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# Educating for "intelligent environmental action" in an age of global warming

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> If you want to understand nature, you must be conversant
> with the language in which nature speaks to us.
> *Richard Feynman*[1]

What does it mean to be "conversant with the language in which nature speaks to us," and how do we help others develop this capacity? From a pedagogical perspective, if we want to address climate change and help people become a part of the solution rather than the problem, we must answer this question. One of the authors watched as her two-year-old son took the hand of another little boy on the playground and brought him over to the fence to "see the pretty sunset." His sense of wonder and enthusiasm for sharing it inspires hope for the future, and yet there is strong evidence that people of all ages understand little of the language or patterns of nature. Too often, as children grow up, they lose their appreciation for and sense of connection to the natural world. This is, in itself, a deep loss. But even if we retain an appreciation for the beauty of nature, few of us ever develop an understanding of the inherent complexities and dynamics of our environment. To solve environmental problems, an intuitive appreciation for nature is certainly necessary, but it is by no means sufficient. How do we learn the patterns of nature? How do we encourage the development of "environmental intelligence" and, more importantly, "intelligent environmental action"? With urgent concerns such as climate change on the horizon, the answers to these questions form an educational imperative.

This chapter is based in part upon the work of Understandings of Consequence Project, which is supported by the National Science Foundation, Grant No. REC-9725502 and REC-0106988 to Tina Grotzer and David Perkins, Co-Principal Investigators. Any opinions, findings, conclusions or recommendations expressed here are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Research on people's understanding of global warming sends a clear and compelling message. People, even those deemed well educated, do not hold effective mental models of global climate change upon which to base decisions about their actions (e.g., Bostrom *et al.*, 1994; Sterman and Booth Sweeney, 2002; see also Bostrom and Lashof, Chapter 1, this volume). This research continues to find that people tend to confuse global warming with ozone depletion, do not understand the causes of global warming – rarely mentioning energy use and automobile emissions as causes and naming pollution in general as the most commonly cited cause – and do not realize that even if we act now, we will continue to see an increase in global warming. For example, Sterman and Booth Sweeney (2002) found misconceptions amongst MIT Sloan School of Management students, such as the belief that it would be sufficient to stabilize emissions at current rates, and that we can wait to see what happens and then act. They write that while it is not surprising that school children do not understand the processes governing climate change, it is more disturbing that highly educated adults do not. Disturbing, yes; surprising, well, maybe not ....

In this chapter, we suggest that given the complexity of the concepts and lack of opportunity to learn them, there's no particular reason that non-scientists would understand or be able to act upon climate change issues, and that the problem needs to be reframed in terms of how we can help people of all ages learn what they need to know. The current adult population grew up in a time when the curriculum did not offer the understandings necessary to enable people to understand the language or patterns of nature in general, or climate change issues in particular. Educational standards are just beginning to reflect the growing awareness of the importance of global warming as a topic of science education, and current curriculum standards in many states have just begun to address climate change directly. This raises a number of questions: "What can we do *now* to educate the present adult population about climate change?" and "How can we help tomorrow's adults better understand environmental issues?" What *is* involved in learning the language or patterns of nature and achieving a deep understanding of global climate change? And even if people hold deep understanding, what else do they need in order to choose actions that support decreases in greenhouse gas emissions and increase the ability to respond to climate change?

## Two lessons on educating for intelligent action from education research

There is deep interest in the question of what people need to learn to understand the biosphere, and many ideas from diverse and eloquent perspectives on what educational components need to be included (e.g., Thomashow, 2002). While it is an important first step, as others have argued (e.g., Bostrom *et al.*, 1994), to assess what the public's knowledge looks like in contrast to scientific determinations of what they need to know, the educational problem for achieving understanding extends far beyond that. We need to consider the terrain between lay and expert mental models and figure out what it takes to help learners traverse that terrain. This involves understanding the patterns in how people perceive and think about environmental issues – cognitive and perceptual assumptions or default patterns that are likely to impede understanding and the ability to act. Further, if we set educated action as opposed to inert knowledge as the bar for success, then the educational challenges are extensive. We need to help the public develop the ability to understand climate change but also the sensitivity to perceive opportunities that invite action and, subsequently, the inclination to act.

