Advancing Transdisciplinary Dialogue in Geoscience Education Research

EARTH EDUCATORS' RENDEZVOUS
LAWRENCE, KS, JULY 16-20, 2018

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GRAND VALLEY STATE UNIVERSITY

SCIENCE LITERACY

First…

WELCOME!

Who are we?

- Associate Professor, Director, Coordinator
  - Ph.D. Science Education
  - MS Natural Resources
  - MS Science Education
  - BS Ecology and Evolutionary Biology
- Former high school science teacher
- 9 years as tenure-track/tenured faculty
- Education and STEM discipline

Who are we?

- HIGH SCHOOL STUDENTS' CLIMATE LITERACY THROUGH EPISTEMOLOGY OF SCIENTIFIC MODELING (CliMES; NSF DRK-12, DRL 1720838 1719872)
- FOSTERING UNDERGRADUATE STUDENTS' DISCIPLINARY LEARNING AND WATER LITERACY (WELL; NSF DUE-1609598)
- WATER EDUCATION LEADERS for SECONDARY SCIENCE (WELS2; USDA-NIFA PD-STEP/Title IIA)
- EXCELLENCE IN EDUCATION FOR FOOD, ENERGY, AND WATER (E2FEW; USDA-NIFA HEC)

Who are we?

- Assistant Professor
  - Ph.D. Science Education
  - MS Geology
  - BA Geology
- Two years as Postdoctoral Research Associate

Who are we?

- AGI Education Department
  - *EarthComm*
  - *Investigating Earth Systems*
- Research Background
  - Geologic expertise and problem solving
  - Importance of social capital for persistence in STEM (Geoscience) (NSF-DGE)
- Journal of Geoscience Education
  - Associate Editor
  - Co-editor on *Interdisciplinary Teaching and Sustainability*

Why are we here?

- Over the past several years, the GER community has been engaged in a systematic effort to identify ambitious goals for geoscience education research
- Achievable within ten years
- Point to areas where individual researchers can make large contributions without prescribing particular projects that should be pursued.
- Anticipated to have significant impact on K-16 geoscience education teaching and learning

Why are we here?

- NSF-funded workshops at the first three Earth Educator Rendezvous meetings:
  - *Synthesizing Geoscience Education Research* (2015)
  - *Geoscience Education Research Community Planning* (2016)
  - *Geoscience Education Research Grand Challenges and Strategies* (2017)
- St. John, K. (Ed.) (2018). *A Community Framework for Geoscience Education Research*. National Association of Geoscience Teachers: https://nagt.org/nagt/geoedresearch/GER_framework/index.html

Why are we here?

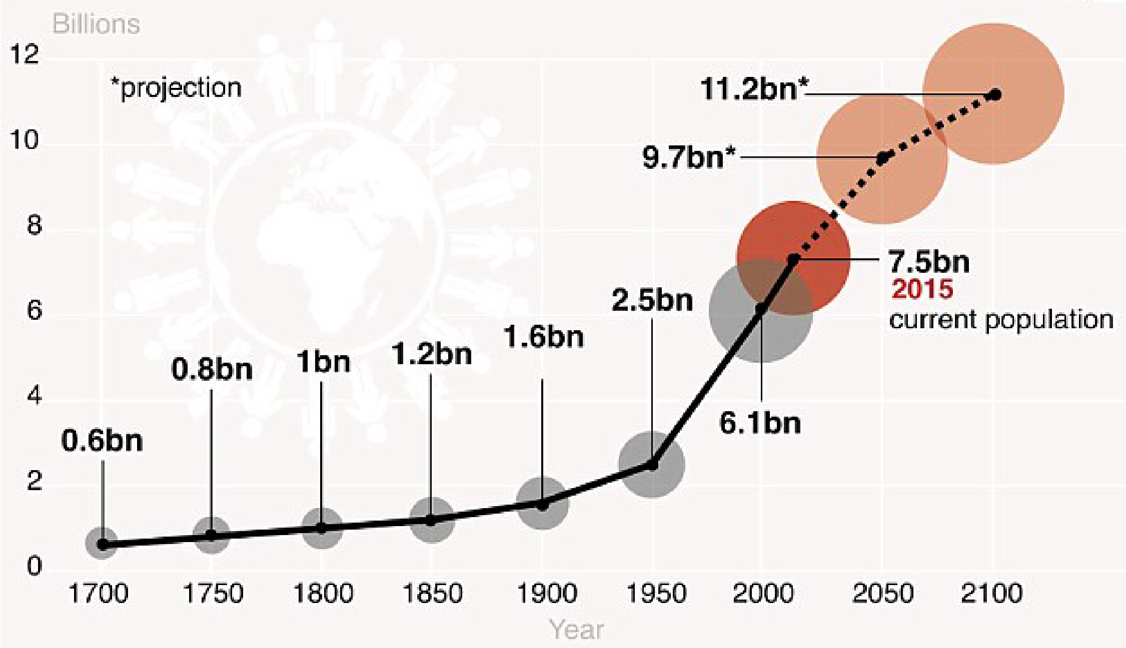
- "*A Framework for Transformative Geoscience Education Research*" NSF DUE-1708228
- Kristen St. John (PI; James Madison University)
- Kim Kastens (Lamont-Doherty Earth Observatory)
- Heather Macdonald (College of William and Mary)
- Karen S. McNeal (Auburn University)
- John R. McDaris (SERC at Carleton College)

Why are we here?

