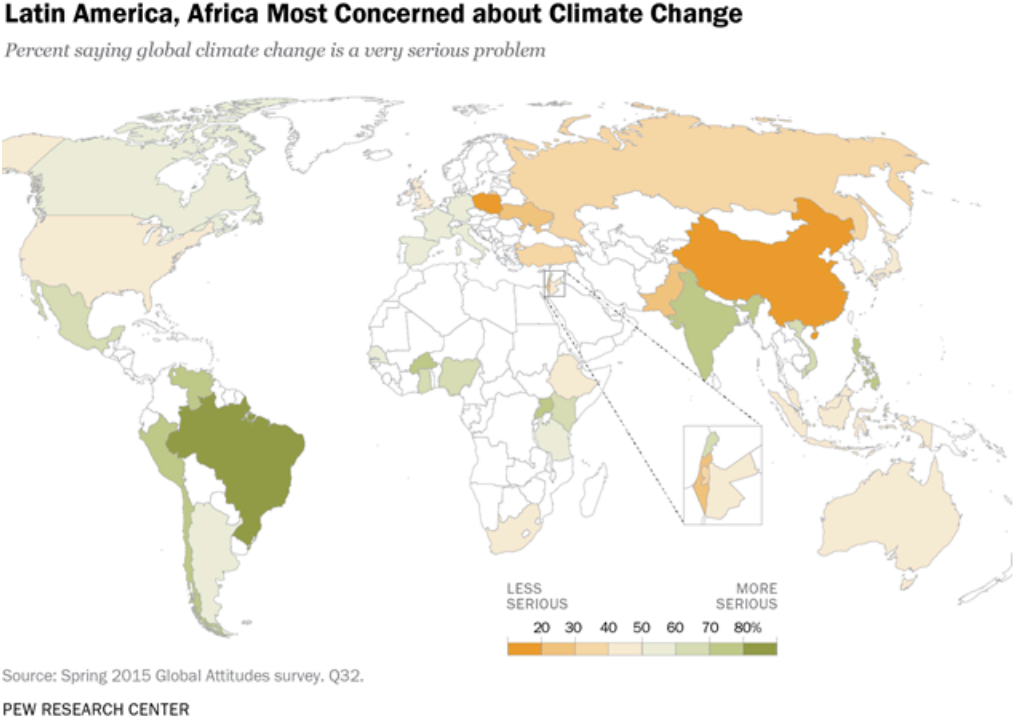


Figure 9: Climate change concern levels by country. (Pew Research Center, 2016)

This is further cause for concern because many pathways to climate change mitigation and resiliency in developing countries involve international aid from countries like the United States that have profited from decades of high greenhouse gas emitting industries (IPCC, 2023). If the general public of these countries believe they should not be concerned about climate change, or that it will only be a problem for other countries, they will be much less likely to support these types of contributions, with the perception that their government should not bear any responsibility for climate change at the global level.

Overall, when public awareness of climate change is low, there is a lack of public support for climate action and climate change education programs, reinforcing the lack of awareness (Monroe et al., 2017). There is significant potential to use education to build this support, because understanding of climate change science is highly correlated with opinions that human action is responsible for climate change (Harker-Schuch et al., 2013), and that both individuals and governments must take actions to address it. Despite the lack of a comprehensive, internationally-agreed upon guidelines for climate change education, there are hundreds of smaller-scale environmental or climate change education programs being implemented cross the globe, with unique perspectives and strategies that the international community can learn from.

Chapter 5: Carbon Mitigation Potential of Climate Change Education

Increased universal access to education is a priority of UNESCO's sustainable development goals, but it is acknowledged that increased access to education will lead to faster economic growth and therefore higher carbon emissions in some countries (O'Neill et. al 2020). However, higher rates of education are also attributed to slowing fertility rates and slower population growth, which drastically reduces carbon emissions, and is also associated with reduced vulnerability to climate change impacts.

There is also evidence that climate change education can have a direct result not just on pro-environmental attitudes and behaviors but on carbon emissions. A 2018 study of the impacts of one climate education course at the college level found impacts on students that lasted far into the future. The average emissions decrease of each student, per year, was 3.54 tons of carbon dioxide (Cordero et al., 2018). Compared to a person's average carbon footprint in the US, about 16 tons per capita in 2017, this reduction is extremely significant, beyond the individual scale. The majority of students who took the course said they were making more pro-environmental decisions, and attributed them at least in part to experiences and information learned through the class. Examples of behavior changes reported include increased recycling and use of sustainable materials (95% of students), reducing energy use in homes (86% of students), and decreasing food waste (64% of students). Based on the results of this study, the average annual emissions decrease of each student was 3.54 tons of carbon dioxide per year (Cordero et al., 2018), compared to the average individual carbon footprint in the US, which is 16 tons of carbon dioxide per year.

With modeling of a realistic possible implementation plan of climate change curriculum over the next 30 years, climate change has the mitigation potential of 20 gigatons of carbon

dioxide by 2050. By starting with 1 million students, and with realistic growth to 38 million students by 2050, climate change education can prevent 20 gigatons of carbon from entering the atmosphere (Cordero et al., 2018), which would have a significant impact on mitigating disruption of the carbon cycle, and rank as a stronger climate change solution than others like offshore wind energy or electric vehicles

