Climate Change and Global Warming

Balance and Perspective in our Middle and High School Classrooms

Caroline Martin

It is my observation that, in recent years, a disjoint has emerged between what we teachers imagine life holds in store for our middle and high school students and what they imagine for themselves. Rates of depression and anxiety in the teenage population are believed to be at an unprecedented high. Many attempts to explain this have aimed one glaring eye at smartphones and another at the existential threat that climate change poses. In our classrooms, we are uniquely positioned to offer inspiration to the youth of today, to empower them to take active part in the shared endeavor of making this world a better place for all.

There is scarcely an academic subject touching on a wider variety of areas than climate change. As a discipline, it has as equal a footing in university classrooms of sociology, politics, and philosophy as it does in those of engineering and the physical and biological sciences. And yet, it is amongst the newest areas of study taught in middle and high school classrooms, and with its inception has come a unique set of exertions for the teacher.

Diversity of subject matter in and of itself certainly puts an onus on the teacher to read more widely and experimentally than for the more established disciplines. For the latter there are available several decades worth of reliable curricular exempla replete with canonical textbooks, but climate change also stands aloof amongst these mainstay disciplines for the near impossibility of its being taught in the abstract, that is, for the near impossibility of teaching it without evoking a palpable feeling of threat. In fact, it is a striking feature of 21st century education that many middle and high schools are offering climate change courses designed explicitly to prepare the upcoming generations to understand and tackle a very real and somewhat imminent suite of catastrophes for humanity.

The mere catalogue of problems pertaining to this crisis is dizzying, ranging in dynamics from scorching temperatures or widespread floods in some reaches of the globe, to infectious disease outbreaks or failure of the cocoa bean in others. It might seem curious to list the potential loss of chocolate here, but for West African countries, such as Ivory Coast and Ghana, who produce up to two thirds of the world's supply, failure of the cocoa crop means economic disaster. Irrespective of complex feedbacks, what is most alarming is the conviction with which these problems are propounded, their having been researched and ratified by the soundest scientific minds of our time, with the resounding argument being that there is a looming threat to the global civilization. It is undeniably helpful, and not just for the teacher, to know that there is a giant problem of global reach to be tackled, but what makes it exceedingly difficult, particularly for that teacher, is that the threat, in some form or another, is broadcast sub-daily, often in the personalized newsfeeds of our and our students' smartphones, causing goodness knows what degrees of alienation, subconscious panic, numbing, and attention wandering. We regrettably carry the threat around with us in our pockets, intermingled with our social lives, shopping lists, podcasts, photo galleries, and bank accounts. And thus it is that the shared experience of teachers and students alike results in our spending several waking hours immersed in a flood of information, no small part of which pertains to a "doomed" planet.

With an emphasis on STEM beginning in many kindergarten classrooms, the age of awareness of global threats is increasingly younger and younger. As is attested to by my public-school-attending nine-year-old's ready ability to recite the harmful effects of extreme weather events, climate change subject matter, sadly, in many an early-stage classroom is in no way sugar-coated for ease of children's digestion. Unlike the abstraction permissible for many other subjects, the problems that we are encountering because of climate change make it difficult for teachers to pose such problems as specific tools designed to teach the fundamental tenets of, say, scientific investigation. For example, it is too tempting, while teaching the logarithmic arrangement of the pH scale, to avoid informing students that ocean acidification could cause the collapse of the marine ecosystem – after all they will hear and see it on the news anyway. At least in Waldorf school classrooms, teachers can deliberately choose when and in what manner to introduce both conceptual and actual ramifications to children. Like most pedagogically appropriate lessons, at least through grade 9, a reflection of reality can sometimes be healthier than reality itself.

