IDENTIFYING AND PRIORITIZING GEOSCIENCE EDUCATION RESEARCH GRAND CHALLENGES: DRAFT PLANS FOR A COMMUNITY RESEARCH AGENDA

259-5

Kristen St. John, James Madison University (stjohnke@jmu.edu); Cinzia Cervato, Iowa State University; Kim A. Kastens, Columbia University; Heather Macdonald, College of William and Mary; John R. McDaris, Carleton College; Karen McNeal, Auburn University; Heather L. Petcovic, Western Michigan University; Eric J. Pyle, James Madison University; Eric M. Riggs, Texas A&M University; Katherine Ryker, Eastern Michigan University; Steven Semken, Arizona State University; Rachel Teasdale, CSU Chico.

ABSTRACT

Fourteen years ago the Wingspread Project helped establish geoscience education research (GER) as an important research field and highlighted overarching research questions for GER at the time. Since the release of this report, GER has grown as evident from an increase in the quality and frequency of geoscience education research articles, the establishment of the NAGT GER Division, the creation of an online home for GER via the GER Toolbox, an increase in the number of GER graduate programs, and the growth of tenure-eligible faculty positions that support geoscience education research.

As an emerging STEM education research field, the GER community is examining the current state of their research and considering the best course forward so that it can have the greatest collective impact on advancing teaching and learning in the geosciences. As part of an NSF-funded multi-step effort to meet this need, 45 researchers drafted priority research questions, or "Grand Challenges", that span ten research themes on undergraduate geoscience teaching and learning. These themes include research on: students' conceptual understanding of the solid and the fluid Earth, K-12 teacher preparation, teaching about Earth in the context of societal problems, access and success of underrepresented groups in the geosciences, spatial and temporal reasoning, quantitative reasoning and use of models, instructional strategies to improve geoscience learning, students' self-regulated learning, and faculty professional development and institutional change. For each theme, several Grand Challenges have been proposed, and are now ready for their first round of peer review, which at GSA will include this presentation and a Town Hall event.

It is our vision that the final outcomes of this community-grounded process will be a published guiding framework to (1) focus future GER on questions of high interest to the geoscience education researcher and practitioner community, (2) provide funding agencies with a strong rationale for including GER in future funding priorities, (3) increase the strength of evidence of GER community claims, and (4) elevate the visibility, stature, and collaborative potential of GER in the geosciences and in STEM education research.

RESEARCH THEMES

	Research on:
1	Students' conceptual understanding of geology/solid Earth science content
2	Students' conceptual understanding of Env/ocean/atmosphere/climate content
3	Elementary, middle, and secondary Earth science teacher education (working with teachers and future teachers in all settings)
4	Teaching about Earth in the context of societal problems
5	Access and success of under-represented groups in the geosciences
6	Spatial and temporal reasoning
7	Quantitative reasoning, problem-solving, and models/modelling
8	Instructional strategies to improve geoscience learning in different settings and with different technologies (e.g., place-based instruction, teaching large lectures, online instruction)
9	Geoscience students' self-regulated learning/metacognition and affective domain
10	Institutional change and faculty professional development, TA training

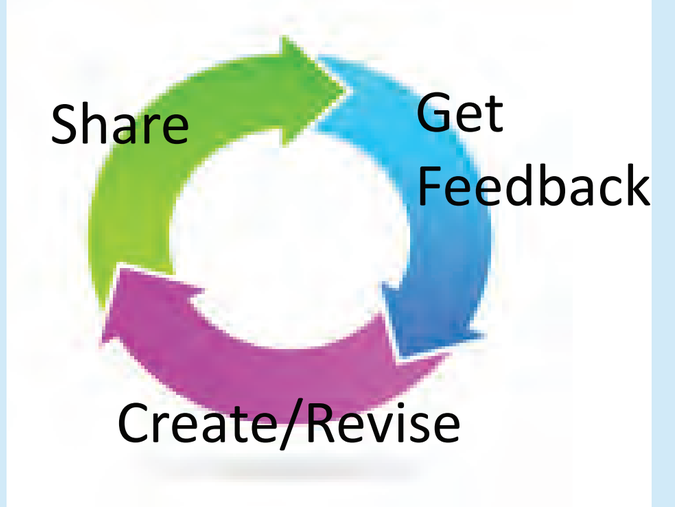
Themes informed by:
Focus group discussions at the 2015 GER workshop, Results from the 2016 and 2017 GER Surveys, the DBER Report (Singer et al., 2012), the Wingspread Report (Manduca et al., 2003), the Earth in Mind II Synthesis report (Kastens and Manduca, 2012), and Lewis and Baker (2010, JRST).