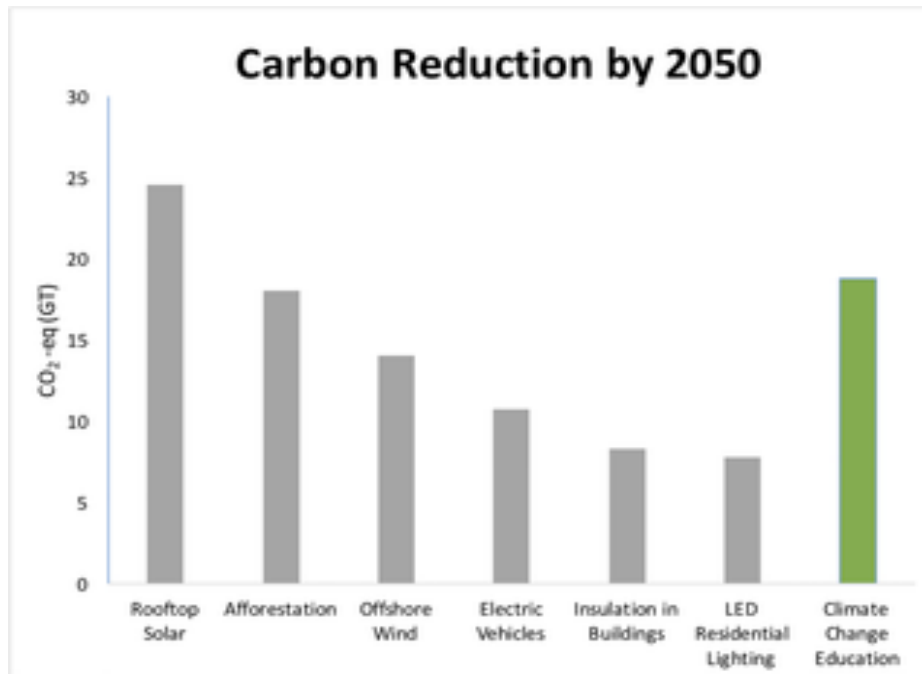


Figure 10. A comparison of the carbon mitigation potential of various carbon reduction technologies modeled from 2020-2050 (Cordero et al., 2020)

The mitigation potential of environmental education does not end with the 20 gigatons modeled in the 2018 study. Almost 17% of the world’s population, or 1.29 billion people, are students in primary or secondary schools around the world, and this number is only expected to increase in the coming years, increasing the mitigation potential of education as well (United Nations, 2018). Higher education is expected to grow almost 200% by 2040, with a projected future number of 594 million students in higher education (United Nations, 2018). The impact of climate change education is not limited to the students who receive it. Numerous studies have

proven that students can have a significant impact on the environmental attitudes and behaviors of adults in their families and communities (Lawson et al., 2018).

A study of 30 girl scout troops in North Carolina found that troops that participated in a residential energy use program significantly increased their energy-saving behaviors after the program and continued to do so more than seven months later (Boudet et al., 2016). Troops that participated in a food and transportation program also significantly increased their food and transportation energy-saving behaviors after the program (Boudet et al., 2016). This shows that interventions for youth audiences can increase energy-saving and sustainable behavior long-term for both children and parents. Another U.S. based program found that programs that facilitate youth engagement, in this case curriculum surrounding marine debris issues and solutions, can contribute to mitigating environmental issues by raising community awareness (Hartley et al., 2021). This study also found that youth outreach, facilitated by this education program, to local officials and voters is an effective strategy to build community support for addressing marine debris (Hartley et al., 2021). Another long-term study of parent's attitudes regarding climate change in coastal North Carolina found that children who participated in a climate change education program significantly impacted their parent's self-reported climate change concern (Lawson et al., 2019).

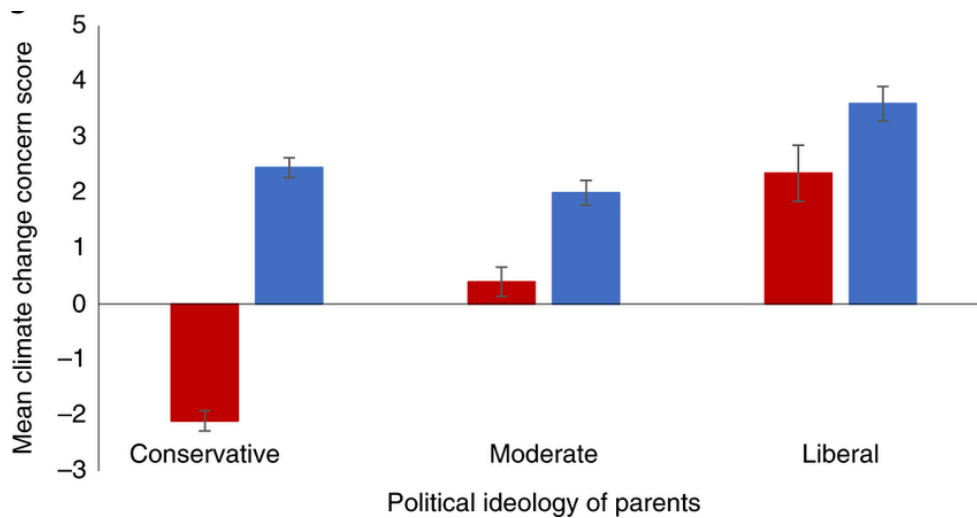


Figure 11: Parents of children in the climate change education treatment group expressed significantly higher levels of climate change concern after the program, with the strongest effects among conservative parents who displayed the lowest level of climate concern before the intervention (Lawson et al., 2018)

Children have the ability to influence their parents on a wide range of controversial social topics, and while climate change is a politically controversial topic, when children are learning about climate change, they are less influenced by social factors than adults, and more likely to be receptive to new information regardless of their political environment at home (Stevenson et al., 2013). Therefore, intergenerational learning represents a significant opportunity to reach audiences that would normally be very resistant to climate change education, and change not just behavior but perceptions about climate change.

Young people have historically been significant contributors to mobilizing their families and communities towards environmental action, including enacting change through engagement with policymakers (Lee, 2020). Children represent a receptive audience that can be reached easily through school with a wide range of environmental education programs, (Lawson et al., 2018). They also have a unique ability to communicate and potentially change the opinions of older generations, when information coming from other sources may be blocked out by them.

