Chapter 12

Core Idea ESS3: Earth and Human Activity

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What is this DCI and why is it important?

> The DCI examined in this chapter is ESS3: Earth and Human Activity. Connecting the ESS [Earth and Space Sciences] to the intimate scale of human life, this idea explains how Earth's processes affect people through natural resources and natural hazards, and it describes as well some of the ways in which humanity in turn affects Earth's processes. (National Research Council, 2012, p. 170).

As stated in the *Framework*, the disciplinary core idea of Earth and Human Activity (ESS3) recognizes both the impact of the Earth's processes on humanity and societal interactions with the Earth as drivers of environmental change. This core idea explains how the Earth's processes of natural resources and natural hazard impacts humans as individuals, communities, and activity systems; concurrently, it also describes ways in which humanity affects Earth's processes. Humans are dependent on the earth's resources. Throughout history, civilizations have flourished or withered relative to the extent to which the local environment was able to provide the resources needed to sustain the population. The Earth is a planet of finite resources, and its growing population currently consumes them at a rate that cannot be sustained. The quality and quantity of water is of serious concern in many parts of the world. Naturally, water quality and many other environmental concerns are closely related to questions of human health. In order for us to develop practical solutions to these serious challenges we must have both a scientifically literate workforce and a citizenry that is capable of formulating and vetting policy solutions and practical actions to assure that our natural environment is able to sustain the demands of an ever increasing human population.

The existence of natural threats such as tsunamis, earthquakes, drought, and volcanic eruptions have shaped communities and culture. Understanding the causes of natural hazards as well as the extent to which scientific models are able to predict their frequency and severity is essential to building understandings of ways to mitigate their impacts on human populations in the future.

Human activity has also become one of the most significant agents of change to Earth systems, with both positive and negative effects. At times humans have been excellent stewards of the Earth's resources, developed cultivation techniques to enhance the production of needed resources and protecting the environment from undesirable hazards. However, the growing human population has placed enormous stress on the Earth in terms of providing clean air, clean water, and arable land for the production of food.

Humans have also had a profound impact on the earth's climate. As documented by published reports by the Intergovernmental Panel on Climate Change (IPCC), at least since the time of the Industrial Revolution human activities have vastly increased the concentration of greenhouse gases in the atmosphere to levels unprecedented in the past 800,000 years, and it is extremely likely that human influence has been the dominant cause of the observed warming at the surface of Earth since the mid-20th century (IPCC, 2013). In addition, projected reductions in surface ice caps, sea-level rise, more extreme weather events, and ocean acidification due to carbon dioxide emissions are all anticipated to have significant consequences for ecosystems and human economic and cultural systems, which cannot be fully predicted.

Climate change has been identified by numerous scientific agencies as one of the grand challenges of our time. Resolution of this challenge will require a human response – one that is informed by scientific understandings as well as active debate about economics, policy, politics, and ethics. Global climate change is distinguished as one component of this DCI that has gained increasing attention and consideration by the scientific community as well as by society as a key driver of a current profound environmental change on the planet. Understanding climate change requires a rigorous understanding of the nature of matter and energy, the chemical changes involved in combustion, the impact of climate on habitats and the diversity of life these habitats support, and other key concepts in the life and physical sciences. Like many of the other grand challenges we face today, sophisticated understandings draw on multiple disciplines not only in the natural sciences but also in social sciences and humanities.

Component ideas of this DCI identified by the *Framework* are (A) Natural Resources, (B) Natural Hazards, (C) Human Impacts on Earth Systems, and (D) Global Climate Change. These four ideas overlap significantly. For example, our use of natural resources that produce greenhouse gases influences climate change. Climate change influences natural hazards such as extreme weather events and sea level rise.

Component A of this DCI, Natural Resources, focuses on how humans depend on a variety of natural resources, including air, water, soil, minerals, metals, energy, plants, and animals. Some of these are replaceable/renewable in the timeframes of human lifetimes; others are renewable on the timeframe of many generations; and others are essentially not replaceable. Understanding the nature of renewable and non-renewable resources necessitates consideration of responsible short term and long term management. Many of the material resources necessary for industry are not distributed uniformly over the planet, and where present, often require processing to increase concentration to a level required for use. Human populations have been drawn to live in areas that offer ample natural resources, and over time as the population has increased in both specific areas and overall, such natural resources have become scarcer.

