Connecting Controversy and Complexity

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Abstract

The authors share interest and experience in programming for both teaching about complex adaptive systems (CASs) and about controversial issues. Controversial issues are a subset of complex issues, as these issues always (we suggest):

- are evolving;
- involve the interplay of different disciplines;
- are composed of multiple nested subsystems (indicating an importance for understandings of scale);
- are better understood from perspectives that include contextualization in space and time (perspectives that include the history of the system);
- are partially defined by feedback; and
- are not necessarily greater than, but qualitatively different from the sum of their parts.

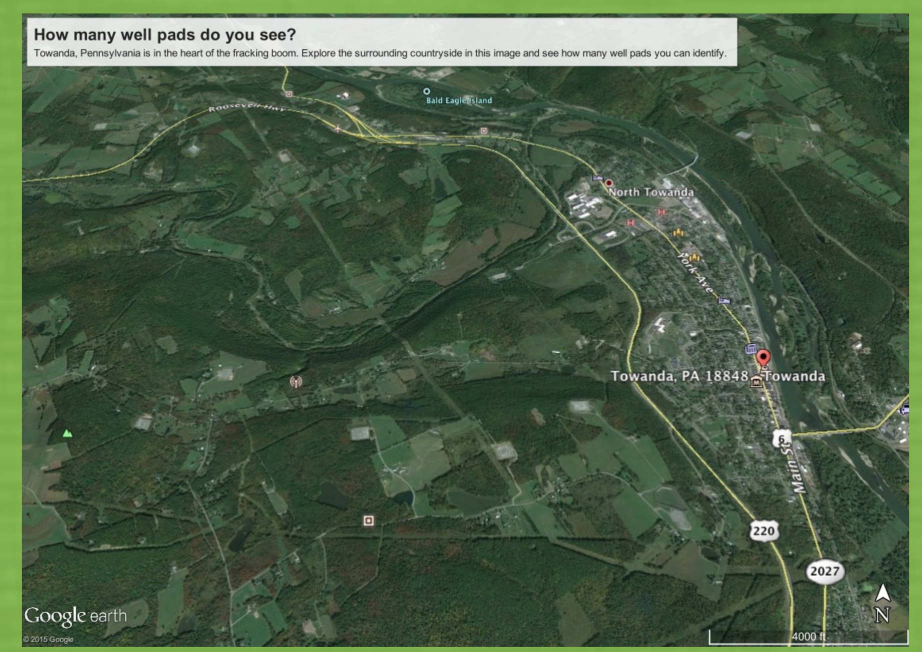
There are many more shared characteristics than space allows.

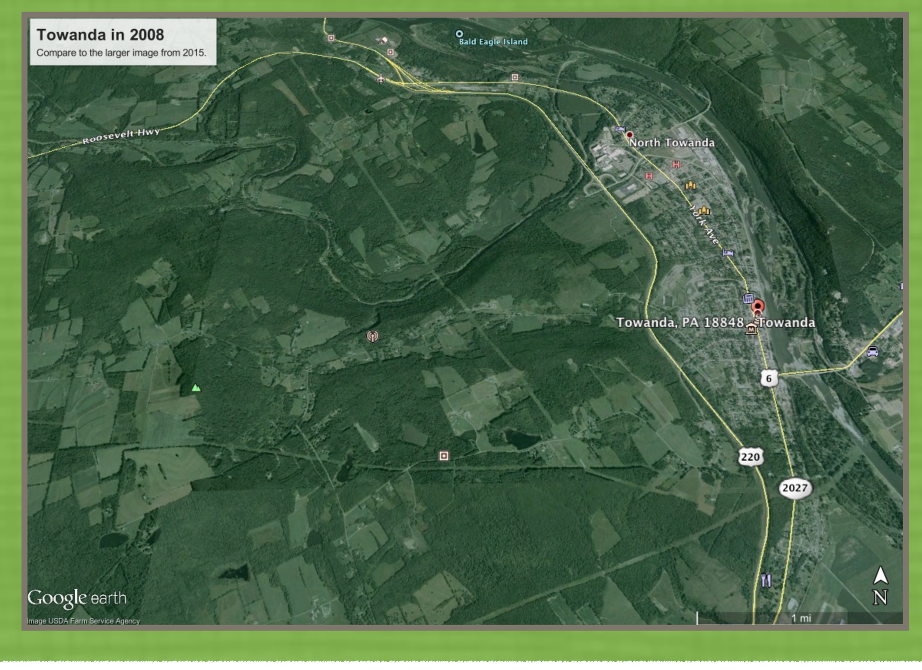
In this program example, we will share approaches and resources from our experience in climate and energy education, especially as related to hydrofracking and the Critical Zone Observatory Network. Shared resources will include rules of thumb for teaching about controversial issues, and an adaptation of Craven's "Credibility Spectrum," for evaluating the reliability of media as related to any controversial issue.