However, all education programs do not have equal potential to facilitate action and change attitudes and behaviors. The program described above used a highly localized approach by focusing on climate change impacts like sea level rise and flooding in student's home area, so the information they communicated to their parents was very specific (Lawson et al., 2019). Through decades of climate change education programs and their evaluations from countries around the world, common practices have emerged that extend the impact of these programs. By learning from current literature on climate change education and focusing on identifying best practices, policymakers and educators can begin harnessing the untapped potential of strategic climate education as a tool for carbon mitigation.

Chapter 6: Best Practices for Climate Change Education

In the previous studies, it was not simply learning about climate change and climate science that resulted in the pro-environmental and carbon reduction behaviors of the majority of students. Many science-focused forms of climate change education, or information provided by mainstream sources like news outlets, approach climate change with a crisis narrative and attempt to use fear appeals, which only disempowers and discourages students from engaging with the topic or taking action (Bartlett et al., 2020). Climate change education should approach these issues through a different lens in order to affect change.

Eugene Cordero identified key design elements of the curriculum that led to successful carbon mitigation. These included connecting climate change to students' lives through projects like asking students to reflect on how climate change would impact their personal and professional lives, or having students calculate and track their personal energy use. Another key strategy identified was providing students with the experience of creating change, where they developed a community action project that focused on a specific way to reduce emissions in one of their communities. Many students also cited that the course created a culture of environmental stewardship and action, through community-based social marketing and social norms that were developed through group projects and class discussions (Cordero et al., 2018).

These strategies were found to be successful in this case study, however there is broader research that looks at climate change education strategies comprehensively and across many different examples. The North American Association for Environmental Education (NAAEE) funded one such research study, that looked at all citations in an academic database addressing climate change education, and identified 49 sources that focused on assessing climate change education strategies. Of these sources, two themes were identified as the most common:

Focusing on making information personally relevant, and using active and engaging teaching methods (Monroe et al. 2017).

Personal Relevance

Adding personal and local relevance to the very large-scale and sometimes seemingly distant threat of climate change is important in changing attitudes and behaviors. Curriculum focused on local issues with opportunities for hands-on investigations create better learning outcomes than standard school curriculums without this focus (Pruneau et al. 2003). For example, students in coastal California learned the most about climate change adaptations when it was taught through the lens of local threats like sea level rise, that were directly relevant to their daily lives (Bofferding and Kloser, 2015). Students in South Africa completed an environmental education course that focused on future risks associated with climate change, and had significant changes in their perceptions of current and future climate change impacts, as well as their perceived preparedness and ability to adapt to these impacts (Nkoana, 2018). When students learn about climate change through the lens of how it will impact their lives, they are more likely to connect with these issues on a personal level, and they also become more prepared to take action. Another important part of adding personal relevance is education that connects climate change with individual behaviors, which makes these concepts of sustainability or carbon mitigation more tangible for students, and helps them see the direct link between human actions and climate change.

A common theme found in strategies that target personal relevance is having students calculate and keep track of their environmental impacts using tools like carbon footprint calculators. The environmental impact of actions and resource use is often invisible in everyday life, but when online modeling tools show a clear picture of this impact and allow comparison to

other carbon footprint metrics, such as the average carbon footprint of someone in the United States, this can provide new perspectives and understandings of personal impacts (Edstrand, 2015). However, what students take away from these activities should not be that their individual actions, such as eating meat or purchasing single-use plastic, are responsible for climate change. Rather, these activities help frame climate change as an issue students are able to have an impact on, and they can contribute to improving their environment through every day choices. Effective climate change education should include helping students develop relevant skills, like critical thinking and problem solving, as well as scientific literacy, so they are able to understand the full scope of the problem, how it may impact their lives, and how they are connected to this large-scale issue (Anderson, 2012).

Engaging teaching methods

The other key theme identified is using active and engaging teaching methods. Using experiential and inquiry-based teaching methods such as student discussions or debates, labs, and field trips, has been proven to be most effective for environmental science education. Moving beyond standard lecture-style classroom discussions, climate change is a topic that often requires different instruction methods for students to fully understand. Engaging students with projects involving art, creative writing, or media creation can help students connect to the environment and express complicated feelings about climate change, and can result in transformative learning that changes students perceptions of the issue (Bentz, 2020). Documentaries and videos can bring students face to face with the real human impacts of climate change that communities around the world are struggling with, and exploring scenarios through role-play activities or games can engage students in a different way, allowing them to practice thinking from another perspective (Monroe et al., 2017).

Discussions and Simulations

Deliberative discussions give students the opportunity to compare different perspectives and opinions on an issue, and think critically about what they know to recognize there may be gaps in their understanding. When these discussions are framed through a real-world lens, such as what a particular company or organization's response to climate change should be, it also helps students understand the complicated social and political factors at play (Klosterman and Sadler, 2010). A common practice to teach about environment or natural resources issues is role-play and simulations of real world issues. There has been a recent increase in the development of climate change related games, that commonly involve students being responsible for making decisions that have direct impacts on a simulated climate or environment, like determining a country's renewable energy policies, managing a wildlife preserve, or regulating overfishing in a fragile ecosystem (Wu and Lee, 2015). Another strategy involves taking perspectives of different stakeholders in a discussion, to understand the many complex interests and institutions involved in environmental decision making, using the example of a proposed highway being built near a suburban community (Hartley et al., 2021).