- *Teaching about Earth in the Context of Societal Problems*
- 1 of 10 themes
- Students "must understand the societal relevance of geoscience topics as well as their ethical dimensions." (Mosher et al., 2014, , p. 3)
- Knowledge and consideration of societal issues are critical for geoscience majors and non-majors alike, all of whom will vote and make decisions that should be based on sound science

Why are we here?

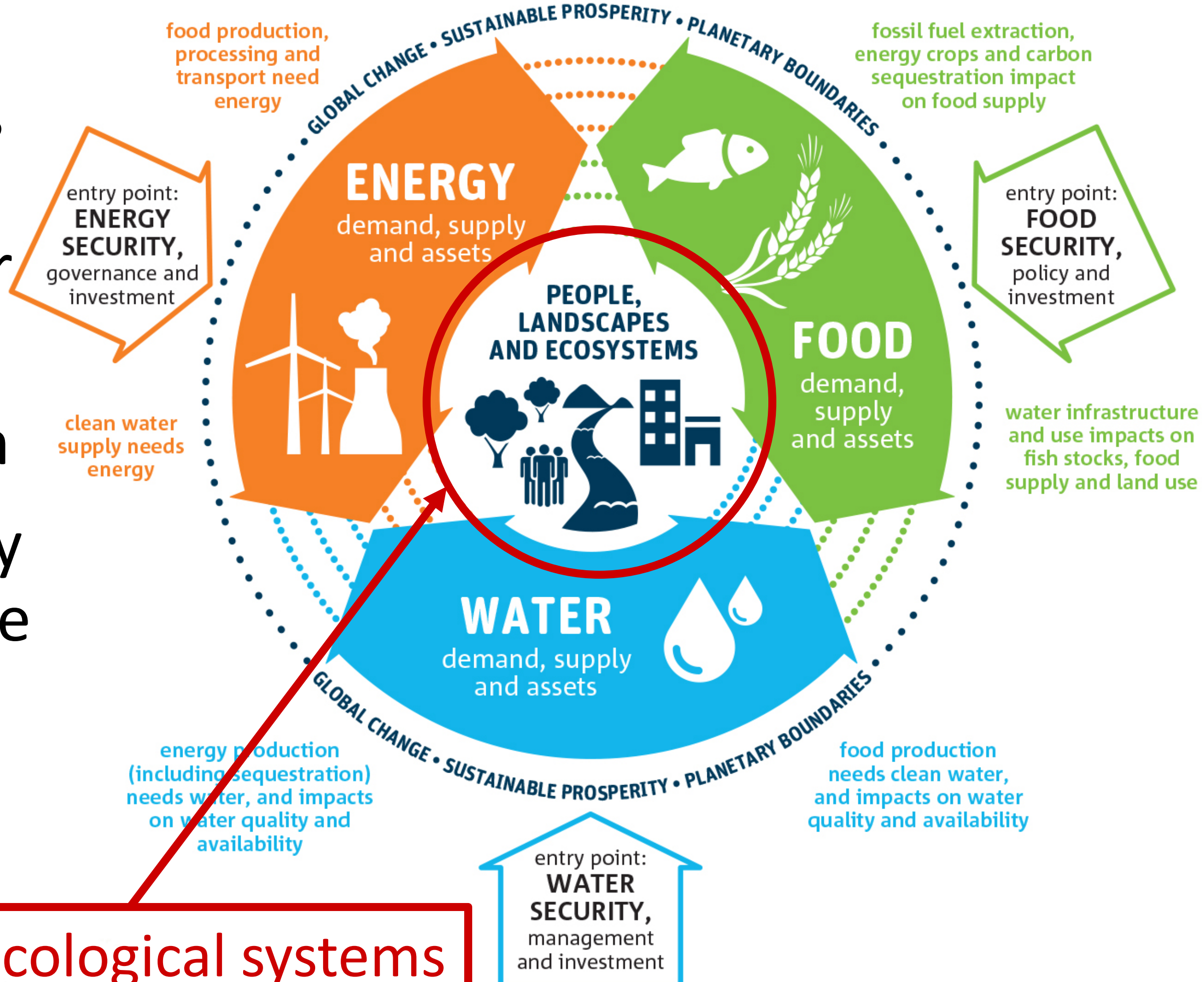
- By 2030, projected world population of 8.3 billion people
- Nearly 1 billion more people in 15 years



- 50% projected increase by 2100

Food-Energy-Water Nexus

- Interrelationships between food, energy, and water
- 70% freshwater used for irrigation
- 30% global energy used in agriculture
- 7% of global energy used to move water



Socio-ecological systems

Future Projections

- Global demand for food is expected to increase by 70% by 2050
- Global energy consumption is expected to increase by about 50% by 2035
- Global water demand for the manufacturing industry is expected to increase by 400% from 2000 to 2050
- Urban population of the world is forecast to grow to 6.3 billion people in 2050 from 3.4 billion in 2009

Addressing Societal Challenges

- Need problem-solvers, innovators, and leaders
- Systemic effort to prepare future generations for challenges in the Nexus
- ‘Science for all’ a long-standing goal of science education reform (AAAS; 1990 NRC, 2013; 2000; 1996)

BUT PREPARE THEM TO DO WHAT??