This chapter introduces two lessons, relevant to global warming and to public education efforts as well as learning in schools, which can be drawn from a broader survey of the literatures in science education, cognitive development, and learning theory. As we elaborate below, this is just a start. The educational challenges surrounding climate change are many, and the particular cognitive issues in understanding global warming invite some of the most difficult problems in education to rear their ugly heads. This suggests a fair amount of humility about the endeavor, but also the importance of mining contributions from diverse disciplines. Finally, we consider that the path to making educational decisions based upon what we want people to perceive, know, and do is anything but straightforward. However, we also suggest areas where we believe our collaborative energies are well spent seeking answers. So what are some lessons from the educational research for teaching the complex issues involved in global warming?

*1. People have a tendency towards default perceptual and cognitive patterns that impede understanding and acting on global warming. We need to find ways to address these.*

When dealing with complexity, people reveal a set of "reductive biases" (Feltovich, Spiro, and Coulson, 1993) and they tend to make certain simplifying assumptions (Grotzer, 2004; Perkins and Grotzer, 2000) about the structure of the causality involved. Understanding global warming involves grasping a number of concepts that challenge these default patterns of thinking and reasoning.

Educational research shows, for example, that students tend to search for causes that are spatially local and temporally close to their effects (e.g., Driver, Guesne, and Tiberghien, 1985; Grotzer and Bell, 1999; Koslowski, 1976; Lesser, 1977; Mendelson and Shultz, 1976; Siegler and Liebert, 1974). In general, people are not good at extended searches to assign cause or agency to factors that fall far away from an effect in space or time. The common tendency is towards efficiency. By contrast, the causes and effects of global warming are often separated in space and time (see also Dilling and Moser, Introduction, this volume). An increase in greenhouse gases in one part of the world leads to changes in climate that come decades after, and often thousands of miles away from, these initial emissions.

People also tend to overlook causes that are non-obvious in favor of those that are obvious (e.g., Brinkman and Boschhuizen, 1989; Leach *et al.*, 1992). Greenhouse gases are not visible or physically tangible, making it easier to dismiss them when analyzing the primary causes of climate change. Even in the case of easily observable outcomes, as in the sunset example in the introduction, non-obvious causes are typically overlooked. While not related to greenhouse gases, brilliant sunsets result from another non-obvious cause – particulate matter associated with smog that alters the refractive angle of sunlight. Particulate matter is not easily visible with the naked eye and so it is not usually accounted for as a cause of brilliant sunsets. Greenhouse gases pose an even greater challenge because the causes *and* the outcomes (at least at this stage) are difficult to detect without long-term attention to patterns and careful measurements. The combination of spatial gaps, temporal delays, and non-obvious causes makes it all too easy to ignore the causes of global warming.

The temporal aspects of global warming are difficult for other reasons as well. In order to realize that global warming is occurring, we need to be able to track patterns over time. People are not necessarily good at reasoning about patterns over time, and too often extrapolate from the moment (Dorner, 1989). They typically do understand systems that involve simple accumulation, for instance, increasing trash in landfills, or – more visible to the general population – along highways. However, once complications are introduced such as exponential growth or variations in rate of change, people find it harder to track the patterns. Positive feedback loops, where one event triggers other events that increase the cause of the initial event, introduce further complexity into rates of change. For examples, global warming causes a decrease in the polar ice cover, which reflects solar radiation. When the ice melts, the dark-colored land or water that lies beneath it absorbs more solar radiation, serving to exacerbate the initial problem by increasing local surface heating. Understanding these feedback patterns requires an understanding of patterns that fall outside of the typical accumulation models.