Component B of this DCI focuses on natural hazards. Humans and the environment are affected by natural hazards such as severe weather events (floods, blizzards, droughts and hurricanes), earthquakes, volcanic eruptions, wildfires, landslides and coastal erosion. These events have the ability to disrupt populations and activities, and cause significant changes to the physical environment. Through a combination of historical and current observations and understanding the ways in which global Earth systems interact to create such events, humans have a good understanding of where such natural hazards commonly occur and the conditions that create them. Although these natural hazards cannot be prevented, humans use their understanding of where and how such events typically take place in order to design systems that can protect and mitigate against the severe affects of these events, as well as developing increasingly more accurate prediction systems.

Component C, Human Impacts on Earth System, focuses on the impact of human activities on the environment, particularly those related to meeting the needs of an increasing and industrialized human population. We have modified the shape of rivers, created lakes, and removed water from underground. We have transformed large areas of forests, grasslands, and wetlands into agricultural areas or human settlements. Over time, humans have become one of the most significant agents of change to the Earth’s interconnected systems, with rippling impacts that cause both anticipated and unexpected changes across systems. For example, these human actions have altered or eliminated many natural habitats and led to the extinction of numerous species. Pollution caused by human activities has affected the condition of the atmosphere, rivers, and lakes, harming organisms and impacting human health. Human activity has affected the environment in ways that have resulted in changes in the number and frequency of natural hazards, such as storms and droughts. However, with sustained effort and responsible management, some of the negative impacts of human activities on Earth systems can be reduced or even reversed. Examples include regulating the amount of contaminates that are released into the atmosphere and water systems, which has reduced acid rain and stream pollution over time. Similarly, the development of new alternative energy sources combined with greater efforts to reuse and recycle existing materials can lessen the environmental impacts that would have resulted from the use of fossil fuels.

Component D of this DCI, Global Climate Change, focuses on the notion of climate change as a driver of change on the Earth’s surface processes. It exemplifies the interaction of humans' activities and natural effects, which in the case of climate, is predicted to have major environmental and societal consequences if humans do not engage with informed personal and societal action. Through using scientific evidence of past climate conditions to develop predictive models, we have the capability to anticipate the ways that the climate will change over the long term and how the other earth systems will respond to these changes. Many of these changes and responses will be uneven, and will impact various regions of the globe differently. As such phenomena are incredibly complex with numerous natural, economic, political and behavioral factors affecting the long-term outcomes, there are inevitable uncertainties in these model forecasts. However, climate change models provide data that can be used to make informed decisions and plan for ways to address and adapt to the anticipated future environmental conditions.

This DCI is also strongly related to other disciplinary core ideas such as ESS-2 – Earth systems. Understanding how humans interact with the earth requires a more fundamental understanding of the earth's systems and how energy and matter are cycled through the hydrosphere, geosphere, and atmosphere over scales that range from the global to the microscopic and from timescales of billions of years to fractions of a second. LS-2 – Ecosystems: Interactions, energy and dynamics is also highly relevant to this DCI since understanding the interaction between living and non-living components of an ecosystem is necessary to explain how ecosystems can be affected by human-induced physical changes such as ocean acidification or the salination of soil due to sea level rise.

Existing standards such as National Science Education Standards (NRC, 1996) include expectations for learning about human use of natural resources. However, there are very few expectations articulated for student learning about anthropomorphic climate change. NSES was published in 1996, eleven years prior to the first IPCC report. This DCI is consistent with established science since the publication of NSES.

How do students' understandings of this DCI develop over time?

Throughout their K-12 science education, learners are expected to develop an understanding of how now, unlike any other time in the Earth's and human history, the planet's surface processes and human activities are interacting in ways that are resulting in significant changes to the environment (Earth Science Literacy Initiative, 2010; National Geographic Society, 2013).