The session will draw from experiences in a range of settings that includes middle school through college in the science classroom, and teacher professional development and public programming.

While attention will be given to both formal and informal education, special attention will be given to tying the teaching of complex and controversial issues to the NGSS and its focus on "three-dimensional science".

Fracking Complexity:





The top map to the right shows Towanda, Pennsylvania and some of the surrounding area earlier this year (2015). The bottom map shows the same area in 2008. Study the maps and the differences between them with an eye towards the characteristics of complex systems listed in the abstract.
Clearly, the system is changing and that change is both driven by and measured by a wide range of disciplines.

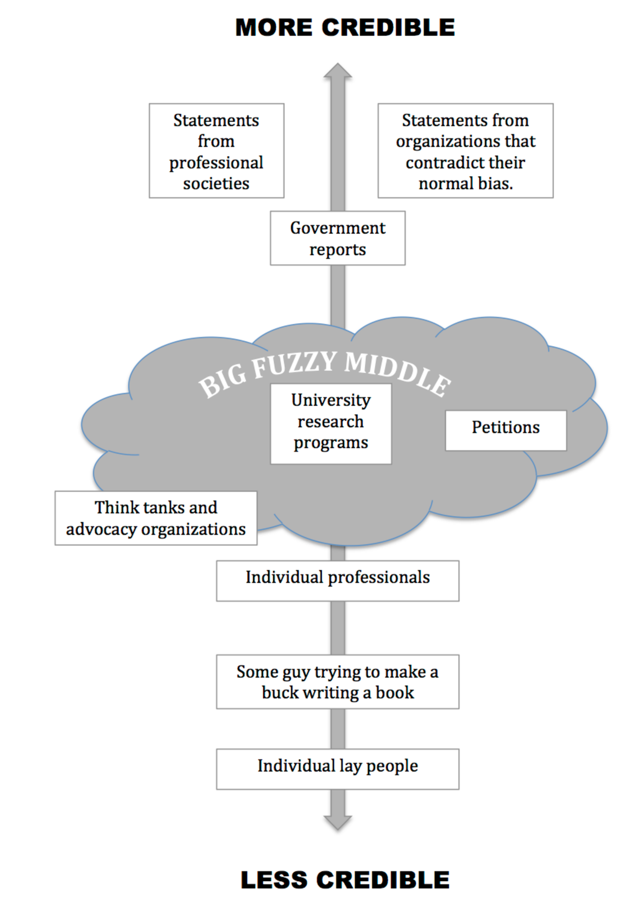
Changes in technology and scientific understandings make the exploitation of reserves of natural gas economically feasible while also creating new hazards. As new hazards emerge others diminish. The increased production of natural gas has happened in concert with reduced production of coal.

New York State is heavily dependent upon fracked gas from Pennsylvania. New York produces only about 3% of the gas used within the state. For the last several years, more of New York's electricity has come from natural gas than any other source and most New York homes are heated with natural gas. Thus, natural gas is New York's largest energy source, with gasoline a distant second.

The largest natural gas power plant in New York is the Ravenswood Generating Station in Queens. In the first half of 2013, the plant used 12,200,000 mcf of natural gas to produce 1,300,000 megawatthours of electricity.* During that same time period, the average unconventional gas well in Pennsylvania produced a minimum of 210,000 mcf of natural gas.** Therefore, the gas required to power the largest natural gas power plant in New York State required the gas from fewer than 60 wells. Well pads for horizontal wells commonly accommodate six wells meaning that the well pads shown in the adjacent image could produce more gas than the largest power plant in the largest US city consumes.