Beyond this, natural systems often have the ability to "absorb" a certain amount of change until enough change has accumulated so that it becomes noticeable, or smaller effects interact so that at a given threshold, the system's equilibrium "tips" and profound changes occur. For instance, while climate change is commonly viewed as a slow and steady process, it is now generally accepted that a sufficient disruption of the balance of temperature and salinity in the ocean as a result of melting polar ice could trigger massive climate shifts over a very short period of time (National Research Council, 2002). Patterns that have no obvious effects early on are easily ignored until it is too late. These have been referred to as "creeping environmental phenomena" (Glantz *et al.*, 1999). In the social realm, systems that change in non-linear ways are sometimes said to cross a "tipping point" – a concept that is beginning to find its way into public discourse (Gladwell, 2000). However, most people still analyze evidence using a simpler accumulation model, so when there are no visible effects, it is all too easy to think nothing is happening.

People tend to give linear or narrative causal explanations that are story-like in the form of "first this happened, then it made that happen," and so on. These have a domino-like quality to them (Grotzer, 1993, 2004). Global warming does not fit well with linear, narrative causal forms. It is the result of multiple intertwined causes, and results in multiple effects at many different levels. Instead of serving only one role in the causal story – as the effect at the end of the chain of causes – effects act as further causes.

When thinking about the origin of an observed phenomenon, most people envision a centralized cause, often with a single agent (like a sergeant in charge of a platoon) or with a coordinated set of agents (like a town decision-making board). People have a harder time envisioning multiple causes that are dispersed. The causes of global warming, however, are exactly that: spread out or decentralized. The effect emerges due to the collective actions of many people – it is an emergent causality. The behavior followed by many individual actors gives rise to what can be dramatic effects (e.g., Resnick, 1994). This runs counter to the default assumptions of most people which tend towards what Resnick (1996) has called the "centralized mindset." It assumes an orchestrated leader or some pre-existing, built-in "inhomogeneity" in the environment is responsible for complex patterns. Working with a computer program called StarLogo, Wilensky and Resnick (1999) found that students are typically shocked to see how individual rules of interaction at one level lead to emergent effects at another level, and that they find it very difficult to predict macro-level properties that emerge in systems as a result of micro-level interactions (e.g., Penner, 2000).

Notice that centralized causes also typically have a centralized and easily identifiable intent. In emergent causality, the effect emerges due to the collective actions of many agents whose actions have no coordinated intent. Agency is distributed and non-intentional (in terms of the specific outcome). Because agency and intent at one level are not easily connected to outcomes at the emergent level, it is difficult for people to see their individual role in the process – resulting in diffusion of responsibility. One person's effort, for instance, to reduce their own greenhouse gas emissions by driving less or turning off the lights at home does not directly result in an observable impact, and it is difficult to encourage behavior that seems futile at the individual level without a sense of the collective, emergent effects (see the discussion on urgency in Moser, Chapter 3, this volume). In emergent causality, there can be intention at the level of the individual actors, yet the broader effect does not necessarily stem from a broadly defined social intention. Understanding the role of intention in systems with trigger effects where the magnitude of the resulting effect may have little to do with any one particular agent, or in self-organizing systems where there is no clear internal or external agent, is also conceptually challenging. The relatively lower salience of many fine-grained actions compared to more dramatic individualized ones is a barrier to recognizing distributed agency. It is very difficult, from a cognitive stance, to juggle the actions of many individual parts and imagine or predict outcomes.

What does it mean to attend to these default patterns when educating about global warming? How might we use the information on people's reductive biases in our attempts to educate students or the current adult population? Becoming aware of people's reductive biases should enable us to find better ways to get our messages across. For instance, we could use computer technology to display simulations of global environmental problems or to explain causal connections between our actions and climate change and so on in public places such as malls or libraries. These could serve to make non-obvious effects more obvious. In the design of programs in the popular media, we can seek ways to reveal how the causal patterns can "sneak up on us" and, through simulated time lapse or dynamic imagery, help the public perceive and attend to these hard-to-perceive patterns. We can also make listeners aware of their default tendencies (e.g., through short, fun games on touch computer screens) and how these tendencies can eventually lead to unanticipated and potentially hurtful consequences.