Elementary School

In early elementary school, the Earth and Human Activity DCI expects that learners will recognize that natural and human activities can influence natural resources such as land, water, air, and other living things in the local environment (Component A: Natural Resources). Learners gain the understanding that meeting the needs of living things, including humans, requires an understanding of the need to locate and process natural resources. For this component idea, learners might investigate habitats and the basic needs of living things in their local area. For the Natural Hazards component idea, learners might investigate severe weather phenomena, as well as the ability to forecast and respond to natural hazards. In upper elementary school (grades 3 to 5), learners will progress in their understanding that natural and human actions are related to environmental challenges. They should consider ways to prepare for natural hazards (such as developing warning systems for earthquakes, volcanic eruption, tsunamis and forecasting severe weather) and consider ways to reduce the human impact on the environment. At this level, learners should be able to use science ideas to consider means for protecting Earth's resources (e.g., renewable and nonrenewable energy sources) and reducing natural hazards and human impacts of Earth's processes.

Middle School

In grades 6-8, the Earth and Human Activities DCI progresses by introducing more sophisticated concepts related to human use of natural resources and to monitoring (with the goal of predicting) and mitigating environmental hazards. While most environmental hazards cannot be eliminated, they can be reduced (e.g., by locating and avoiding hazardous danger zones). At this level, students will investigate more deeply the geologic phenomena that cause natural hazards. Here, after learners have had opportunity in earlier years of schooling to gain an initial understanding that natural and human effects may interact to impact the environment, specific impacts of global climate change are introduced, such as global atmospheric warming. Humans are recognized as the most significant agent of change to Earth's systems. For example, human activities have significantly altered the biosphere by changing or destroying natural habitats, resulting in the extinction of many living species. Emphasis is on understanding distributions of natural resources; forecasting and mitigating natural hazards; designing methods for monitoring and minimizing human impacts on the environment; studying the effects of resource consumption on Earth systems, and factors that have caused the rise in global temperatures over the past centuries.

High School

In grades 9-12, the Earth and Human Activities disciplinary core idea expects learners to engage in developing sophisticated understandings of the complex and dynamic relationship between humans and the Earth System. Learners understand how economic, social, environmental, and geopolitical dimensions interact. Learners recognize how the availability of resources guides the development of human society and how benefits as well as risks (e.g., economic, social, environmental, and geopolitical) are associated with resource extraction. Learners understand how natural hazards have been a driving force throughout human history, including on population changes and migration. Some natural hazards (e.g., flooding, forest fires) are increasing in frequency and intensity due to increases in human population densities in areas prone to environmental changes. They explore how international agreements regulating human activities may mitigate the extent of these global impacts (e.g., acid rain and the ozone hole). As part of the Human Impacts component idea, they also consider the role of scientists and engineers in developing technologies that produce less pollution and waste, and how these developments may aid in maintaining the biodiversity necessary for a sustainable future. Since global climate change is so complex and may occur slowly over time as well as quickly, climate modeling is used to understand the process. How the ocean, atmosphere, and biosphere interact and are modified in response to human activities is under active investigation. For example, understanding the current health of the coral reefs (the biosphere) necessitates consideration of how a human activity—releasing increased amounts of carbon dioxide in the environment (the atmosphere), has resulted in the acidification of the coral reefs' environment (ocean).

A Case in Point:
How Learners Develop An Understanding of Global Climate Change

Woven throughout the Earth and Human Activities DCI are concepts relevant to understanding the topic of global climate change (NOAA, 2009) in progressively more sophisticated ways. Due to increased attention to human produced (anthropogenic) climate change as a significant driver of ongoing changes in the environment that must be monitored carefully (Moran, 2010), and as it exemplifies a key aspect of the interactions between natural and human systems that is a focus of the Earth and Human Activities DCI, we present it in additional detail[1].

Elementary school: Foundations for understanding global climate change

Beginning in the early elementary grades, the ESS3 DCI emphasizes that learners need to understand that human activities influence resources in the local environment, land, water, air, and other living things. This idea is foundational for later explorations of global climate change. In developing an early understanding that human activities can and do impact the natural environment, learners will be better equipped to understand the specific contributions of human activities to global climate change. By upper elementary school, the ESS3 DCI elaborates upon the idea of human actions related to environmental problems and solutions. One key focus is on learning about renewable and nonrenewable energies, and how their use affects the natural environment. In learning about the ways in which various forms of energy are generated, learners gain foundational understandings of the connections between energy, natural resources, and sustainability. Building on standards from earlier grades, learners might consider specific impacts of energy choices.