Critical Epistemic Questions

What do we know?

[Knowledge of STEM concepts]

How do we know it?

[STEM practices, processes, and inquiry]

Why does knowing it matter? What can we do with this knowledge?

[Knowledge in use]

Dimensions of Scientific Literacy

National Research Council

Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. It also includes specific types of abilities. (NRC, 1996, pg. 22)

Organisation for Economic Co-operation and Development

Scientific literacy is the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity. (OECD, 2003, pgs. 132–33)

American Association for the Advancement of Science

Science literacy…has many facets…being familiar with the natural world and respecting its unity; being aware of some of the important ways in which mathematics, technology, and the sciences depend upon one another; understanding some of the key concepts and principles of science; having a capacity for scientific ways of thinking; knowing that science, mathematics, and technology are human enterprises, and knowing what that implies about their strengths and limitations; and being able to use scientific knowledge and ways of thinking for personal and social purposes. (AAAS, 1990, pg. xiv)

State of Scientific Literacy

- Unfortunately…"evidence mounts that scientific literacy is far from what it could or should be" (NRC, 2007, pg. 20)
  - U.S. students underperform on standardized science assessments
  - Gains in science literacy among undergraduate students are modest (Impey, Buxner, Antonellis, Johnson, & King, 2011)
  - PK-16 science learning environments not characterized by features of effective instruction
  - Science curriculum broad, fragmented, and conceptually disconnected
  - Lack of public understanding of science
- Significant effort required to foster science literacy globally

State of Science Literacy

There is "solid evidence" of recent global warming due "mostly" to "human activity such as burning fossil fuels." **[agree, disagree]**

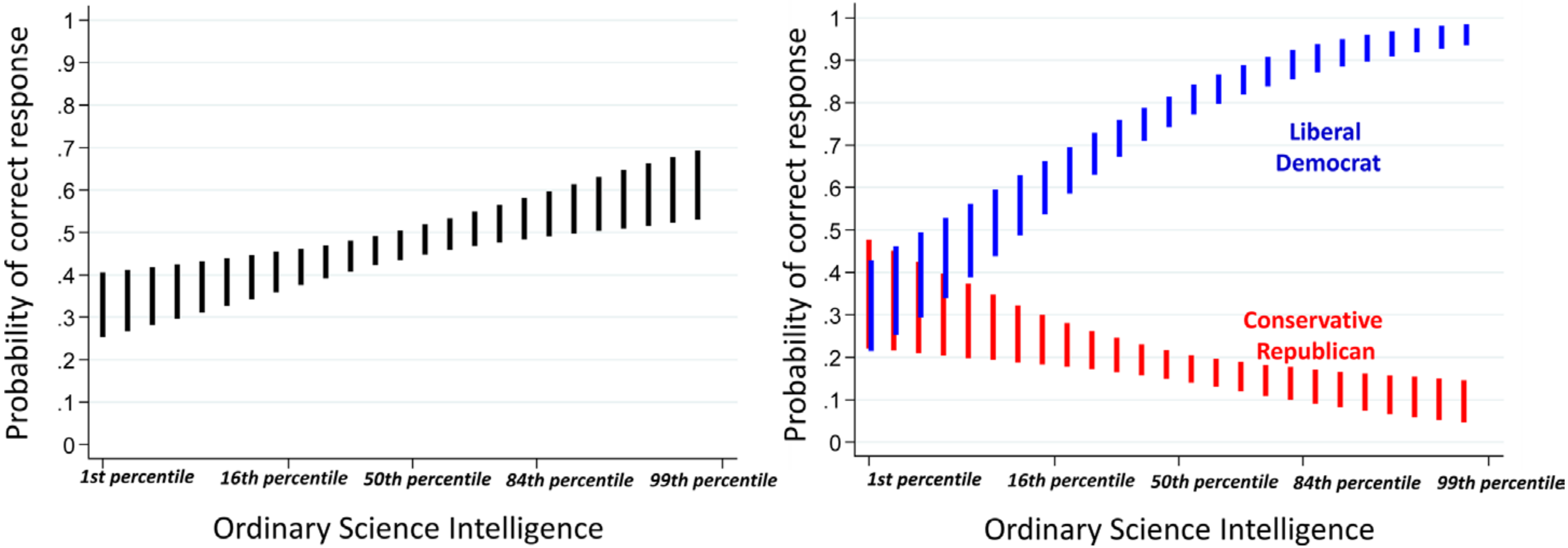


Image credit: The fraction of respondents who agree with the statement above the figure, as a function of their performance on questions covering general science knowledge on non-controversial subjects. The left frame shows the aggregate response, while the right frame is subdivided by self-identified political identification of the respondents. By D.M. Kahan, Advances in Political Psychology 36(S1), 1 (2015). © 2015, John Wiley and Sons.

Why are we here?