As we educate for the future, we need to make today's students aware of the structures of complexity so that they are less likely to reduce complex patterns to simplistic ones. This is a problem that education researchers are working to tackle. For instance, researchers have developed a curriculum designed to restructure the ways that students think about causality within given science concepts (e.g., Grotzer, 2002), electronic building blocks that simulate causal and systems concepts to allow students to discover the complex behaviors related to particular structures (Zuckerman, 2003), and computer programs, such as StarLogo (Resnick, 1994) that allow students to experiment with how rule-based interactions of individuals give rise to complex system-level effects. This work has demonstrated significant improvements in students' ability to reason about complex causalities and systems behaviors (e.g., Grotzer, 2003; Grotzer and Sudbury, 2000, Resnick, 2003; Wilensky, 1998; Zuckerman, 2003).

*2. We must attend to and develop the public's sensitivity, ability, and inclination to behave intelligently and consider how these three aspects of behavior interact to challenge our efforts.*

Environmental education has long sought to engender environmental awareness and appreciation as well as the inclination to care for the environment. In many respects, this recognition surpasses what happens in other areas of education. Environmental educators (e.g., Thomashow, 1995) have designed thoughtful curricula for making people aware of their connection to and dependence on the Earth, and to help students develop an ecological identity and sense of ecological citizenship. These efforts are of the utmost importance.

The educational literature underscores another type of sensitivity and inclination that requires attention. If we want intelligent environmental action, we need to help the public learn how to act on climate change, to perceive opportunities that invite action, and subsequently, to be inclined to act – at a particular moment. Behavioral psychology suggests this can be aided by giving people very specific instructions on the action, frequent prompts, peer support, and recurring positive reinforcement (Clark, Kotchen, and Moore, 2003; DeYoung, 1996; Frahm *et al.*, 1995; Kollmuss and Agyeman, 2002; McKenzie-Mohr, 2000; see also Tribbia, Chapter 16, this volume). Perkins, Jay, and Tishman (1993) define three dimensions of the disposition towards intelligent performance: sensitivity, ability, and inclination. Sensitivity involves the ability to recognize occasions to apply a particular skill, understanding, or piece of knowledge. Ability refers to having that skill, knowledge, or understanding in one's repertoire. Inclination refers to being motivated to apply the particular skill, knowledge, or understanding in the given instance.

In terms of global warming, one can know quite a lot about the issue and can even care about it, but if on a moment-to-moment and day-to-day basis, one cannot recognize opportunities to use that knowledge, then it doesn't do a whole lot of good. While that sounds obvious, education efforts often focus on ability – leaving out sensitivity, and sometimes inclination, too. Perkins *et al.* (2000) found that of the three dimensions, sensitivity appeared to be the largest stumbling block for students. Even when students had the ability to understand particular patterns, they didn't identify instances of them. In part, this may be related to the reductive biases discussed above. One's default assumptions hinder one's ability to recognize alternative patterns. We've probably all had an experience where we realized in hindsight how we might have done something in a better way. The challenge is how to help people become mindful of everyday opportunities to change their behaviors in real time. The experience of 20/20 hindsight is only helpful if it changes what we do next time.

Moving from having the ability to engaging in new action patterns is a notoriously prickly problem in education that is subject to all sorts of situational variables. However, there are some straightforward ways to increase the likelihood that people will recognize action opportunities. What does it mean, then, from a public education stance, to attend to sensitivity, to growing the awareness for "actionable" opportunities?[2] Here are some examples. Articles on global warming could include a list of typical everyday actions and then list an alternative set of "choices for the environment" so that when people are engaged in the actions, the moment becomes a trigger for considering an alternative choice. Similar to campaigns that encourage parents to read to their children or know where their children are, ads could ask, "It's 10 p.m. Have you planned out your day tomorrow to minimize the driving you have to do? Do it for the environment – for yourself and your family." Public service announcements could focus on key decision points; for instance, the choice of a new car and the big environmental consequences that choice has over time.