At the elementary school level, an early understanding that humans can incite positive environmental change may have important affective implications for later

[1] Climate change education is the focus in our NSF-funded project MADE CLEAR (Maryland and Delaware Climate Literacy Education, Assessment, and Research), www.madeclear.org; www.ClimateEdResearch.org).

introductions to global climate change, empowering learners to consider ways they can contribute to productive solutions as scientifically-literate citizens, and potentially, as future practicing scientists or engineers. A performance that is posited to be particularly effective in learning this DCI is for learners to communicate solutions for reducing human impact on the local environment. Initially, the expectation is on solutions that are accessible to young learners (e.g., reusing paper, recycling cans and bottles), and that pertain to the local environment (i.e., familiar to and experienced by the learner), in order to make concrete the concept of solutions that reduce human impact on the environment. By fifth grade, learners should be investigating and synthesizing information about ways individual communities use science ideas to protect the Earth's resources and environment. At the upper elementary level, learners could meaningfully develop this DCI through student engagement in research of their own community's climate change mitigation practices, or case studies across local or global communities.

Middle School: An explicit focus on learning the drivers of climate change

At the middle school level, the component core idea of global climate change takes a step forward in sophistication by focusing more explicitly on the topic. Most directly related is the emphasis on learning about factors that have resulted in the rise in global temperatures over the past century. Learners may benefit from examining human activity factors, such as fossil fuel combustion, as well as natural processes, such as volcanic activity. Of prime importance is to learn about the role of human activities in contributing to the rise of global temperatures. Related to understanding this idea are investigations such as examining issues concerning population growth and per-capita consumption of natural resources, and constructing arguments about how such factors impact Earth's systems. These topics have a clear connection to understanding the drivers and mechanisms of human activity impacting global climate change, especially as learners examine consumption of energy resources or, perhaps, consumption of food products whose production may contribute to changes to Earth's terrestrial, aquatic, or atmospheric systems.

Middle school learners also are posited to benefit from learning about climate change by investigating solutions to environmental issues. They could design methods for monitoring and minimizing a human impact on the environment, such as by protecting and restoring wetlands which is a critical concern for coastal communities needing to buffer the impacts of climate change due to sea level rise and storm surge. Middle school learners also are posited to be able to engage productively in using data to forecast future catastrophic events in order to inform the development of technologies, such as technologies for forecasting hurricanes and floods, which could be used by community members to mitigate and adapt to severe weather.

High School: Deepening and broadening an understanding of climate change

In high school, learners build upon their learning about forecasting catastrophic events and mitigating human impact on the natural environment now with an increasingly direct emphasis on global climate change. Examining the nuances of the dynamic relationship between humans and the Earth system, especially through the lens of global climate change, holds the potential to contribute to the development of the kinds of science and engineering literacy that will prepare high school graduates to address major global environmental challenges. For example, high school learners should be able to analyze geoscience data and climate models (e.g., precipitation or temperature data) in order to forecast and plan informed actions based on rates of climate change and associated future impacts such as changes in sea level and glacial ice volumes. An added dimension is movement from consideration of the impact of climate change from a focus on regional changes to global ones. This emphasizes the idea that climate change has differential impacts across the Earth, depending upon various geophysical factors. By the end of high school, learners should have analyzed at least one example of a climate change and forecasted its associated impacts. By building on their thinking about design solutions from middle school, high school learners should also evaluate or refine technological solutions for reducing impacts of associated activities on natural systems. One example would be for them to critically evaluate the use of large-scale geoengineering solutions for altering global temperatures.

At the high school level, learners examine global climate change from a variety of perspectives. They illustrate the ways in which human activities are modifying the relationships amongst Earth systems, as well as the ways in which issues associated with natural resource use (e.g., fossil fuel consumption) and natural hazards (e.g., severe weather potentially associated with climate change) have influenced human activity. As human activities lead to changes on Earth, changes on Earth lead to changes in human activities. For example, an examination of changes in sea level reveals that new patterns of temperature and precipitation, and changes in the types of agriculture that are possible and impossible in new climatic conditions, can have significant impacts for human populations—potentially even driving mass human migrations which will place stress on the world's social systems.