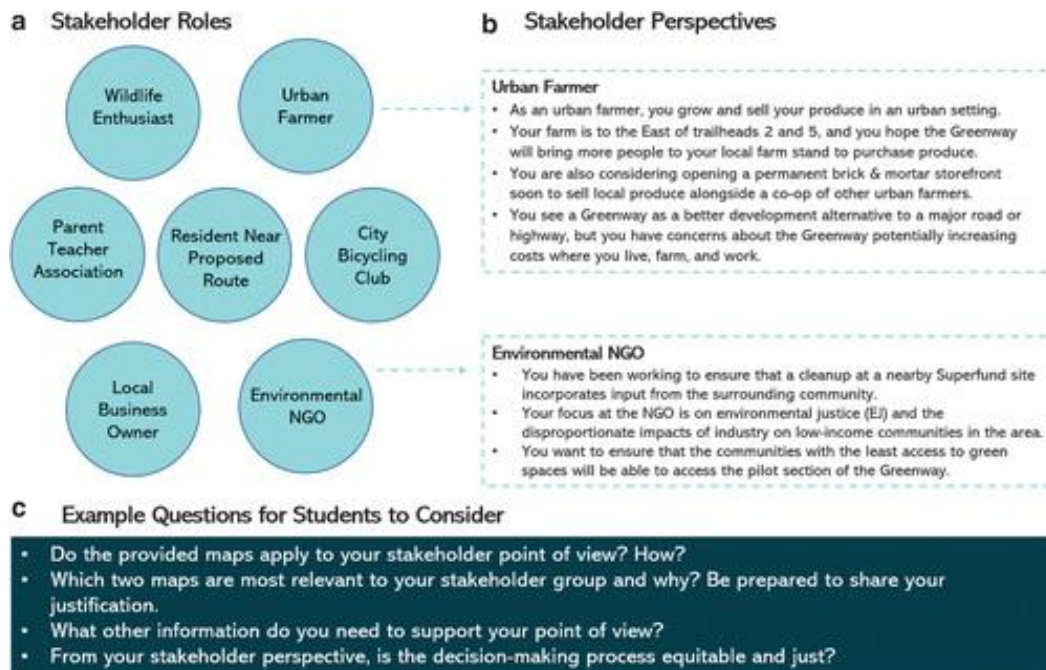


Figure 12: (a) Stakeholder roles and examples of (b) different perspectives that students are asked to consider for their decision making in the case study with (c) example questions (Environmental Protection Agency, 2023).

These approaches can also introduce students to a ‘tragedy of the commons’ scenario, that can be compared to economic development and resulting global carbon emissions, but starting with a more accessible scale. Students are introduced to the idea of a common pool resource, like access to nature or healthy ecosystems, that must be governed by competing interests. Another example involves a simulation of fishing in the ocean, whichand represent different fisheries that must make the decision of how many fish to harvest each season (de Oliveira et. al 2023). They are able to practice the complicated decision-making required to balance economic, social, and environmental factors, while competing with other fisheries that may be harvesting more fish with no regard for the environment. One pilot project looked at an environmental management and sustainable action game called GREENIFY, found that the platform facilitated the

peer-creation of climate change discussions, created positive pressure, and motivated participants to take informed action (Lee et al., 2013).

Games like this help students understand how the common pool resource of clean air and a stable climate is shared, and why global cooperation on reducing carbon emissions is complicated. This perspective taking will build understanding in students that is crucial to navigate the field of climate change adaptation and mitigation, and the complex perspectives and discussions that are necessary to achieve positive action (Wu and Lee, 2015).

Interactions with Science

Other strategies for active and engaging teaching of climate change issues include directly interacting with climate-related science and climate scientists. This strategy can also spark interest in STEM fields for students who may not have otherwise considered it as a career option (Kirsch et al., 2019). If the goal of climate change education is to help develop students that are “Environmentally knowledgeable, and, above all, skilled and dedicated citizens who are willing to work, individually and collectively, toward achieving and/or maintaining a dynamic equilibrium between quality of life and quality of the environment.” (Hungerford et al., 1998), then this education must include an understanding of the history and causes of climate change, as well as an understanding of the certainties and uncertainty associated with climate change. If students are to be environmentally knowledgeable and able to spread information to their communities, they must also be able to understand and address the many common misconceptions about climate science. Additionally, this education should include the consequences of environmental degradation and climate change, and, possibly most importantly, knowledge of different adaptation and mitigation strategies that can help transition to a more sustainable future.

There are many different opportunities for students to interact directly with climate change science. For example, one study found that using virtual reality to teach students about ocean acidification fostered prosocial behaviors, promoted empathy and connectedness, and empowered students by helping them visualize and understand the impacts of their daily choices on the environment, in this case marine ecosystems affected by increasing acidification (Fauville et. al, 2020). Other examples of virtual reality use in environmental education show it can be a powerful tool to help visualize invisible impacts. Education using virtual reality to show the total water usage of a person's daily habits, or the amount of coal needed to heat up their average shower, has been shown to lead to changes in perspectives of resource use, and changes in behavior (Bailey et. al, 2015).

In addition to personal data collection and visualization, when school curriculum involves other forms of citizen science, where students are contributing to data collect of scientific information, they build skills for future STEM careers, and have the ability to facilitate engagement from their families and larger communities as well (Bhattacharjee, 2005). One study in the UK found that in a program called Heat-Cool, where students used infrared cameras to explore urban heat issues and how trees can cool cities, positive motivation and increased engagement were observed in almost 90% of the students (Kumar et al., 2023). Data collected by students can not only contribute to local resource management and conservation projects, it also increases their ability to communicate scientific findings to outside audiences, and study complex systems (Ballard et al., 2017). One study of the impacts of a climate change education program in Puducherry, India, involved providing students with the training and materials to monitor water quality in their communities, and found that this activity-based education significantly increased students' knowledge and skills to solve local water resource issues

(Alexandar & Gopalsamy, 2012). It is also essential to involve young people's perspectives in discussions and responses to climate change issues, as one project involving participatory research in Brazil found that focusing on student perspectives and concerns to guide a research project further enabled them to articulate their thoughts and take action (Trajber et al., 2019).

Citizen science programs also encourage students to take further action beyond data gathering; one study on the impacts of a butterfly conservation citizen science project found that 95% of participants reported an increased involvement in conservation after the program (Lewandowski et al., 2017). Another pilot project involving Girl Scouts with a citizen science program, 'Think Like a Citizen Scientist', found that 81% of participants went on to undertake community action projects, with 66% completing projects that involve educating or inspiring others to take action (Smith et al., 2024). Involving students with citizen science can have significant impacts on participants' capacity building and future attitudes and behaviors, as well as direct impacts on community awareness and management of environmental issues.

