APPLICATION OF CONCEPTUAL MAPPING TO CLIMATE CHANGE EDUCATION: MOVING TOWARD THE 'ADJACENT POSSIBLE'

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Abstract. Three forces converge to create a time of transformation: global attention to climate change; the development of the Next Generation Science Standards; and increased emphasis on the significance of metacognition. Johnson's work provides understanding of the social context that supports innovation, particularly the concept of the 'adjacent possible.' Two new applications of conceptual mapping are submitted: a concept map of climate change/ education linked to multiple resources and a strand map of weather/climate standards. Conference attendees are asked to offer feedback on these maps and to collaboratively construct a metacognition toolbox to address complex socio-environmental challenges.

1 Introduction: Changes Call for Innovation

Three forces converge to create a time of transformation: global attention to climate change; the development of the Next Generation Science Standards; and increased emphasis on the significance of metacognition. “Climate change is the greatest challenge of our time… In short, it threatens our planet, our only home,” asserted Thomas F. Stocker, the 2013 IPCC co-chair (Gilis, 2013). The concept of climate change has found a solid fit in the Next Generation Science Standards currently being adopted/adapted/or rejected at the state level in the United States (NGSS Lead States, 2013). The NGSS include strand maps with learning progressions that demonstrate how the key concepts of science may develop in students' minds over the K-12 grade span. Strand maps are similar to concept maps in showing cohesive connections among concepts. They differ, however, in that they are at a more general level and are designed to represent a population's development of complex concepts over years rather than an individual's thinking of specific concepts with a variety of propositional linkages at a particular point in time. In a recent report in *Science*, researchers found that, “whereas most U.S. science teachers include climate science in their courses, their insufficient grasp of the science may hinder effective teaching.” (Plutzer et al, 2016) Clearly, the implementation of high quality climate change education in the classroom is lacking. Meanwhile, a call for increased emphasis on metacognitive abilities has been sounded by the revised Bloom's taxonomy (Krathwohl, 2002) upon which many of the cognitive objectives of classroom work are built; the American Association for the Advancement of Science (National Research Council, 2000 and 2005); and the National Science Teachers Association (Bybee, 2002).

In response to these developments, Johnson offers a perspective on the origins of innovation in his book *Where good ideas come from: the natural history of innovation* (Johnson, 2010). He focuses on the 'adjacent possible,' a term he credits to chemist Stuart Kauffman, but applied by him to the conceptual world in addition to the physical world. Innovation often emerges as the next "good idea" built on a new vision of available building blocks. "We take the ideas we've inherited or that we've stumbled across, and we jigger them together into some new shape." He sees innovation as the work of both the individual and the collective.

2 Individual 'Adjacent Possible'

"All of us live inside our own private versions of the adjacent possible. In our work lives, in our creative pursuits, in the organizations that employ us, in the communities we inhabit—in all these different environments, we are surrounded by potential new configurations, new ways of breaking out of our standard routines." (Johnson, 2010) In the past, this researcher has applied conceptual mapping to science education research, teaching, learning, and evaluation of standards (Gorman & Heinze-Fry, 2014). Provided below are links to two new applications, the individual 'adjacent possible':

- a weather/ climate change strand map:
  - http://cmapspublic2.ihmc.us/rid=1PY4HNMV1-21VP2Y3-5K29/StrandMap-PreK-12-WC.cmap.cmap
- a concept map of climate change/ education linked to digital resources:
  http://cmapspublic2.ihmc.us/rid=1Q1B9HWXL-4CKNSV-3XJG/Climate%20Change%20Bite-Sized.cmap
  - Please offer your feedback about the utility of these innovations and how they might be improved.

3 Collaborative 'Adjacent Possible'

Johnson (2010) asserts that "innovative environments ... expose a wide and diverse sample of spare parts—mechanical or conceptual—and they encourage novel ways of recombining those parts... The trick is to get more parts on the table." The urgency of the changes described above compel researchers to develop tools to think more deeply, clearly and transparently; to solve more complex problems; and to make more complex decisions. Many researchers have applied concept maps and Vee heuristics to science education, sustainable development and other challenges (Novak & Gowin, 1984; Novak, 1998; Åhlberg, 2004; Iuli & Helldén, 2004; Vanhear & Pace, 2008; Proctor & Bernstein, 2012). A preliminary metacognition toolbox that demonstrates these tools and a few others already "on the table" can be found at: http://cmapspublic2.ihmc.us/rid=1Q3X92V22-1PP4FDW-DW81/Metacognition%20and%20Sustainability%20%2526%20Resilience.cmap With the draft metacognition toolbox as a catalyst, researchers are asked the following questions to move the community to a collaborative 'adjacent possible.':

1. In what specific ways could concept mapping, vee heuristics, and additional metacognitive tools be used
    1. to address climate change and other complex problems?
2. How can a metacognition toolbox be structured to facilitate substantive responses to complex problems?

This international conference offers an innovative environment from which such a toolbox can emerge.

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