BACKGROUND AND CONTEXT

NSF project: ***A Framework for Transformative Geoscience Education Research***

Goal: to engage the community in setting ambitious goals for geoscience education research (GER) that will be achievable within ten years and will have significant impact on undergraduate geoscience teaching and learning.

A year-long process of community engagement.



Steps in the Process:

✓ **Identify themes** that define the spectrum in which GER operates and has the potential to impact undergraduate teaching and learning.

Primary focus of the summer GER workshop, the GSA Town Hall, and the upcoming online survey

Articulate and prioritize grand challenges for each theme that are of high interest to the geoscience education researcher and practitioner community.

Recommend strategies to address the prioritized grand challenges. These will be strategies that the community views as providing the strongest opportunities for rapid achievement of transformative GER.

An important juncture early this year: At the 2017 EER GER Workshop, ~45 geoscience education researchers assembled into working groups to draft priority research questions, or "Grand Challenges" (GCs), that span ten research themes on undergraduate geoscience teaching and learning. Draft GCs and strategies were presented and critiqued by the other workshop participants and feedback was used to revise their work.

EARTH EDUCATORS' RENDEZVOUS
GSA 2017
AGU

April 2017	June 2017	July 2017	August-September 2017	October 2017	November 2017	December 2017	January 2018
Online GER Grand Challenges survey	Webinar on survey results	GER Project Workshop; + Research and Practice Forum	Revise	GER Grand Challenges and Strategies Town Hall	Revise	Online open comment period/ survey	Revise and write white paper

Broad Dissemination: NSF, direct mail to all geoscience departments, post to the online GER Toolbox, Commentaries in JGE, EOS or GSA Today, and a cross-DBER journal.

PROPOSED GRAND CHALLENGES (PRIORITY RESEARCH QUESTIONS) FOR EACH RESEARCH THEME
WG = working group GC = grand challenge

WG1: Research on Students' Conceptual Understanding of Geology/Solid Earth Science Content

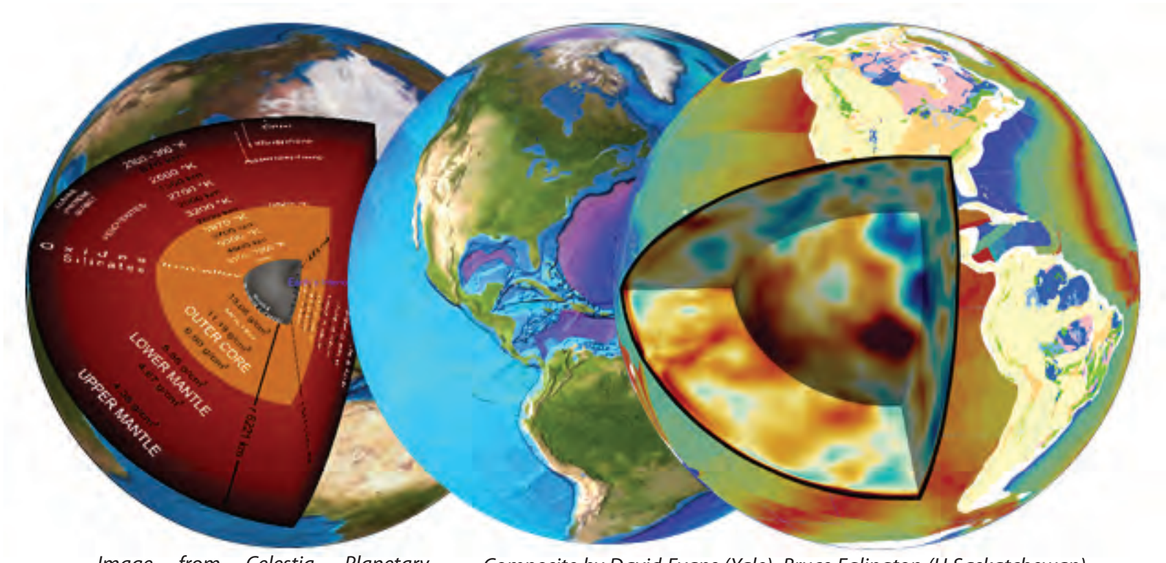


Image from Celestia, Planetary Interiors Module by user "Fenerit"