Project-Based Learning

Providing students with opportunities to implement climate or sustainability-related projects in their schools or communities is a powerful way to engage them, and directly demonstrate their personal potential for taking action. Key barriers to implementing carbon mitigation or sustainability focused projects are the financial, social, and political feasibilities of these efforts (Burch, 2010). It is often not the science that presents issues, but the social aspect of implementing any changes from the status quo. Project-based learning helps students understand, starting on a smaller community scale, that there are different interests at play that shape different responses to environmental issues, and learn how to navigate them (Monroe et. al, 2017). A common example of project-based climate education is focusing on energy use, either

in schools or at home, calculating total energy use similar to a personal carbon footprint, and brainstorming strategies to reduce it. For example, at one school in the United Kingdom, students collected data and monitored energy use in their classrooms, and planned different action projects that resulted in the school reducing their electricity use by 35% (Leigh, 2009). Another energy use education program in Crete resulted in both students and parents using more energy-efficient behaviors in their homes, showing how the impact of these projects can reach beyond students and into families and communities (Zografakis et al., 2008).

Giving students the opportunity to be leaders and advocates not only helps grow their relevant skills, but spreads climate education to age groups like adults where there is little opportunity for education interventions. One project in Canada had students conduct a research project on local impacts of climate change, and they produced a video with their findings that was widely shared among their communities and other schools in their area (Pruneau et al. 2003). This resulted in numerous students developing action projects, like planting trees, to mitigate these local climate impacts, and post-project interviews with the students revealed that for many, this activity changed their perspectives on climate change and made them feel more empowered. Education that emphasizes the abilities of individuals to help bring about positive change is a powerful tool to spread climate action. Framing these large issues in a motivational way that focuses on solutions can improve engagement with climate change, and increase people's intentions to adopt climate-positive behaviors (Gifford and Comeau, 2011).

In an analysis of climate change education programs in Korea compared to international programs, researchers found that participating in a community-based participatory program, students had a much greater sense of agency over environmental issues, and were more likely to practice pro-environmental actions in their families and communities (Park et al., 2020). Another

study in Colorado found that after an after-school program that helped students develop action projects, participants demonstrated increased knowledge about the causes and consequences of climate change, and climate change solutions (Trott, 2017). Students also reported an increased respect for nature and sense of responsibility, increased engagement in pro-environmental behaviors, and an increased interest in science (Trott, 2017). It is demonstrated that project-based climate education programs have great potential to not only build students' skills for future climate-related careers, but also have direct impacts in their shorter-term attitudes and actions. There is also evidence that framing community projects through an environmental justice lens can be a powerful catalyst for students to engage with complex social issues, and increase self-efficacy for climate change action (Bartlett et al., 2022).

Chapter 7: Education for Environmental Justice

In addition to facilitating more pro-environmental attitudes and actions that can reduce carbon emissions on the individual and community scales, environmental and climate change specific education can have much larger impacts by supporting environmental justice movements. This education not only can prepare individuals from climate-vulnerable communities to understand and adapt to impacts of climate change, but it can also give them the information and skills they need to create change on a larger scale. Communities living in heavily polluted areas may be unaware of the link between income or minority populations with environmental degradation, or avenues to address environmental injustices. For students from communities that are unaffected by environmental concerns like pollution or climate change, who may have a difficult time understanding or relating to these issues, environmental justice education is a powerful and necessary pathway to recognize the need for action (Kearns, 2014).

All students, regardless of socioeconomic status or home environment, should be taught how systemic inequalities exacerbate environmental justice issues, like unequal access to clean air, clean water, and green spaces. Students from communities that lack this access should recognize their rights to a healthy environment, and students from communities where these are not concerns need to recognize that these issues do exist, even if they are fortunate enough not to experience them. Individuals from any community can play a role in advocating for policy change and government action to address these inequalities. Many forms of climate change education that are not focused only on the science, also help students develop the necessary skills to be environmental advocates. Education programs that include practices like providing

ownership and empowerment variables, or real-world experiences, foster critical thinking skills and build environmental literacy, as well as skills like perspective-taking, communication, and negotiation. Inclusive forms of education that focus on diverse perspectives, like indigenous stewardship history and knowledge, also can help amplify the voices of marginalized communities and apply pressure. A comprehensive education on environmental justice should also include education on transitional and epistemic justice. Transitional justice involves recognizing responsibility and repairing past injustices, which in an environmental context can be incredibly localized, or as large-scale as developing nations experiencing more climate change impacts while being responsible for far less greenhouse gas emissions than developed nations (JustEd, 2023). Epistemic justice involves universal participation and access to information, acknowledging there are different systems of knowledge and ways of viewing the world, and working against the exclusion of these different systems from mainstream conversations (JustEd, 2023). All of these perspectives are essential in creating a future world where environmental injustices and climate change impacts can be addressed in an equitable way. There have been hundreds of notable examples of environmental justice movements resulting in positive change, in most cases led by affected community members, and in many cases also supported by individuals outside the community that learned about and became committed to these issues.

There has been growing research interest in the potential of environmental or climate change education to facilitate environmental justice in recent years. Authors have identified several key conclusions from literature reviews and case studies on the subject. For environmental education to result in any sort of positive social change, it is essential to include knowledge about the society, and its history and structures, with an emphasis on how social and economic processes shape environmental decision making. If environmental education includes

only material on natural science systems, there will be a huge gap in understanding the powers and interests that shape the majority of environmental issues, and opportunities to change these unjust systems. Authors of *Justice and Equity in Climate Change Education* concluded there are four strategies needed for climate change education that facilitates justice; incorporating best pedagogical practices for STEM education, centering and amplifying the voices that are most marginalized in environmental justice issues, making explicit connections between historical injustices and the perpetuation of climate change, and supporting students to become agents of change both in their communities and on an international scale (Sover & Walsh, 2022).