* Data available from the Energy Information Administration at: http://www.eia.gov/electricity/data/browser/#/plant/2500?freq=M&start=200101&end=201503&ctype=linechart&ltype=pin&columnchart=ELEC.PLANT.GEN.2500-ALL-ALL.M&linechart=ELEC.PLANT.GEN.2500-ALL-ALL.M&pin=&maptype=0
**This makes the conservative assumption that wells without production data in the database produced no gas.

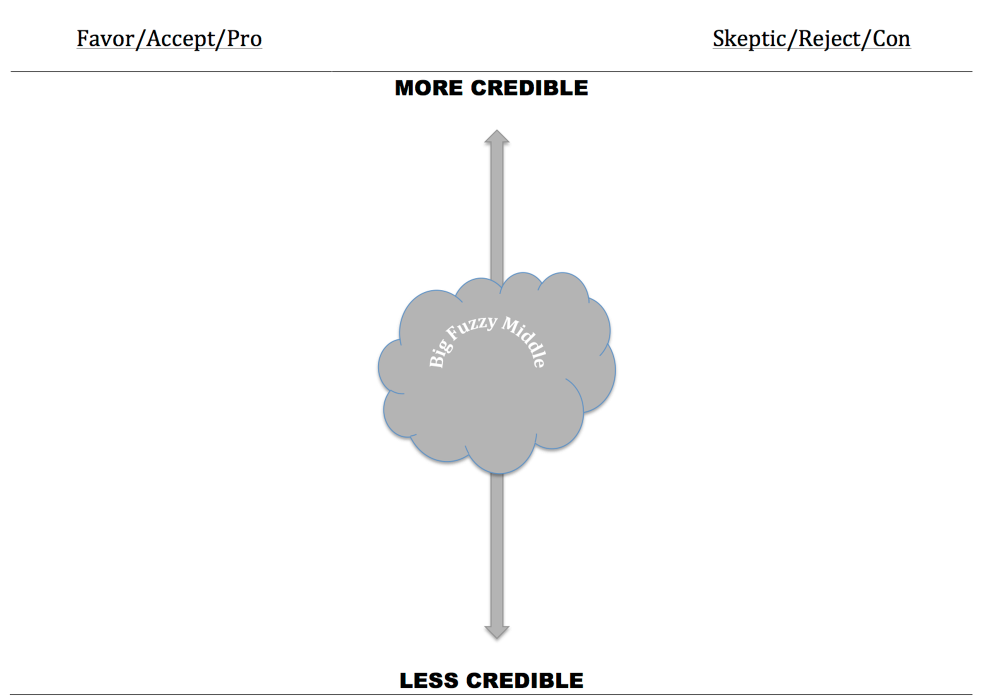
Credibility Spectra:



A naked credibility spectrum for the global warming debate. Or other stuff.

Craven, G. (2009). *What's the worst that could happen? : a rational response to the climate change debate* (1st ed.). New York: Perigee.

Craven (2009) developed a "credibility spectrum" for discussing the climate change controversy. Using this framework, information sources can be evaluated along an axis ranging from being "strongly for" to "strongly against" a position on an issue. The vertical dimension of this spectrum, provides a weighting value to evaluate the sources of information. Craven (2009) suggests the rank-order (from most to least credible) shown in the figure to the left. The figure below shows an adaptation by Pyle that adds another dimension to Craven's original spectrum. The Post-it Notes show evaluations by his students. Again, consider this work in relation to the characteristics listed in the abstract.



Credibility Spectrum with adaptations by Eric Pyle.