Composite by David Evans (Yale), Bruce Eglington (U Saskatchewan), and Andy Darling showing Auer et al.'s (2014) tomography for the mantle, Eglington's geological unit compilation for the continents, and Mueller et al.'s (2008) seafloor-age model for the oceans

CG#1: What are ways to further develop current and to discover new ways of understanding critical concepts for developing Earth Systems thinking on processes from the surface to the core, and links to other Earth system components?

GC#2: What are the most useful ways to disseminate results on solid earth student concept research to K-16 and informal educators?

GC#3: How can we incorporate and K-16 and informal educators' experiences and observations to sustain the dialogue between practitioners and researchers in solid earth education?

WG2: Research on Students' Conceptual Understanding of Environmental, Ocean, Atmospheric & Climate Science

Cat. 5 hurricanes José and Maria on September 19, 2017. Images courtesy of NASA.

GC #1: How do we identify and address the challenges to the conceptual understanding specific to each discipline: environmental science, ocean sciences, atmospheric sciences, and climate science?

GC #2: How do we teach complex interconnected Earth systems to build student conceptual understanding, e.g., climate change?

GC #3: What approaches are effective for students to understand various models (numerical and analytical) that are used for prediction and research in atmospheric, oceanic and climate sciences, including model limitations?

GC #4: How do the societal influences, affective elements, personal background and beliefs, and prior-knowledge of students impact their conceptual understanding of Earth system sciences?

GC #5: How do we broaden the participation of faculty who are engaged in educational research in environmental sciences, atmosphere sciences, ocean sciences and climate sciences and implementing research-based instruction?

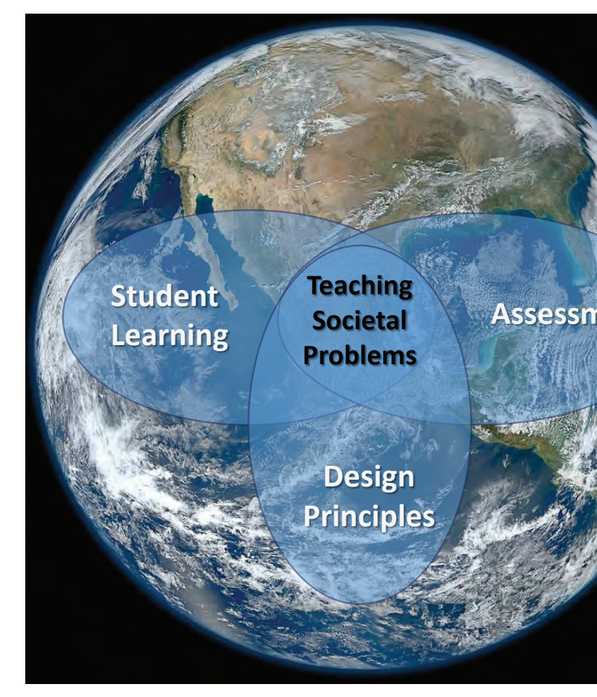
WG3: Research on K-12 Earth Science Teacher Education

CG#1: How do we attract and support a greater number of future K-12 earth and space science teachers who represent the diversity of K-12 learners?

GC#2: What are effective models for incorporating earth and space science into undergraduate K-12 teacher preparation?

GC#3: How do we best prepare future K-12 teachers to engage in earth and space science to promote "3-dimensional" learning as described in A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas?