To facilitate positive change, environmental education should also include education for citizenship, such as developing the necessary skills to speak and write about the subjects being taught, analyze differing perspectives and discourse, as well as engage with the institutions and systems that are responsible for environmental damage. Some scholars argue that teaching and learning about environmental justice includes the moral duty to act on what is learned about as unjust (Haluza-Delay, 2013), which shows why this kind of education can be perceived as controversial by schools and parents. While necessary to include environmental justice topics in climate change education, this addition will generate further criticism about the politicalization of education. Teaching about centuries-long systemic injustices can be perceived as undermining the ideals and current state of democratic equality in a country, which can face sharp criticism in political climates around the world, from the United States to China. Additionally, teaching about these systems of inequality undermines other systems like capitalism, and discussions of these topics in schools would often be considered radical by a moderate or right-leaning audience. There are many issues still to be solved in educating students and communities for environmental justice. There is currently a lack of inclusion of environmental justice related topics in

mainstream climate change education. There is also a lack of research in this field, so there is not comprehensive data on whether environmental education programs are addressing any environmental justice or equity concerns, or have education outcomes that relate to environmental justice. Researchers and activists entering a community that is experiencing environmental injustice must be intentional about how they are involved, and ensure that they are incorporating knowledge from community members (Van Horne et al., 2023).

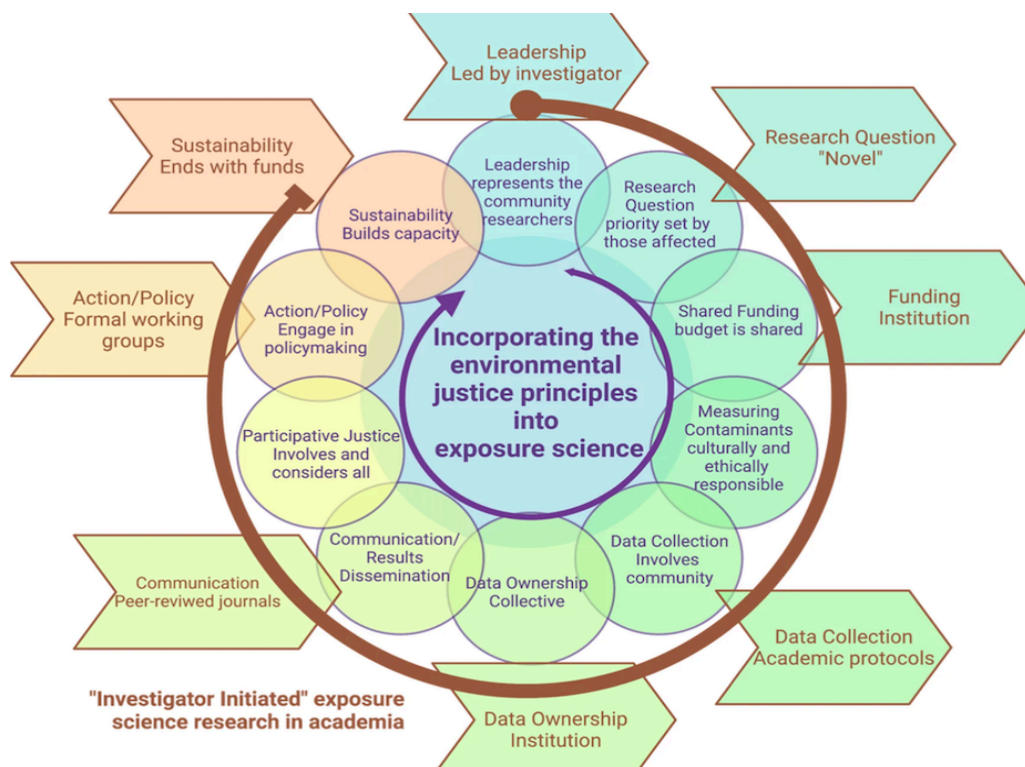


Figure 13. A framework for incorporating environmental justice principles, including community involvement and access to research, into exposure science (Van Horne et al., 2023).

Members of communities experience environmental injustices have a lived experience and personal knowledge of these issues and their history in their communities, and funding for projects should also be used to support community needs by providing mechanisms for raising awareness, capacity building, and engaging with politicians and policy makers.

One common example of an environmental justice education framework involves working with youth from affected communities, and providing opportunities to learn about and

connect with nature and ideas like the right to clean air and water, which result in changed attitudes and behaviors, as well as pathways to action for affected students. One project, called ‘A Day in the Life’ worked with high school students from different neighborhoods in Los Angeles to collect air pollution data with PM_{2.5} (fine particles <2.5 μm in diameter) sensors (Johnston et al., 2020). Students brought these sensors around their neighborhoods and schools for a day, and used photography and videos to document their daily lives and exposure to pollution. Through this project, students developed a greater understanding of air pollution by mapping air pollution sources in their communities, and learned how to communicate their findings and issues about air pollution to their families, classmates, and even at a national conference (Johnston et al., 2020). This is an example of community-driven participatory research that helps bridge the gap between lived experiences and technical research into these environmental justice issues, by giving community members access to involvement.

Participatory research can also serve to deconstruct power dynamics and provide information about environmental health risks to residents, sharing access to scientific knowledge (Minkler et al., 2008). These programs increase capacity for youth and adults to engage with environmental justice issues and participate in the political systems that can address these issues.