Learning challenges for students

Understanding the disciplinary core ideas associated with Earth and Human Activity presents several challenges for students. One major challenge for students' understanding of Earth and environmental sciences is conceptualization of large spans of time and space. Students often have difficulties understanding the vastness of Earth's and the universe's history (e.g., Dodick & Orion, 2003; Libarkin & Anderson, 2005). Deep time refers to the knowledge that the universe has existed for an extraordinarily long time and also that life, especially humans, have existed for a brief period of that history. Countless millennia or even thousands of years are conceptually challenging notions for students to grasp in relation to their comparatively short personal life history of only a decade or two. Robust understanding of the notion of deep time, however, is particularly relevant as students consider the use and formation of natural resources, ESS3.A. Many students have difficulty understanding the span of time required to generate fossil fuels and the rate at which humans consume this resource relative to its formation. Students also struggle to understand why natural resources are concentrated in some geologic areas and not others, making the notion of resource reliance hard for students to grasp. The idea of deep time is one that is needed for understanding Earth and Space science described in the framework and NGSS, as well as in life sciences like evolutionary biology.

In addition to deep time, the understanding of geographic scale is another important discipline-wide challenge that students encounter (e.g., Dickerson, Callahan, Sickle, & Hay, 2005; Jones, Tretter, Taylor, & Oppewal, 2007; Tretter, Jones, & Minogue, 2006). The scale of the Earth is so grand that students frequently have conceptual difficulties with understanding the relative impact of local, regional, or global issues. For example, exploring scale in terms of ESS3.B: Natural Hazards proves challenging for many students who consider events like hurricanes as only relevant to Florida, earthquakes to California, or that tornadoes exist that are large enough to cause damage across an entire state, such as Kansas.

Understanding the mechanisms underlying geologic and climactic events is a third challenge for many students. Too often students reflect on superficial aspects of events, such as identifying only the inputs and outputs of systems, without knowing how or why events take place. Without a mechanistic understanding of events, students may have difficulty predicting future events based on data or interpreting graphic representations of data that illustrate future scenarios. This is particularly relevant for notions of global climate change – ESS3.D. For example, to explain global climate change students can often identify that an increase in CO_2 (an input) will cause temperatures to rise thus causing glacial ice melt and sea level rise (an output), but students often fail to grasp the mechanism by which those two events are related (e.g., the enhanced greenhouse effect) or how rises in global temperature can be mitigated (e.g., Boyes & Stanisstreet, 1993, 1994, 1997, 1998, 2001; Choi, Niyogi, Shepardson, & Charumsombat, 2010). Without an understanding of the mechanism, students lack the capacity to consider ways they as individuals or as a part of society can contribute to reducing human-induced climate change and the relative contributions specific actions provide to changes in climate (Jin & Anderson, 2012; Osterlind 2005; Smith, Wiser, Anderson, & Kracjik, 2006).

The *Framework* also acknowledges the social implications of the disciplinary core ideas relevant for Earth and Human Activity. Influenced by alternative views, students frequently have difficulty understanding how social, economic, and political factors shape human impact on the Earth systems and vice versa (Roth & Lee, 2004; Sadler, Simmons, & Howes, 2005). Many students conceive of events like global climate change (ESS3.D) to affect only natural systems (e.g., water, carbon, and energy cycles). In many instances students do not consider how a changing climate can also affect humans, especially in terms of the relevant social, economic, and political implications that influence actions such as global climate change mitigation efforts. Many students believe that reducing greenhouse gas output is a straightforward charge. However many other factors act as obstacles for reducing use of fossil fuels and increasing use of renewable energy sources that do not contribute to a changing climate.

Lastly, understanding how their personal contributions can impact the environmental issues challenges students (Andersson and Wallin, 2000; Boyes & Stanisstreet, 1993, 2001; Lester, Ma, Lee & Lambert, 2006; Pruneau, Gravel, Borque, & Langis, 2003; Skamp, Boyes, & Stanisstreet, 2013). Often students feel compelled to contribute to environmental issues in meaningful ways, but have difficulty identifying productive strategies or methods that have lasting impact. For example, students have reported that participating in beach cleanups, reducing aerosols spray usage and recycling plastic materials were all actions that could be taken to directly mitigate global climate change (e.g., Pruneau et al., 2013). In many cases these actions contribute to the sustainability of ecosystems, reduce the impact of natural hazards (ESS3.B), and improve the longevity of natural resources (ESS3.A), but have little or no impact on reducing human induced climate change.