- *Teaching about Earth in the Context of Societal Problems*
- A long-standing perspective and emphasis in the science education community
  - Science-Technology-Society (STS)
  - Socio-scientific Issues (SSI)
- Focus on…
  - Application of knowledge to real-world
  - Nature of science
  - Interrelationships between natural systems and humans

Why are we here?

- Individuals can be supported to learn to use geoscience-related knowledge, beliefs, skills, and commitments to make decisions about real-world challenges associated societal problems
- Programs and interventions can be designed as ‘decision support’ to foster scientific literacy
- Diverse target audiences (i.e., ‘cradle to grave’)
- Affords novel theoretical, pedagogical, and analytical lens through which to both foster and understand scientific literacy

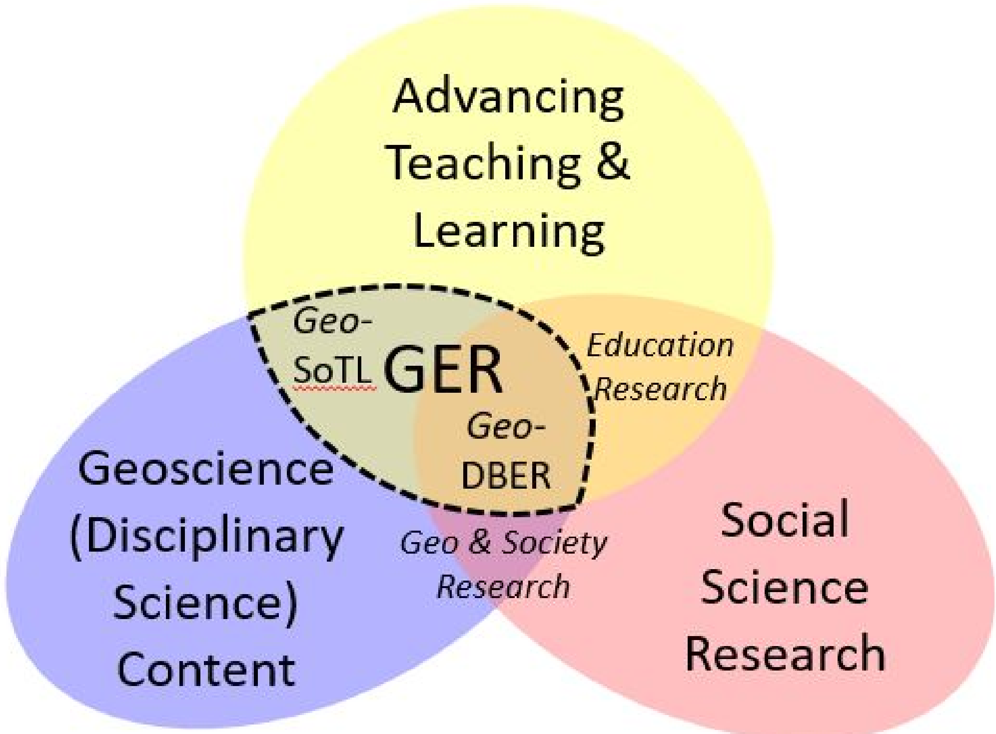
Why are we here?

Need for more research:

- Grand Challenge 1: *How does teaching with societal problems affect student learning about the Earth?*
- Grand Challenge 2: *What are the design principles for curriculum needed to teach with societal problems?*
- Grand Challenge 3: *How do we assess the influence of teaching with societal problems in terms of student motivation and learning about the Earth?*

Why are we here?

Need for more research:



Geoscience education research Venn diagram. Figure by St. John, 2018, modified from one by Lukes et al. (2015)

Why are we here?

Teasdale, R., Scherer, H., Holder, L., Boger, R., & Forbes, C.T. (2018). Research on teaching about Earth in the context of societal problems. In St. John, K. (Ed.), *A Community Framework for Geoscience Education Research*. National Association of Geoscience Teachers:

https://nagt.org/nagt/geoedresearch/GER_framework/theme4/index.html

Workshop overview

- *Advancing Transdisciplinary Dialogue in Geoscience Education Research*
- Advance research around GER grand challenges associated with teaching about the Earth in the context of societal issues
- Integration of geoscience education and education research
- Encourage interdisciplinarity and dialogue across communities

Workshop goals

- Examine collective interest in teaching about the Earth in the context of societal issues.
- Identify strengths and limitations of different theoretical frameworks for explaining how teaching about Earth in the context of societal problems leads to student learning.
- Analyze and review different specific measures or methods for studying teaching and learning about Earth in the context of societal problems.
- Discuss and develop possible paths forward for longitudinal or multi-institutional studies related to teaching about Earth in the context of societal problems

Workshop agenda – Day 1

- Setting the stage and session framing
- Getting to know one another
- Articulating outcomes for learners
- Exploring theoretical frameworks
- Locating current teaching and research work in this space

Workshop agenda – Day 2

- Methods demos
  - Structured decision-making
  - Socio-scientific reasoning – QuASSR
- Generating research questions in this space

Workshop agenda – Day 3

- Invited panel
- Collaborative research proposals

Invited Panel

- Donna Charlevoix, Ph.D., UNAVCO
- Anne Egger, Ph.D., Central Washington University
- Steven Semken, Ph.D., Arizona State University
- Laura Zangori, Ph.D., University of Missouri