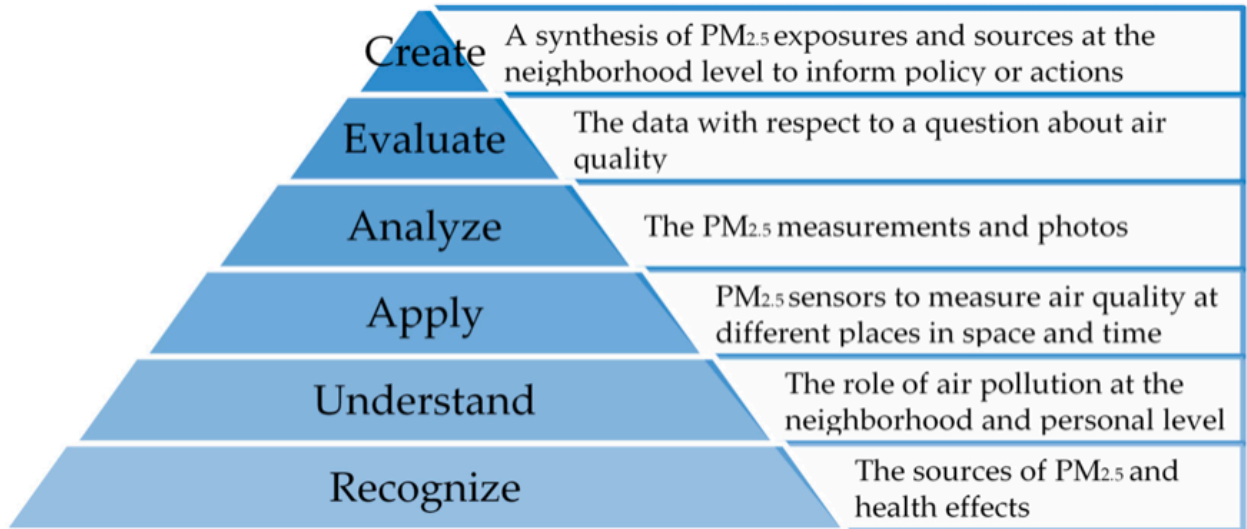


Figure 14. Application of the Environmental Health Literacy Triangle to the *A Day in the Life* participatory research program (Johnston et al., 2020).

Environmental health literacy is defined as an understanding of the link between environmental exposures and health, or more comprehensively:

“Environmental health literacy integrates concepts from both environmental literacy and health literacy to develop the wide range of skills and competencies that people need in order to seek out, comprehend, evaluate, and use environmental health information to make informed choices, reduce health risks, improve quality of life and protect the environment” (Society for Public Health Education, 2015).

The latter half of this definition deals with the action mechanism of environmental health literacy, that connects this literacy to environmental justice. It is difficult to know what actions need to be taken to improve quality of life, if there is limited access to pollution or environmental health information. There are many tools for research into environmental justice or pollution, such as the EPA’s mapping tool EJSCREEN, which identifies vulnerable communities by

combining demographic and environmental burden information, however there is a lack of curriculum or education materials to utilize these tools (Hartley et al., 2021), leaving teachers to figure out implementation themselves. There is a need for more resources directed into developing local environmental justice education materials, which can have a cascading effect as community awareness and support grows.

One study at the University of Michigan found that environmental justice pedagogies support the highest level of self-efficacy for climate change action when programs helped students develop confidence in a particular skill set related to the action, and when the scale of the issue was within their ability to address it (Bartlett et al., 2022), making local environmental issues a more significant opportunity for self-efficacy. In a collaboration between U.S. EPA's Office of Environmental Justice and Office of Research and Development and the Chesapeake Bay Foundation, Environmental Justice professional learning programs were developed for teachers, who then incorporated activities using local EJSCREEN data and case study scenarios in their classrooms. These pilot programs found results that indicate using real-world data and situations can connect students to different communities and support their understandings of environmental justice (Hartley et al., 2021). The potential for utilizing these mapping tools to inspire environmental justice go beyond classrooms, with studies showing engaging adult stakeholders in these activities can make issues more personal and relatable, which increases support for environmental management regulations and actions (Vukomanovic et al., 2019). This collaboration yielded a model for how youth-led and data-focused environmental justice education and action can further impact a community.

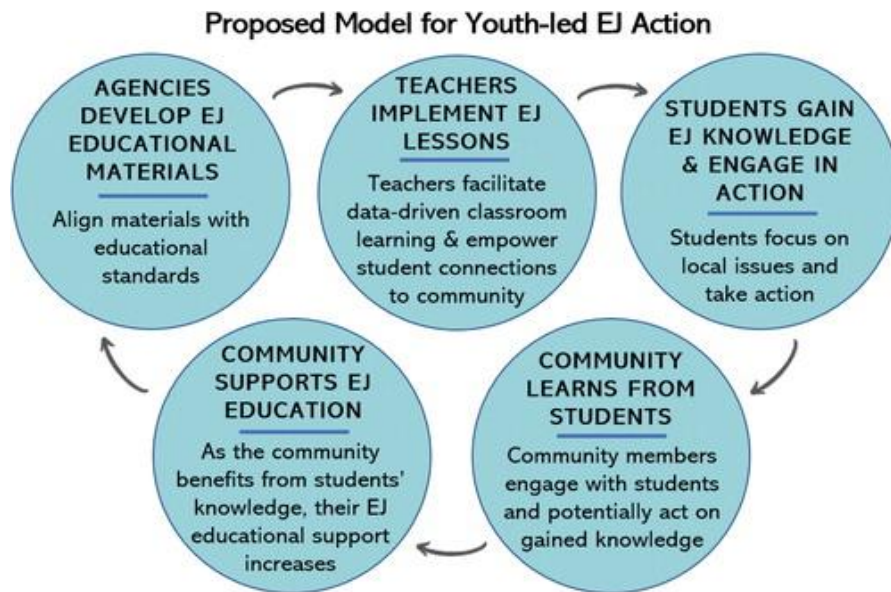


Figure 15: A model for youth-led environmental justice action that can create multiple positive feedback loops in a community (Hartley et al., 2021).

Projects that involve locally-focused experiential activities, like gathering research and role-playing in a discussion, actively help students build the necessary skills to engage and communicate with outside audiences. With local environmental justice issues, there are often gaps in data collection, research, or understanding from affected communities (Haluza-DeLay, 2015), and when youth engage with these issues it can benefit the whole community through raising awareness and facilitating greater action. For example, one pilot program using the EJSCREEN tool had students complete research projects investigating local environmental justice issues, which sparked student involvement in numerous local organizations and action projects (Hartley et al., 2021). These programs not only engage students with science disciplines helping to address inequalities in science education, they can also improve students' sense of place, motivation, and confidence in their ability to solve problems, as well as provide pathways for communities to directly address environmental injustices (Kearns, 2014).