Providing ballast against this information overload, and plenty of complementary teaching tools and career incentives, is the treasure of positive initiatives, from

the steerings of intergovernmental policy to local grassroots efforts (I'm especially grateful for the incredible Threefold campus, home to the Green Meadow Waldorf School, for its many Earth-embracing enterprises, and to the Rudolf Steiner School in Manhattan, for providing an abundance of nature and narrative in a jungle of concrete). The Paris Agreement, entered into force in November 2016, has promoted peace and positive growth among 196 or so often otherwise disparate nations. Many laudable organizations, such as the U.S. National Science Foundation, have funded incredibly innovative research endeavors, opening up avenues of collaboration and inspiring scientists, engineers, policy makers, farmers, local activists, authors, and children to work together for the greater good of our planet. In the middle ground, a host of formidable organizations, such as our universities, research institutions, and museums, offer high school students merit-based internships to train in research techniques specifically to tackle climate change. One leading organization for offering student internships is the Woods Hole Oceanographic Institution, in Cape Cod, MA, where a host of environmental projects are offered annually that help pave the way towards leading careers in science and engineering.

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Contrast this picture with the final decade of the previous century, when, as a high schooler who elected to study geography, I was taught to avoid throwing my candy wrappers on the sidewalks (or "footpaths," as they are called in Ireland) and to preferably purchase "non-CFC" aerosol products because there was a hole, somewhere above the Southern Hemisphere, in something called the ozone layer, which is part of something with even remoter reaches called the stratosphere. In geography class, I also, among other things, learned about the meanderings of rivers, the ecology of the permafrost, the anatomy and action of glaciers, the economic contrasts across different regions in Italy, longshore drift, and the definition of "pig iron." Whilst I may have been cautioned as to how many cups of water it takes to make a carton of orange juice, our different modules in geography were taught to us as individual facts in isolation. We did not learn how steel production in China, and our consumption of that product in the West, contributes deleteriously to a rise in greenhouse gases; nor did we learn that a melting permafrost does the same. Instead, we learned that groins and jetties would protect our beaches and not to build a house too near a cliff's edge. I was not taught to unite different complex geological processes and diverse human economic activities into one global picture of critical concern. This I learned to do in the 21st century, as an adult, while reading for a PhD in geochemistry.

Back in the late 20th century, I and my adolescent pals, in our combined good fortunes of geographical isolation and geological ignorance, were free from any internalized weight of burden of responsibility, hence we were free from any consequent inertia. In contrast, we most assuredly rebelled a little during the early stages of the anti-litter and anti-CFC campaigns of the time, gaily throwing candy wrappers on the footpaths, precisely because we were told not to, and unashamedly ignoring deodorant labels, choosing our purchases instead on the basis of scent or what was otherwise most fashionable. Whilst we did come around eventually to better practices and sounder judgements, it is important to acknowledge that such inane behavior is almost the birthright of the teenager, forming part of a series of blunders we all at that age make, one lending itself so favorably to correction and the healthy shaping into adulthood of the growing child. At no point during my perpetration of adolescent indiscretions did I internalize environmental threat or believe that I was the cause of any real harm to our planet. Nor, by the by, was I then capable of conceiving that my education and actions could be part of an adventurous solution to an environmental and existential crisis of the magnitude of climate change.

What I have learned from my healthy teenage experiences and from my research into the chemistry of Earth's thermostat is to offer balanced subject material in my science courses, to both my middle and high school students, with careful consideration as to when and how I introduce the current condition of climate change on Earth, and I am grateful that the Waldorf community actively encourages my and my colleagues' efforts to provide rich and varied experiential and theoretical contexts and perspectives.

One particular distinction I find imperative to uphold is the one between "climate change" and "global warming." "Climate change," a phrase evocative of much disaster to some, while giving much reason for sneering to others, has become synonymous with "global warming," a choice and deliberate coinage introduced into the scientific lexicon in August 1975 by Wallace S. Broecker,[1] renowned geochemist who has spent 67 years researching Earth's ocean-climate system at Columbia University's Lamont-Doherty Earth Observatory. Climate change, a combined effect of many planetary and solar-system processes that shifts over varied and lengthy stretches of time in response to perturbations to, and oscillations within and between, these processes, has been the status quo on Earth for the entirety of its vast 4.543 billion year history (see my colleague H. Gilbert's article, also in this issue of the *Research Bulletin*, about Phanerozoic climate change). Global warming, defined by the National Defense Research Council as the observed increase in global annual temperature since the Industrial Revolution,[2] refers specifically to the shifting that Earth's climate system is experiencing today, and as such, is a sub-component of the discipline of climate change.