Thank you

- Mitchell Awalt, SERC
- Monica Bruckner, SERC

Getting to know each other

- Please organize into groups of 3 and introduce yourselves to one another:
  - Current institution
  - Teaching and research responsibilities
  - # of years attending EER
  - Interests and current work related to teaching about the Earth in the context of societal problems
- Group thinking:
  - *What does it mean to teach about the Earth in the context of societal problems?*
  - *Why teach about the Earth in the context of societal problems?*

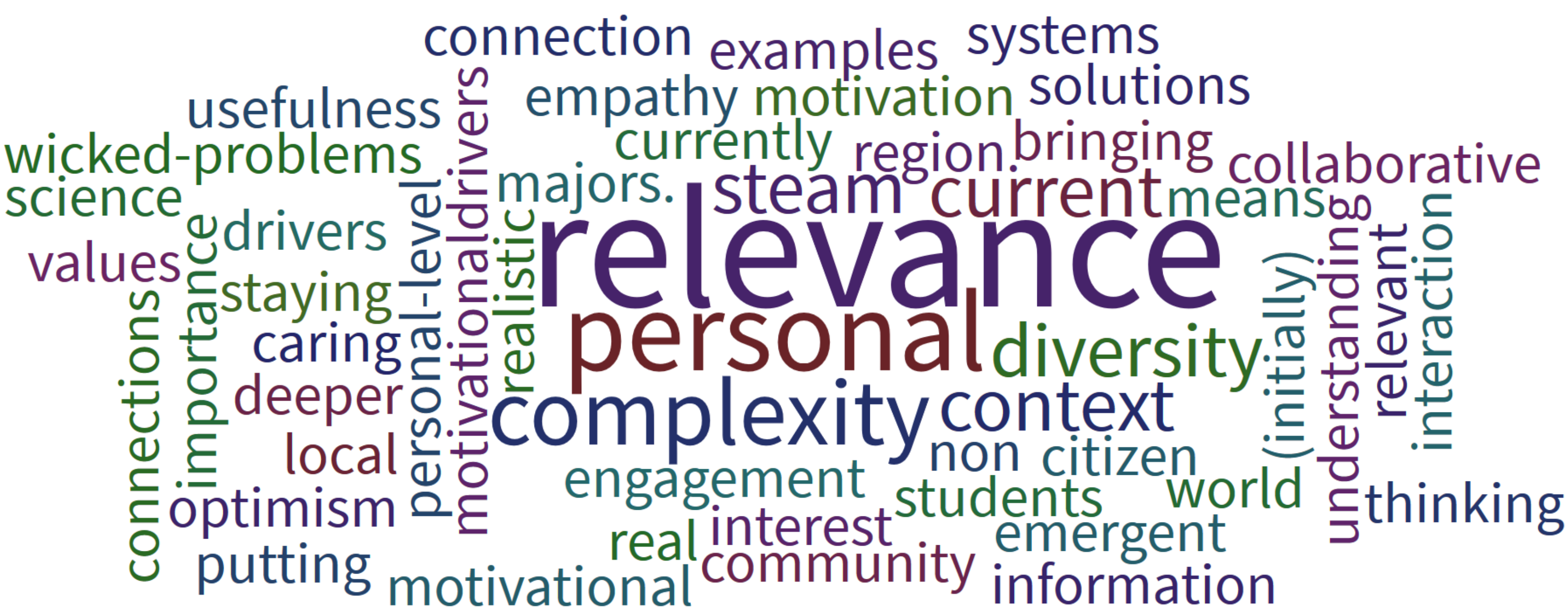
Getting to know each other

- Group thinking:
  - *What does it mean to teach about the Earth in the context of societal problems?*
  - *Why teach about the Earth in the context of societal problems?*
- As a group, identify 3 terms that address these questions
- Add online or text to PollEv.com/coryforbes882
- Text CORYFORBES882 to 37607 to join the session, then they text a response.

Getting to know each other

What does it mean to teach about the Earth in the context of societal problems? Why teach about the Earth in the context of societal problems?

Poll is full and no longer accepting responses



Poll Everywhere

Outcomes – brainstorming

- Let's dive a little deeper into this question:

  Why teach about the Earth in the context of societal problems?
- Brainstorm specific outcomes for learners that would be attainable through this approach
- List these outcomes on a large piece of post-it paper

Outcomes – gallery walk

- Please spend a few minutes visiting other groups' lists
- Add a small post-it note to at least 3 other posters with a question/comment on one or more objectives

Outcomes – discussion

- Return to your groups and review comments, questions, and feedback on your lists
- What trends do we observe across groups? Are there outcomes that are more frequently mentioned?