Critical Zone Science

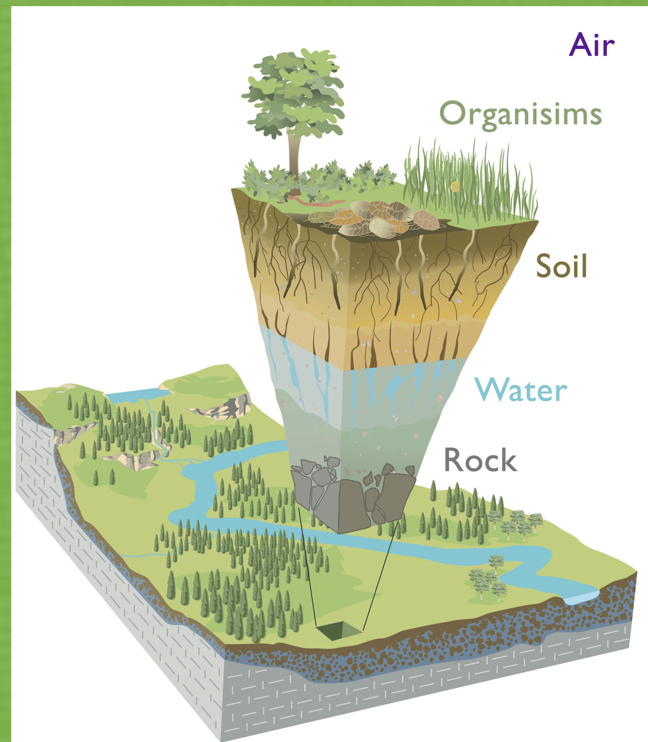


Image modified from Chorover, J., R. Kretzschmar, F. Garcia-Pichel, and D. L. Sparks. 2007. Soil biogeochemical processes in the critical zone. Elements 3, 321-326. (artwork by R. Kindlimann).

From the bottom of the groundwater to the tops of the vegetation is where most life resides. Geologists, ecologists, climatologists and other scientists are doing 3D (NGSS) science in an NSF-funded network of observatories to better understand the Critical Zone.

Critical Zone science is fundamentally interdisciplinary in nature, attentive to complexity, and deeply connected to a range of politically controversial issues, including climate change, energy production, water management, and industrial-scale agriculture's impact on the land.

Fundamental Questions:

Despite the Critical Zone's importance to terrestrial life and many environmental issues, it remains poorly understood. Key questions include:

- How does the Critical Zone form?
- How does it operate?
- How does it evolve?

There are many followup questions as well.

For example:

- How will the Critical Zone respond to projected climate and land use changes?

See more questions about the Critical Zone at: http://criticalzone.org/national/research/.

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NGSS's Three-Dimensional Science

The idea of systems pervades the *Next Generation Science Standards* and controversial issues are more directly addressed than in prior efforts of this scope. Climate change and other human impacts are addressed relatively forthrightly as is biological evolution. Systems thinking is perhaps most conspicuous in the Crosscutting Concepts. Below is an excerpt from Appendix G of the NGSS that highlights the term "system." Systems ideas appear in ways beyond the simple mention of the term, of course. All the Crosscutting Concepts are requisite to a deep understanding of the nature of systems.

> The *Framework* identifies seven crosscutting concepts that bridge disciplinary boundaries, uniting core ideas throughout the fields of science and engineering. Their purpose is to help students deepen their understanding of the disciplinary core ideas (pp. 2 and 8), and develop a coherent and scientifically based view of the world (p. 83.) The seven crosscutting concepts presented in Chapter 4 of the *Framework* are as follows:
>
> 1. *Patterns*. Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
>
> 2. *Cause and effect: Mechanism and explanation*. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
>
> 3. *Scale, proportion, and quantity*. In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.
>
> 4. *Systems and system models*. Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.
>
> 5. *Energy and matter: Flows, cycles, and conservation*. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.
>
> 6. *Structure and function*. The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.
>
> 7. *Stability and change*. For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

It is worth noting that the NGSS and the standards movement more broadly, as well as other school reform efforts, are characterized by the same set of system principles, and are also controversial in nature. It seems likely that applying knowledge of systems and of strategies for effectively addressing controversial subjects has the potential to improve the chances of success of these initiatives.

Rules of Thumb for Teaching Controversial Issues

Working across a range of controversial issues has led us to identifying a set of rules of thumb that we have found effective. They are reproduced below and available for download as a one-page document.