What approaches can we use to teach about this DCI?

Encouragingly, earth and space sciences offer many opportunities for students to learn about current environmental issues, consider ways in which they can contribute to engineering design solutions, and understand how Earth's systems interact with one another to support global, regional, and local ecosystems. Learning the disciplinary core ideas to support understanding in this topic area is not trivial and requires specific supports that teachers can provide.

First, from the perspective of challenges to students' understandings of a disciplinary nature, it is critical that students can not only distinguish between, but also make connections across local and global phenomena (e.g., Clark, Sibley, Libarkin, & Heidemann, 2009; King, 2008). It is important to address how large-scale environmental and climactic events can also manifest themselves on a regional or local scale and vice versa. When teaching this idea it is important that students understand that natural processes can take millions or billions of years to drive environmental and climactic changes. Only recently have humans generated changes that occur more rapidly than ever seen before in Earth's history. Students may benefit from interactive models that represent such changes over time. To demonstrate more recent changes, one example is NOAA's Global Climate Dashboard that provides an interactive mapping of climate change factors, climate variability, and climate predictions from 1880 – 2090 (NOAA, 2014). Other resources demonstrate changes over much longer spans of time. For example, NASA provides teaching materials that use real world data to track CO_2 levels in the atmosphere up to 400,000 years ago (NASA, 2013). Importantly, the resource also describes how scientists collect and interpret the data that support the finding that CO_2 levels are on the rise.

Not only are these core ideas complex in terms of the science knowledge needed to think deeply about environmental issues, these ideas are often associated with sensitive topics such as food and water scarcity, land use, economic and policy issues, among many others. This complexity can often excite students when learning about environmental science, but may also overwhelm students who wish to contribute to the mitigation or adaptation of environmental issues both locally and globally. Although environmental issues are often a combination of both scientific and social factors, it is important to support students' learning of the science behind such issues using real world data and evidence first and then turn to discussions of the economic, political, and social implications. Often students wonder about their personal stake in environmental issues – i.e., what can they do to help? Teaching science first, followed by other social factors sets the stage for preparing learners to engage with environmental science in ways that are based on scientific understandings.

Incorporating current socio-scientific topics like air and water pollution, chemical food additives, and mining of natural resources, is inevitable under the guidance of the framework, but in doing so teachers need to present fairly and equally the multiple sides of the particular issue – especially the social, political and economic factors involved (Kolsto 2001; Stern, 2007; Zeidler & Nielson 2012; Zeidler, Walker, Ackett, & Simmons, 2002). One means to demonstrate multiple perspectives is through stakeholder analysis – not only human stakeholders, but environmental stakeholders such as animals, plants, and geologic deposits. It is important that students are given opportunities to acknowledge and explore multiple perspectives to gain an understanding of the complexity of issues such as the use of natural resources, the prevalence of natural hazards, and global climate change.

Educators can support students' understanding of the nature of scientific arguments and how evidence is used to support scientific arguments (e.g., Nussbaum, Sinatra, & Owens, 2012; Osbourne, Erduran, & Simon, 2004). Scientific, especially environmental, issues can have multiple points of view from which to approach the problem, each with its own corresponding evidence. Encouraging students to investigate these various perspectives for validity encourages students to analyze and interpret data as well as to develop arguments based on evidence. One way to engage students in this way is to assign students stakeholder roles about an issue and ask them to investigate, support, and refute their positions. In this case, it is important to incorporate the primary scientific knowledge needed to understand the issue, but to also emphasize the diversity of drivers behind each position, whether they are political, economic or social in nature. For example, students can participate in the *Great Energy Debate*. This lesson, designed by National Geographic, encourages students to research types of energy used in the US and within their communities, describe how energy consumption can impact land use, and to take stakeholder positions in a mock debate format in order to argue from evidence different perspectives on energy generation, sustainability, and land use (National Geographic Education, 2014). The National Science Teacher Association (NSTA) also offers similar resources to help teachers and students examine environmental issues using this case study approach to investigate various perspectives. For climate case studies, *Climate Change from Pole to Pole* and for energy related content, *Fuel for Thought* offer additional resources for middle and high school teachers. For an even greater variety of science content case studies and lesson ideas, the National Center for Case Study Teaching in Science provides numerous plans and teaching ideas that are readily available online. Through a case study approach, students develop their content knowledge about natural resources (ESS3.A) and their capacity to analyze and interpret data and ask questions from critical perspectives. Activities such as the *Great Energy Debate* can also link to the other disciplinary core ideas such as global climate change (ESS3.D). For example, students may also debate over the impact a changing climate will have in their local area on energy source access and how to sustain future development (ESS3.C) in light of the increase of future natural hazards (ESS3.B).