BREAK

Theoretical Frameworks

- *Teaching about Earth in the Context of Societal Problems*
- What is it? How do you do it? What do learners gain from it?
- Key is to operationalize key elements to guide design of learning environments
- Need theoretical framework(s) to guide this work

Theoretical Frameworks

- *Teaching about Earth in the Context of Societal Problems*
- Let's unpack this a bit more
  - Teaching about Earth
  - Context
  - Societal problems
- Implied emphasis on student learning

Theoretical Frameworks

Teaching about Earth

- Emphasis on geoscience content and concepts
  - Next Generation Science Standards
  - Earth Science Literacy Principles
  - Climate Literacy Principles
- Best practices in geoscience education
  - Curriculum
  - Instruction (e.g., active learning)
  - Assessment

Theoretical Frameworks

Context

- Real-world defines the boundaries of the scientific context
- Interdisciplinary
- Contrast with teaching science as disciplinary canon
- Implications for the real world
- Participatory and emancipatory, broadening participation

Theoretical Frameworks

<u>Societal problems</u>

- Challenges with significant scientific dimensions
- Lots of examples (with significant overlap)
  - Water resources
  - Food production
  - Energy production and consumption
  - Human health
  - Wildlife conservation
  - Climate change
  - Pollution and environmental degradation

Theoretical Frameworks

- Science-Technology-Society (STS)
- Mid 1900s
- Thomas Kuhn's (1962), *The Structure of Scientific Revolutions*
- Recognition that science was not a neutral, value-free endeavor
- Historical and social studies of science itself

Theoretical Frameworks

- STS carried over into K-12 education
- Science for the citizen
- "without understanding, how can we hope to act with intelligence?" - John Dewey (1945) *Science Education*
- Curriculum development in the 1960s-70s
- Inward focus – emphasis on the nature of science
- Continuum from motivator to deep analysis of one or more social dimensions of science

Theoretical Frameworks

- Socio-Scientific Issues (SSIs - Sadler, Barab, and Scott, 2007)

  https://serc.carleton.edu/sp/library/issues/index.html
- Use of controversial socially-relevant real world issues with course content to engage students in their learning

Theoretical Frameworks

- Argument for how SSI encompasses and builds upon earlier STS approaches (Zeidler, Walker, Ackett, & Simmons, 2002, p. 344)
  - Focus on social nature of knowledge construction
  - Offers pedagogical guidance for teachers
  - Acknowledges moral, ethical, and developmental dimensions of learning
- This distinction may or may not be equally important to everyone but is something to consider

Theoretical Frameworks

- Connection to course objectives
- Teaching Controversial Topics
- Data-supported
- Real rather than fabricated
- Contemporary relevance
- Controversial
- Illustrates the nature and process of science
- Value-laden
- Interdisciplinary

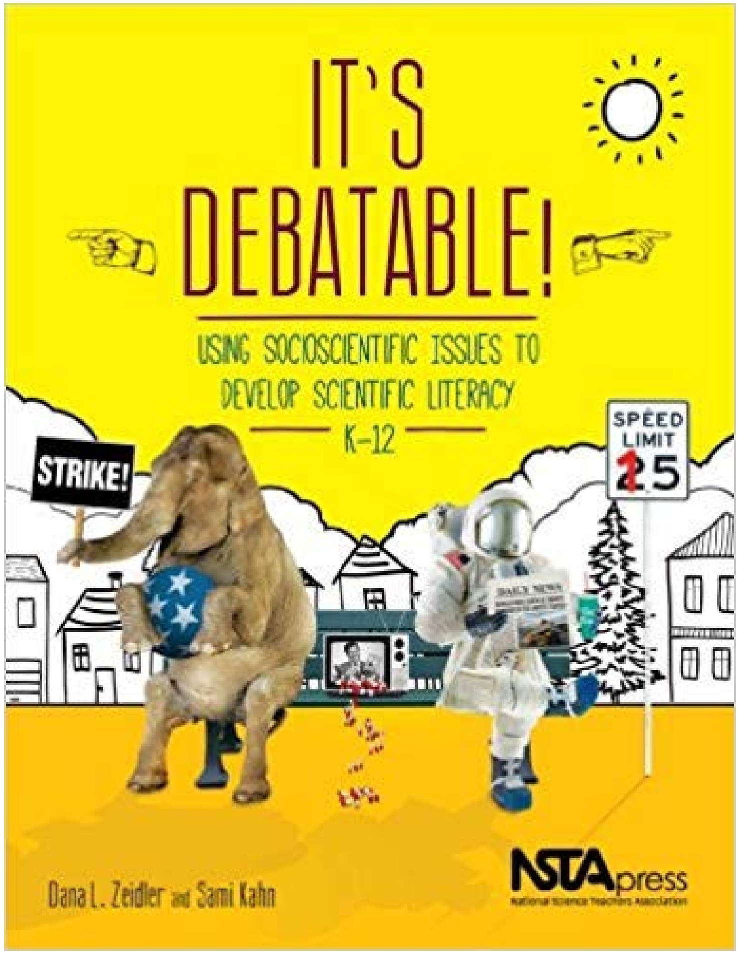
Theoretical Frameworks

Less emphasis on…	More emphasis on…
Discussing science in isolation	Discussing science concepts and understanding in the context of personal and societal issues
Working alone	Collaborating with a group that simulates the work of a scientific community or represents authentic groups found in society
Acquiring scientific information	Acquiring conceptual understanding and applying information and conceptual understanding in making and evaluating personal, societal, and global decisions
Closed questions with one correct answer	Open-ended questions that require students to explain phenomena or take positions backed by evidence
Multiple-choice assessments	Authentic assessments