While sensitivity, ability, and inclination are critical preconditions for action, they can also interact in ways that exacerbate the problem of inaction. For instance, the perceptual and cognitive challenges outlined above relate most directly to the ability to perceive particular kinds of patterns. However, they also affect people's awareness of the problems of global warming and, subsequently, their inclination. So in assessing risk, people attend to and are more easily stirred to action over a risk when its cause is personified or involves intentional agency, is centralized rather than decentralized, is immediate rather than cumulative, and is obvious rather than non-obvious. This can be so despite the magnitude of the effects. Global warming, despite the potential for massive catastrophic effects, sits on the wrong side of each of these tensions. Public education campaigns could make people aware of their tendency to focus on one side of these tensions to the exclusion of others. Imagine a magazine ad that poses the question, "What would you do if a terrorist were working silently to disrupt our weather systems, make our world inhabitable, and destroy life as we know it? Would you act? Would you want your government to act? Well, it is happening, and that terrorist is called Global Warming. It has recruited you as one of its agents – every time you get into your car." The ad could then explain the connection. Making the analogy forces the association in people's minds and makes it more difficult to ignore the non-obvious, cumulative causes of potentially massive catastrophic effects.

One could argue that such approaches play on people's fears. This is certainly true and, ideally, one would want to develop inclination in the most positive ways – that our actions as global citizens matter – as part of developing an environmental appreciation and an ecological identity. This should certainly be a part of the long-term educational process that schools and other communicators engage in, in addition to helping students understand that certain types of causes command their attention more readily than others. However, in terms of public education, there are so many messages competing for people's attention and for limited resources that such comparisons may be needed to help people realize the urgency of a non-obvious, potentially catastrophic problem. (For caveats and concomitant messages and framings, see the chapters by Moser; and Dunwoody, Chapters 3 and 5, this volume.)

In the introduction to this chapter, we argued that if we set educated action as the bar for success, then the educational challenges are extensive. We then elaborated two aspects of the "what should be taught" piece of that challenge: (1) the need to map the terrain between lay and expert mental models in terms of cognitive and perceptual patterns and figure out what it takes to help learners traverse that terrain, and (2) the need to help students and the public develop sensitivity, ability, and the inclination to understand and act on climate change. However, this is really just the tip of the iceberg. For instance, in order to deal well with the challenges of a changing world, people will need to be able to tackle fuzzy, ill-structured problems. They will need to be able to think flexibly and to develop creative solutions to multifaceted, novel issues. They will need to learn the skills of inquiry to find answers to new questions and to apply their understandings to authentic problems at the intersection of science, social and/or public policy, health, communication, and so on (see Bateson, Chapter 18, this volume). When one tries to take on the whole scope of related educational challenges, the magnitude of the problem can be overwhelming – only underscoring the urgency of the call to action.

## Achieving "intelligent environmental action": pedagogical challenges

As we set about deciding *what* to teach, we also need to pay close attention to *how* to educate students and the public to understand various causal and perceptual patterns, and how to develop sensitivity, ability, and inclination. Certain pedagogical challenges become central to the endeavor. For example, in thinking about global warming, there is a critical connection between action at the level of the individual and collective action, and it is natural to think about the problem through this lens. This volume takes that approach. At the same time, as discussed above, the ability to make this critical connection is a highly challenging cognitive task. People have great difficulty reasoning at different levels. At different levels, the definition of what constitutes an "object" and the inherent forms of causality acting upon that "object" vary. For instance, in a traffic jam, at one level the cars are the objects and a focus on their actions leads to an analysis of what to do about the jam. At another level, the jam becomes the object of focus, and rather than analyzing the actions of individual cars, one analyzes the patterns relevant to the jam itself (Wilensky and Resnick, 1999). Similar difficulties have been seen in reasoning about ecosystems where students often extend the outcomes of the interactions between individual organisms to the population level – thus missing population-level effects such as balance and flux (e.g., Driver *et al.*, 1994; Grotzer, 2002; Grotzer and Basca, 2003; Wilensky and Resnick, 1999). Our collective efforts would be well spent identifying and addressing central pedagogical challenges such as these.