It is accurate and imperative to state that the climate change we are experiencing today, that is, global warming, is injurious to human civilizations, and it is vital that we, in our classrooms, arm the upcoming generations with the awareness, compassion, and skill sets, to further essential mitigation efforts. It is also probably accurate and nonetheless imperative to state that teenage mental health today is in a condition of notable decline compared to just a small number of decades ago. Whilst neither climate change nor global warming can be directly or solely blamed for the observed decline in teenage mental health in the 21st century, the feelings of existential threat that teenagers today admit to, combined with their experiences of isolation that is their screen-fueled reality, tasks teachers of climate-change related subject matter with delivering pedagogically-resonant course material and activities.

It is therefore imperative that teachers instill in our students today a view of Earth that is robust in its ability to rebound against a backdrop of constant change. No catalogue of extreme weather events today can rival, at least in time, the knife's edge that life has flourished on for the past several hundred million years. It is a comfort to young students, exposed as they are to newsfeeds that often coldly present only grim facts, to know that our history is one of persistent triumph. Given that teachers cannot shield even young students from awareness of a threatened world, we can instead provide sources of inspiration to them in teaching them that there are many wonderful ways in which they can contribute to the success of our environmentally conscientious endeavors.

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Alongside the unavoidable prophecies of doom, such as are provided by extinction statistics, images of famine, reported death tolls following flashfloods and landslides, video footage of storm surges and hurricanes, and so much more that pops up on smartphones, there should be showcased within this ever-changing landscape, the adaptability and resilience of life, the nothing short of triumphant and heroic travails that the ever-evolving cast of characters comprising Earth's lifeforms have surmounted, and continue to surmount, as together we meet the demands of an ever-changing planet. In point of fact, merely teaching the blunt forecasts and grim deductions that arise from analyses of, say, graphs depicting rises in sea-surface temperatures, may be as directly injurious to the teenage population as global warming to human civilization.

Life on this planet is, and has been for eons, characterized by nothing short of miraculous adaptability and resilience. Teenagers today should be presented with not just the Keeling Curve,[3] the painstakingly compiled daily record of atmospheric CO2 concentration since 1958, but also with Sepkoski's Curve,[4] the vast record of diversity of marine taxonomic families over the course of the past 542 million years. Both graphs can serve to teach many interesting facts pertinent to chemistry and biology, and many interesting skills requisite for a career in data analysis, but only the latter graph

1 Broecker, W. S. (1975). Climatic change: Are we on the brink of a pronounced global warming? Science, 189(4201), 460-463. DOI: 10.1126/science.189.4201.460

2 See the online article "Global Warming 101: Everything you wanted to know about our changing climate but were too afraid to ask," by Amanda MacMillan and Jeff Turrentine, first published on the Natural Resources Defense Council (NRDC) website in March 2016, most recently updated on December 2024: https://www.nrdc.org/stories/global-warming-101

3 This is the daily record of global atmospheric carbon dioxide concentration, maintained and updated daily by the Scripps Institution of Oceanography at UC San Diego. See: https://keelingcurve.ucsd.edu/

4 Sepkoski Jr., J. J. (2002). A compendium of fossil marine animal genera. *Bulletins of American Paleontology* (363), 16 Sep 2002: 1-560. https://strata.geology.wisc.edu/jack/

will impress upon young minds that the diversity of life has been steadily increasing over the course of animal history amidst the full gamut of geological and climatic change. Books such as Stephen Jay Gould's *Wonderful Life: The Burgess Shale and the Nature of History*[5] and E. O. Wilson's *The Diversity of Life*[6] provide incredibly convincing reasons to embrace change on planet Earth and a host of innovative solutions to sharing Earth's resources, and should be considered staple readings when climate change is under study. In another inspirational text, S. C. Morris' *The Crucible of Creation: The Burgess Shale and Rise of Animals*, the author writes:

> We live on a wonderful planet that not only teems with life but shows a marvelous exuberance of form and variety. In comparison with the size of the Earth, its living skin (the so-called biosphere) may be thin, but it is by no means negligible. From high in the atmosphere, where ballooning spiders wafted aloft on their silk-strings have been trapped at heights of more than 4500m and birds such as condors cross tropical storms at altitudes well above 6000m, via the oceans and the green continents, to deep within the Earth's crust where bacteria are known to live at depths of at least several kilometers, life is pervasive.

Whilst global warming does sadly define the state of change that Earth's climate system is experiencing today, and whilst climate change is a much broader topic that extends far beyond the current status of today's environmental crisis, it is vital that in presenting to students hazardous environmental scenarios that the broader features of an evolving and adapting biosphere be brought with equal force to the foreground. Again, it is a comfort to our students to know that the planet and its lifeforms have persisted during such events as "Snowball Earth," the "Permian-Triassic Mass Extinction," and the "Messinian Salinity Crisis", and to learn that after each of the "Big Five" mass extinction events, life radiated and diversified beyond the levels in each preceding period.

It is also vital in our teaching to ensure against the misuse of negative phraseology. The overall warming trend, attributable to the rise of greenhouse gas levels in the atmosphere, can be taught to students as an enhanced "greenhouse effect" with concomitant consequences for the global ocean system. The rise in the concentration of greenhouse gases serves to explain the consequent rise in sea surface temperatures and thus the melting of polar icecaps, the rise in sea level, and the intensification of storms. With these come the terrestrial impacts that dramatic changes to the global system can wreak, such as flashfloods, droughts, and forest fires – what have come to be termed "extreme weather events." Major disruption to ecosystems, such as that which the decline in health of coral reefs can give rise to, is also attributed to the rise in greenhouse gases. Not only are corals sensitive to temperature, but also to the carbon chemistry of the ocean waters from which they source the material to build their skeletons. The reefs that they build provide nurseries for a multitude of fish and as much as 25% of marine lifeforms are known to spend at least part of their life cycles dependent on the ecology of coral reefs. Precisely because of this cascade of intertwined hazards, it is always important to point out to students that without the greenhouse effect, conditions at the surface of the Earth would be too cold to support life as we know it. This is in no way stated to debunk claims that greenhouse gas emissions should be severely curtailed – they should, and our students should know as much – but rather to debunk the negative connotations of the phrase "greenhouse effect," which when used repeatedly and narrowly serves only to numb and alienate the student.

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What we must achieve in our climate change classrooms today is a set of courses, conditions, and boundaries that promote the healthy spiritual growth of our teenagers and that preserve their rightful sense of adventure, whilst preparing and training them to understand and tackle problems that are global in scale and fundamental to the continuance of human civilization. No small task, but the worthiest of ones! Mastery of the mathematical and statistical tools needed to generate climate models will in no way compensate for deficiencies in creativity and gumption. Command of thermodynamics might convince a teenager that ocean temperatures are too hot to support the growth of coral reefs but will only poorly prepare them to understand and appreciate how the ocean behaves or how to demonstrate their care. Finessing one's academic skills (often recognized with "As" on tests) is only half the picture; without the human thirst for life to give good grades good meaning, that finesse will be unlikely to

5 Gould, S. J. (1989). *Wonderful life: the Burgess Shale and the nature of history.* New York, W. W. Norton & Company.

6 Wilson, E. O. (1992). *The diversity of life.* Cambridge, Mass., Belknap Press of Harvard University Press.

come to much fruition.