Rules of Thumb for Teaching Controversial Issues:

1. **Be nice (but there are limits).** Treating those who disagree as either idiots or evil people is unlikely to convince them that you're correct.
   a. **Know your audience.** "Nice" has different meanings with different audiences.
   b. **For the most part, people aren't lying.** They largely believe what they say.
   c. **Advocacy *may* deepen convictions more than understanding.** Evangelism turns on people who agree with you and turns off many who don't. Being certain and being right aren't the same thing, and they aren't all that closely related. Put more faith in people and institutions that are pretty sure than those that are certain.
   d. **Don't let the bastards get you down.** Working on nurturing public understanding of controversial issues will make people angry, and angry people say and do nasty things. Have a support system you can turn to.
2. **Complexify the seemingly simple.** As educators (and like journalists and politicians), we are driven to simplify the seemingly complex. It's often important, but we do it *too* often. The world is complex.
   a. **Move from debate to discussion.** There are often ways to reframe away from false dichotomies.
   b. **Controversial issues are always interdisciplinary.** Pay attention to the tools and strategies of the most centrally-related disciplines.
   c. **Don't forget the importance of the simple.** While acknowledging the issue's complexity is important, there are often simple ideas illuminated within that complexity.
3. **Evidence matters, but evidence alone is not enough.** All of us hold beliefs for which ample conflicting evidence exists.
   a. **Learn about cognitive biases (including your own)** and how to communicate more effectively in light of them.
   b. **State evidence clearly and directly, identifying a small number of key points.** Too many different points cloud the issue.
   c. **Mathematics matters.** Scale plays a central role in many controversial issues, and understanding really large or really small numbers brings special challenges. "Social math" (National Center for Injury Prevention and Control, 2008) uses familiar examples to show volume, mass, or relative number.
   d. **Call out logical fallacies, and hold people accountable for (mis)using them.** There's a taxonomy of problematic argument types. Get to know it and put it to use.
4. **Persistence matters.** Beliefs related to controversial issues are often closely tied to worldviews, and such beliefs do not change quickly or easily.
   a. **People do change their minds on things that matter.** Two words: gay marriage.
   b. **Piling on evidence can bring beliefs to a tipping point.** Of course, not always.
   c. **Reflect on big changes in your own beliefs.** Chances are, it took either a long time or an immersion in the issue.
   d. **Social media may be a better venue for this than classrooms** because connections last more than a semester.
5. **Use the local environment as a starting point** to engage in critical inquiry of the forces working to shape that place. Climate, energy, and evolution, like most topics in Earth science coursework play out in a meaningful way just outside the classroom door. Starting close to home will make the issue more relevant to the learner.

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Related presentation here: http://bit.ly/controversy2014
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So what? How will thinking about this help my teaching?

Successful navigation of controversial issues in the classroom and beyond requires understanding of context and a recognition that the connections amongst ideas and concepts can easily be as important as the ideas and concepts themselves.

Fracking is an evolving issue in a number of ways. The relevant technology is changing rapidly as scientific understandings of environmental impacts deepen and landscapes are altered over time. It involves the interplay of a wide range of disciplines including geology, climatology, environmental chemistry, human history, economics, sociology and more. Understanding any one of these disciplinary perspectives in depth requires at least some understanding of the issue from other disciplinary perspectives, and in the context of its place in space and time. **Credibility Spectra** can help build these contexts and understandings for both learners and educators. And, can help learners to evaluate information relevant to these controversial topics and, perhaps in ways applicable beyond these specific issues.

Critical Zone Observatories offer approaches and data for looking into and across Earth systems and, especially the interplay of those systems. Climate change, land use, and water use are important areas of study in CZ science - a series of controversial and complex issues that require interdisciplinary approaches to build deep understandings for both scientists and other learners.

The Next Generation Science Standards both address complex and controversial issues and are themselves complex and controversial. They provide an overview of what everyone should understand about such issues and these insights should inform their own implementation. How do the Crosscutting Concepts help us to better understand not only science and the nature of science but also of the NGSS itself?

The Rules of Thumb for Teaching Controversial Issues serve as a partial summary of this work that hopefully has utility for a wide range of educators.