Another reason that it is important to give careful thought to "how" is that the material we need to teach does not automatically imply a certain way of teaching it. For example, a common approach that scientists take to teaching scientific concepts to the general population is to figure out what mental models they themselves hold as scientists, and then try to teach those models to the public. However, this strategy ignores the fact that scientists hold a wealth of assumptions that provide the context for those models. For instance, while members of the public might argue that you can't prove with certainty that certain outcomes will occur, scientists assume that the enterprise of science rests on the best available evidence. They recognize that the explanatory models that we use today are the best interpretation that we have based on the current evidence. We are not arguing that the population isn't capable of grasping the concepts, or that they are "scientifically illiterate" and that it would take too long to educate them. We are saying that the lay population does not hold the same set of assumptions as scientists do, and that translating messages for the public involves analyzing, from the public's perspective, how those messages will be heard and understood, and then helping them to transition to more scientifically accurate or complete understandings. Then decisions can be made about what contexts should be offered before energy is spent on miscommunication (see Dunwoody, Chapter 5, this volume). Often there are intermediate causal models (White, 1993) that hold sufficient explanatory power to enable intelligent action on behalf of novices and that are more easily grasped than a full-blown expert model would be. For instance, in teaching about density to young children, educators often use particle models or "dots-per-box" models instead of models that explain atomic mass or bonds and how they account for spacing. The simpler model functions as a useful bridge for those students who do pursue deeper understanding and go on to learn the atomic explanation. Neither educators nor scientists can design these models alone. They need to be the result of a collaborative effort between educators and scientists. We strongly encourage the scientific and education communities to collaborate on defining what those might look like.

As new problems arise in education, there is often a call for extensive research. In deciding what we need to know from a pedagogical standpoint, it is important to carefully mine what we already know from related contexts. One of the best ways that we can move forward is to use the information at our disposal. Thomashow (2002: 193) writes that "we know very little about the cognitive origins of ecological learning and biospheric perception." However, spread across the different literatures in cognitive development, learning theory, science education, environmental psychology, and sociology, there is vast information on how children understand concepts relevant to ecology at different ages (Grotzer, 2003). We have to be willing to look across the typical boundaries of our fields. On balance and in support of Thomashow's assertion, we certainly need to expand upon what we know, and this includes greater awareness of the tacit knowledge and epistemological assumptions scientists hold and how they are learned. Of course there are caveats to borrowing research findings across disciplinary boundaries. It is important to keep in mind the contexts in which information was collected. For instance, developmental research is often carried out so that task demands are carefully controlled for; however, the subjects are seldom, if ever, given optimal educational guidance for learning a set of concepts. Therefore, the research contexts tell us what subjects do with carefully controlled task demands, but not what is possible with optimal educational guidance (Metz, 1995, 1997). Our efforts will be most productive if they build upon the existing research base across disciplines with its limits in mind and an eye towards new possibilities.

We believe that we don't yet know what is possible for helping the public understand global warming with optimal educational support or with purposeful collaboration between educators, scientists, and the many others working on the urgent problem of climate change. But this chapter offers some insights into a few key building blocks: understanding people's default cognitive patterns, recognizing their difficulties understanding complex systems, and developing their sensitivities, abilities, and inclinations to act in environmentally intelligent ways. It is imperative that we help the public become environmentally intelligent and learn to act with that intelligence, rather than just admonish people for not doing so. Dedicating ourselves to that effort inspires optimism that future generations will become "conversant with the language in which nature speaks to us," and that we will be able to admire sunsets with our children.

## Notes

1. While Richard Feynman was referring specifically to mathematics, the question can be asked as to what other patterns one must grasp in order to understand the language of nature. He made the statement in various forms, both written and in interviews. A published source can be found at Feynman (1967).
2. We realize that public school education intended to induce behavioral changes involves significant, but not unprecedented, policy considerations (e.g., education about recycling also led to new behaviors among students and eventually their families). To adequately treat the arguments made in the contentious debate about control over educational content would require a far more substantial treatment than space here allows.

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# CREATING A CLIMATE FOR CHANGE

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*Edited by*

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