Wilmes and Howarth (2009)

Theoretical Frameworks

- *It's Debatable! Using Socioscientific Issues to Develop Scientific Literacy and Citizenship, K-12*
- Dana Zeidler, University of South Florida
- Great resources and model instructional materials for SSI-based teaching and learning



Theoretical Frameworks

Common elements of SSI-based instructional sequences

1. **Identify Topics.** Review sources for current issues related to your subject matter and course objectives.
2. **Collect Resources.** Look for a range of sources reflecting a diversity of viewpoints.
3. **Introduce Topic**. Engage students with magazine headlines, articles, advertisements, YouTube videos, photos, models, or other media.
4. **Prepare Students for Discussions.** Set ground rules for class discussions, emphasizing the value of all ideas, mutual respect for participants, and intolerance for mockery or personal attacks.
5. **Pose Controversial Questions.** Introduce contentious questions and challenge "common knowledge" of subject matter.
6. **Provide Formal Instruction.** Present subject matter in a variety of ways to ensure content coverage and student engagement.
7. **Incorporate Group Activities.** Allow students to investigate issues in small groups, emphasizing the analysis of evidence, reinforcement of content matter, monitoring of understanding, consideration of divergent viewpoints, and full participation of all students.
8. **Provide Guidance in Evaluating Primary and Secondary Sources.** Discuss the importance of identifying bias and provide tools for assessing trustworthiness of research sources.
9. **Assess Knowledge and Reasoning**. A variety of "products" that allow students to demonstrate learning can be developed. Assessment should include content understanding as well as its reasoned applications to the issue at hand.

Theoretical Frameworks

Advantages of SSIs

1. Aligned with best science teaching practice (e.g., 5E model - Bybee et al, 2006).
2. Higher order thinking (Bloom, 1980, and Krathwohl and Anderson, 2001) to evaluate, analyze and synthesize information to address the issue under discussion, rather than a focus on recall of definitions or descriptions of processes.
3. Increases engagement by making science more relevant (Lewis, 2003, and Herreid, 2005). Helps improve students' understanding (Sadler 2002; Hazen 2005).
4. 21st-Century Skills – decision-making, perspective-taking, teamwork, negotiation, etc.
5. Argumention and exposure to alternative ideas (Sadler and Zeidler, 2004).

Theoretical Frameworks

<u>Potential challenges of SSIs</u>

1. Controversial topics can lead to animated discussions
2. Requires additional skillsets of educators to navigate and facilitate
3. Finding room in the curriculum
4. Identifying learning outcomes beyond conceptual understanding

Theoretical Frameworks

<u>Identifying and selecting productive SSIs</u>

I. Is the issue actually a socio-scientific issue (SSI)?
II. Is the issue a productive SSI for the intended audience?
   - Is the issue aligned to state and/or national science standards (or other content expectations for the class)?
   - Are there relevant and accessible social, political, economic and/or ethical considerations related to the issue?
   - To what extent will the intended student audience relate to the issue?
III. What instructional moves need to be made to promote successful implementation of [RI]2 teaching?
   - Is the issue being framed with an appropriate focus?
   - Are there aspects of the underlying science that may need to simplified or backgrounded?
   - Should authentic or hypothetical scenarios be featured?
   - Are local, national, or global themes emphasized?

http://ri2.missouri.edu/issue-selection-guide

Theoretical Frameworks

Outcomes/Competencies for SSIs

- The usual suspects – conceptual understanding, nature of science, scientific practices/processes, etc.
- Unique outcomes
  - Socioscientific reasoning
  - Science-informed decision-making

Theoretical Frameworks

<u>Socio-scientific reasoning</u>

- Competencies associated with negotiation of SSIs
- Primary components (Sadler et al., 2007; Romine, Sadler & Topcu, 2016).
  - Accounting for the inherent complexity of SSI
  - Analyzing issues from multiple perspectives
  - Identifying aspects of issues that are subject to ongoing inquiry
  - Employing skepticism in analysis of potentially biased information
  - Exploring how science can contribute to the issues and the limitations of science

Theoretical Frameworks

Socio-scientific reasoning

- Skepticism
- Complexity
- Inquiry
- Perspective-taking
- Argumentation
- Limitations

Romine, W. L., Sadler, T. D., & Kinslow, A. T. (2016). Assessment of scientific literacy: Development and validation of the quantitative assessment of socio-scientific reasoning (QuASSR). *Journal of Research in Science Teaching*. DOI:10.1002/tea.21368