Participatory education programs can also have a significant impact on the climate resilience of communities, as a case study of three communities in the Philippines shows (Haynes & Tanner, 2013). This study involved local students creating video projects on the topic of disaster risk reduction, focusing on various factors in their communities that exacerbated flood risk, such as mining, deforestation, and vulnerable infrastructure. In each of the three communities, the students' projects were presented to the community and local governments, and had tangible impacts that made these communities more climate-resilient (Haynes & Tanner, 2013). These impacts included influencing the village council to fill in old mining pits and replant trees, getting elevated cabinets and flood-resistant infrastructure installed in their school, and organizing a large-scale tree and bamboo planting event near the banks of the river prone to flooding. This further demonstrates that there are many opportunities for youth-led environmental action, from collecting data to creating videos, that result in safer and healthier communities. Devoting more resources to developing a repository of environmental justice curriculum and programs to facilitate youth-led action will further the impact of mainstream environmental education and contribute to real-world environmental justice efforts.

Conclusions and Next Steps

The need for increased development of resources for climate change education and environmental justice education is clear, as well as the potential for this education to create change on a large scale. However, there are many roadblocks that still exist that make it difficult to include these topics in K-12 curriculum standards. Primarily, there needs to be increased connection and communication between climate change and climate education researchers and education policy-makers, to create learning materials that are founded in scientific principles and best practices for environmental education, and make room for climate change education in curriculum requirements. Involving and training teachers is another crucial step in this process, because if teachers lack a scientific background about climate change or knowledge of experiential education programs, it will be much more difficult to actually implement, regardless of policy changes (Rushton et al., 2023). Improving teachers' understanding and motivation to teach about climate change is a critical first step to bringing this education to students. Starting with teacher training programs for specific curriculum or activities, this can create large-scale positive feedback loops facilitated by intergenerational learning, when students learn about

climate change and spread knowledge to their communities, which increases public support of climate change education programs.

There is currently a lack of comprehensive research regarding how climate change and environmental justice education can lead to behavior change, outside of anecdotal evidence from specific case studies. Additionally, the majority of this research focuses on programs in North America, Europe, and Australia (Anderson, 2014). There are far fewer examples of evidence-based research from countries that are more vulnerable to climate change, where this education can have more significant impacts. Further studies are needed to determine the full potential of education to build resiliency to climate change in these countries, and the impact of education programs on long term behavior, multiple years or even decades into the future, to truly understand the depth of changes in behavior and attitudes (Anderson, 2014). There is a need for further collaboration between academic researchers, government agencies, and educators, to fill these gaps in climate change education research.

In order to create programs and evaluate their effectiveness in increasing understanding of climate change, fostering pro-environmental behavior and attitudes, and facilitating environmental justice, there needs to be a significant effort into developing a standardized framework of measurable outcomes and goals of this education, as well as specific knowledge and skills being taught. While communities have highly local impacts and attitudes about climate change, a general framework to start with can help teachers adapt it for their specific audience. More activities can be developed that can be used across the United States or even across the globe, using a standardized framework to apply local data and scenarios.

While numerous case studies have identified general best practices, further research should identify specific tools and strategies that result in climate-positive behaviors. This

research should incorporate and validate already established best practices, including framing climate change discussion from a lens of hope rather than despair (Stevenson et al., 2015), and focusing on values of ownership and empowerment in hands-on, problem-solving based education (Monroe et al., 2017). Different methods of engaged teaching have varying impacts on the knowledge and capacity building of participating students, and these impacts should be more thoroughly examined in larger scale research studies. Reforms to climate change education should focus on cultivating critical thinking and other necessary skills to enable students to communicate about climate change, and connect learning to local issues and solutions to empower students to create change (Anderson, 2014). Expanded research into the impacts and benefits of climate change education would also further convince policy makers and governments that this is a powerful, cost-effective tool to mitigate climate change, and should be considered a climate change mitigation tool on the same level as renewable energy and electric vehicles (Cordero et al., 2018).

Despite the recognized potential of many existing programs, climate change education is rarely thought of as a carbon mitigation strategy on the same scale as solutions like renewable energy and electric vehicles. Possible reasons for this lack of attention include a bias for implementing technology-based solutions, while education is thought of as a more social or soft-science field that is not taken as seriously. However, climate change education has enormous potential to not only have more significant carbon mitigation impacts, but prepare future generations of students for careers in these technology-based fields to further improve their effectiveness. While many solutions like renewable energy can cause significant environmental harm, such as disturbing habitat or requiring further extraction of natural resources, climate change education is a feasible solution that can be implemented without expensive technology or

lengthy construction timelines. Climate change education should also be considered a powerful tool to support environmental justice from the local to a global scale (Bartlett et al., 2022), and further research into how to best support and empower communities experiencing injustice, using climate change education, is needed to maximize the potential of this tool for positive change and ensure further burdens are not being placed on these communities.

To maximize the full potential, climate change education should be part of international climate policy discussions, including at meetings of the United Nations Framework Convention on Climate Change, with target setting and progress monitoring that would help advance developments in this field (Ma & Chen, 2023). Providing guidelines for all countries to implement climate change education first on a voluntary, then mandatory basis as part of international climate agreements, would ensure students in countries both resilient and vulnerable to climate change will have access to this knowledge. However, before this will be politically feasible, more support must be build for these programs starting on smaller local, regional, and national scales, through the expansion of pilot projects and existing climate change education programs to more communities, and raising awareness of the positive impacts of these programs. Climate change and environmental justice education can have an unlimited scale of positive impacts, and are necessary to prepare the next generation of students for a world that will require a high level of environmental literacy and climate change awareness across society in order to achieve the most sustainable future possible.

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