Young teenagers need not be lectured to as to why they're doing something, because their internal growth and development wither under such a surgical spotlight. Even in 9th grade, it is far more fruitful to have students observe outside of themselves, to busy themselves in laboratory work, for example, defining discretely what are the processes and phenomena they encounter there, than it is to have them labor inwardly as to how they feel about why the world is the way it is. In 10th grade, a more interconnected picture can emerge, one where, for example, the acidity that students measure in their test tubes during the Inorganic Chemistry block can be related to how healthy the growth of a coral reef might be. In that grade also, the students can be encouraged to bring over into their science work the skills practiced in the humanities classes of analogy and metaphor and irony, infusing their work with a human perspective that is approaching maturity. By 11th grade, the students are questioning who they are and why they are in this world. It is vital at this stage of their development that they be encouraged to feel they can take on vast journeys across our planet and that in doing so they can bring about positive change in themselves and in the world.

As a scientific, economic, political, and philosophical subject, climate change is rightfully positioned amongst the set of required courses in any middle or high school curriculum, and as such is frequently taught as individual units in as disparate settings as environmental science seminars and government policy lectures. The problems facing inhabitants of an Earth threatened by global warming are at the same time scientific, sociopolitical, and existential, which places an onus on middle and high school faculty to treat these subject matters from multiple inspirational perspectives.

Litter is bad for the environment, as is the mass production of candy wrappers, and chlorofluorocarbons attack the vital layer of the atmosphere that protects life from harmful ultraviolet radiation. This century's stockpile of digital photographs and videos from around the world has ensured that no classroom remains ignorant of the damage wrought by single-use plastics or extreme weather events. The triumphant fall from grace of CFCs, which can be—and in fact has been—summarized on a commemorative plaque at the University of California, Irvine,[7] is an almost quaint but no less forceful reminder that paradigms can shift. The testimony is in and the verdict is 'Guilty!' Humanity is the defendant, but it's not really clear who the plaintiff is. Perhaps she is Earth herself, but I take too much comfort in the geological perspective to fully believe she is not on humanity's side. Our children's imaginations should not too soon and too disjointedly have this potential for humanity's and Earth's working together be transformed into an untranscendable perspective of solidified hostile relations. Instead, I believe in Earth's rocky example, in the only history book that tells no lies, inadvertently or otherwise. I believe that she is kilometers-thick full of the answers we need to better prepare ourselves for a healthy future. I believe that we should encourage our teenage students to trust in the positive changes that their self-awareness, inquisitiveness, and critical thinking can bring about for the greater good of humankind. I believe that our students are the very light of this ever-changing world and that it is our job to ensure that they believe it, too.

Caroline Martin, PhD, *began teaching chemistry at the Rudolf Steiner School in NYC in 2019 and is now part of the middle and high school faculty at Green Meadow Waldorf School in Chestnut Ridge, NY. Caroline has degrees in geology and geochemistry, and in 2014 completed her PhD dissertation on the topic of long-term climate stability. Caroline also conducted climate-related research at the Lamont-Doherty Earth Observatory of Columbia University and at the Woods Hole Oceanographic Institution on Cape Cod, where she was a Fulbright scholar.*

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7 The American Chemical Society's commemorative plaque, recognizing the discovery of CFCs' harmful effect on the ozone layer, was issued at UC Irvine, April 18, 2017, designating the event a National Historic Chemical Landmark. It reads as follows:

> At the University of California, Irvine, F. Sherwood Rowland and Mario J. Molina discovered that chlorofluorocarbons (CFCs) could deplete Earth's atmospheric ozone layer, which blocks the sun's damaging ultraviolet rays. When the scientists reported their findings in 1974, CFCs were widely used as refrigerant gases and as propellants in aerosol sprays. Rowland and Molina convinced skeptical industrialists, policymakers, and the public of the danger of CFCs. The scientists' advocacy — and the discovery by other researchers that the ozone layer over the Antarctic was thinning — led to worldwide phaseout of CFCs and the development of safer alternatives. For their work, Rowland and Molina shared the 1995 Nobel Prize in Chemistry with another atmospheric chemist, Paul J. Crutzen.

The story of the discovery and its effects is available from the American Chemical Society at
https://www.acs.org/content/dam/acsorg/education/whatischemistry/landmarks/cfcsozone/cfcs-ozone.pdf