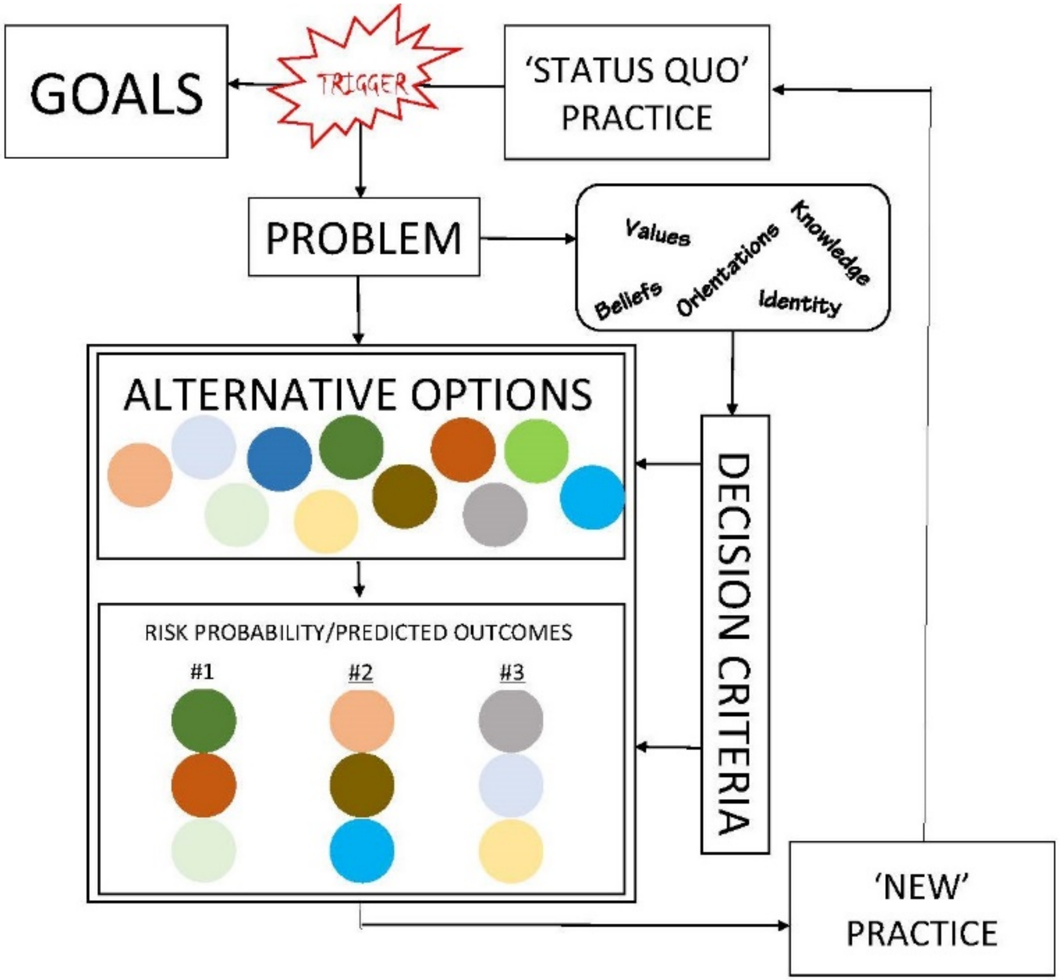
Theoretical Frameworks

<u>Science-informed decision-making</u>

- A natural concluding step for socio-scientific reasoning
- "You can know all you need to know about your world and still not know what to do, which choices to make" (Mullen & Roth, 2002, pg. 1).
- Not just using knowledge to analyze SSIs, but ultimately making decisions about them
- Based on work from decision sciences (e.g., Arvai et al., 2004; Hammond, Keeney, & Raiffa, 2015) and the STEM education community (e.g., Halverson, Siegel, & Freyermuth., 2009; Sadler, & Zeidler, 2005)

Theoretical Frameworks

- Science-informed decision-making
- Identifying options and trade-offs
- Using explicit decision criteria
- Foundation for maintaining America's global competitiveness (NRC, 2009)



Theoretical Frameworks

Science-informed decision-making

1. Define the Problem: What is the crux of the problem as you see it?
2. Options: What are the options? (Discuss and list the possible solutions to the problem.)
3. Criteria: How are you going to choose between these options? (Discuss important considerations and what is valued in an outcome.)
4. Information: Do you have enough information about each option? What scientific evidence is involved in this problem? What additional information do you need to help you make the decision?
5. Advantages/Disadvantages: Discuss each option weighed against the criteria. What are the tradeoffs of each option?
6. Choice: Which option do you choose?
7. Review: What do you think of the decision you have made? How could you improve the way you made the decision?

(Dauer & Forbes, 2016; Ratcliffe, 1997; Sabel et al., 2017)

Theoretical Frameworks

Concluding thoughts

- Teaching science in the context of real-world issues is an approach that has been around awhile in various forms
- These frameworks share many core elements
- Central question – *what does teaching geoscience in the context of societal issues afford both educators and learners that is novel?*

Small groups

- Individually, locate your current teaching and/or research endeavors in the matrix on the white board.
  - Use color-specific post-its for research and teaching
  - Write your name on them
  - Stick them one or more cells of the matrix that reflect your current work
- In small groups, share a bit about how your work aligned with these outcomes, learning contexts, and elements of theory (i.e., why you put post-its in those cells)

Workshop agenda – Day 2

- Methods demos
  - Structured decision-making
  - Socio-scientific reasoning – QuASSR
- Generating research questions in this space

Roadcheck

- Please see link on the SERC website:

  https://serc.carleton.edu/earth_rendezvous/2018/program/morning_workshops/w3/monday_roadcheck.html