Finally, educators should strive to provide students with realistic and meaningful ways of contributing to the issues (e.g., Anderman, Sinatra, & Gray, 2012). Students often feel compelled to take responsibility for their actions in ways that improve environmental issues and too often messages about environmental issues take on doom and gloom perspectives that can paralyze learners. Helping students identify ways they can make a personal difference at home, and within their school, community, and society improves students' engagement with science. A positive strategy is to accompany lessons on environmental science topics with clear action statements that can provide students with a means for engaging in the topics. These positive experiences need to be integrated into the learning experience to encourage students to act on an individual, family, school, or community level to address the problem. Incorporating students' families and communities participation through events like science nights or green carnivals offer ways for students to demonstrate their science knowledge while also engaging others in learning about appropriate civic action for these environmental issues (Birmingham & Calabrese Barton, 2014).

Another strategy for initiating discussions about meaningful environmental actions is to help students understand how they personally use natural resources. For example, using a carbon footprint calculator is one way students can determine their energy use and carbon outputs in their home, school, and community. From this information students can begin to explore specific methods to become efficient energy users. Interactives, such as the climate change mitigation simulator featured by the National Academy of Sciences, offer students a portal for engaging in salient mitigation and adaptation strategies (NAS, 2014). The American Association for the Advancement of Science (AAA) offers lessons such as *Energy for You* that help students identify energy sources in their communities using real world data and provides examples of how to maintain and preserve energy resources for future generations (AAAS, 2014). Additionally, project InTeGrate (Interdisciplinary Teaching about Earth for a Sustainable Future) offers teaching resources adaptable for high school classrooms that encourage students' awareness of and participation in mediation strategies (InTeGrate, 2014). It is important that lessons addressing the disciplinary core ideas within Earth and Human Activities end with a hopeful message for change and offer students specific methods for becoming environmentally savvy in their daily lives.

Conclusions

Of all the fields of scientific study, the earth sciences are one of the most interdisciplinary. This is particularly true for the disciplinary core idea of ESS3: Earth and Human Activity, which focuses on society's interactions with the planet's complex systems. Duschl, Bismark, Greeno & Gitonmer (2013) note that there has been very significant change in the nature of earth science research with advances in technology.

Historically the earth sciences have been oriented toward solving very practical problems of commerce and industry. For example, mapping the earth's terrain was key to establishing the transportation pathways to facilitate trade. Mining and energy exploration required a thorough understanding of geographical formations. Today, earth sciences research is motivated by a different set of concerns and utilizes different methodologies. Changes in technology have enabled the development of sophisticated visualizations and quantitative models for exploring, explaining, and predicting earth's complex systems. In particular, understanding the earth requires reasoning across multiple systems, such as the biosphere, the hydrosphere, the geosphere and the atmosphere. This research is driven by the desire to create predictive quantitative models that can provide the detailed knowledge to explain and explore an ever-changing biosphere. The component ideas of ESS3 reflect this contemporary view of the earth sciences.

The biggest takeaway from this chapter's overview of ESS3 is the central understanding that natural effects and human activities are intimately linked in some clearly identified ways. This realization, strategically advanced across K-12 schooling as guided by the *Frameworks*, offers opportunity for humans to take informed and responsible actions (individually and collectively) to produce and maintain a sustainable planetary environment.

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