WG4: Research on Teaching about Earth in the Context of Societal Problems

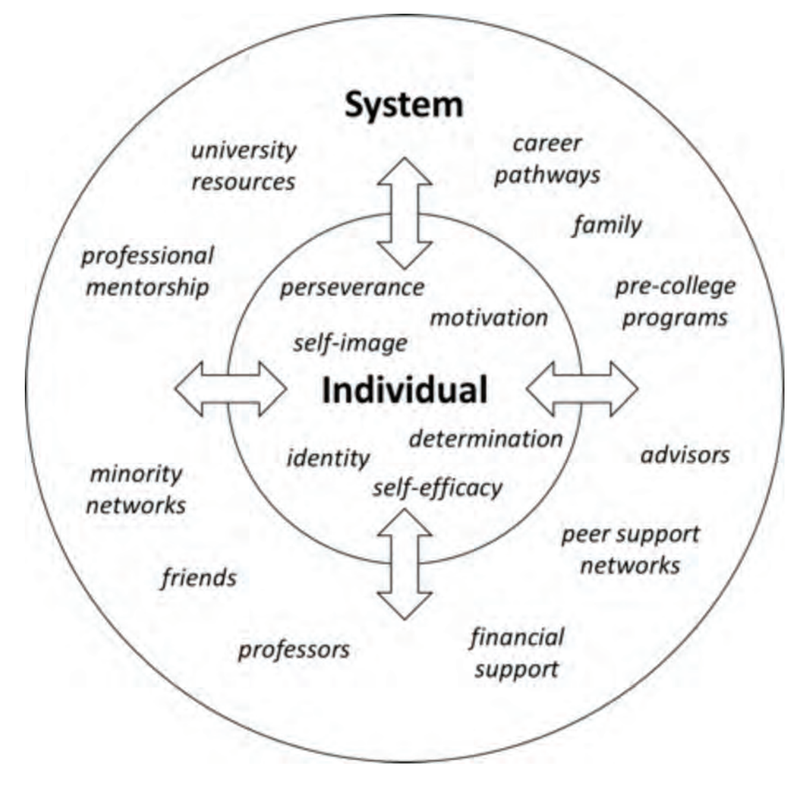


CG#1: How does teaching with societal problems effect student learning about the Earth?

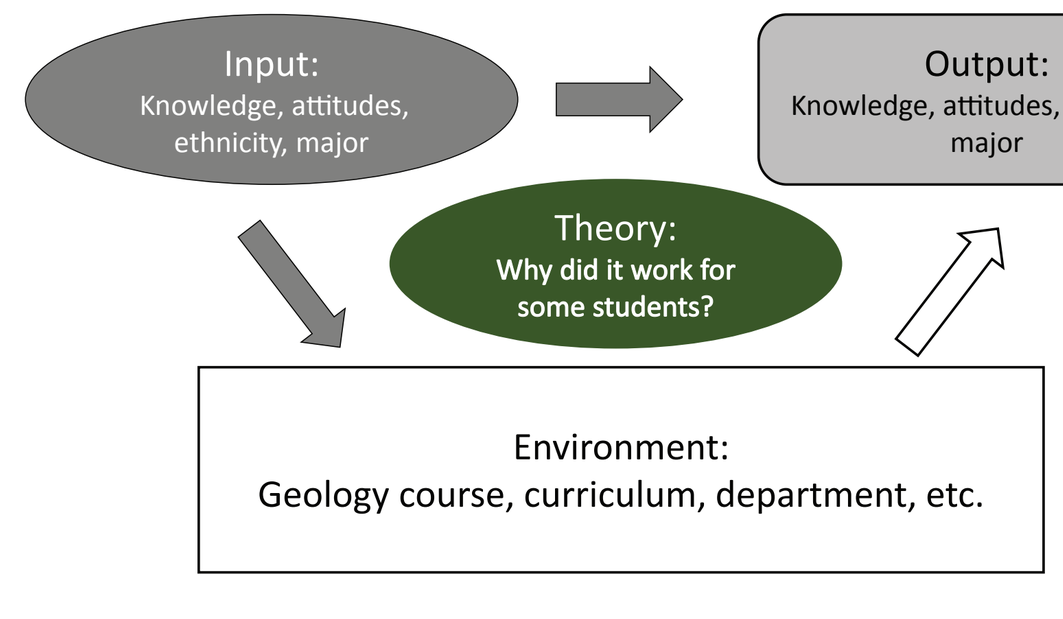
GC#2: What are the design principles for curriculum needed to teach with societal problems?

GC#3: How do we assess the influence of teaching with societal problems in terms of student motivation and learning about the Earth?

WG5: Research on Access and Success for Underrepresented Students


System
university resources
career pathways
family
professional mentorship
pre-college programs
perseverance
motivation
self-image
Individual
identity
determination
self-efficacy
advisors
minority networks
peer support networks
friends
professors
financial support

Macrosystems Framework: Individual in context of surrounding systems
Wolfe and Riggs, 2017, in press, JGE

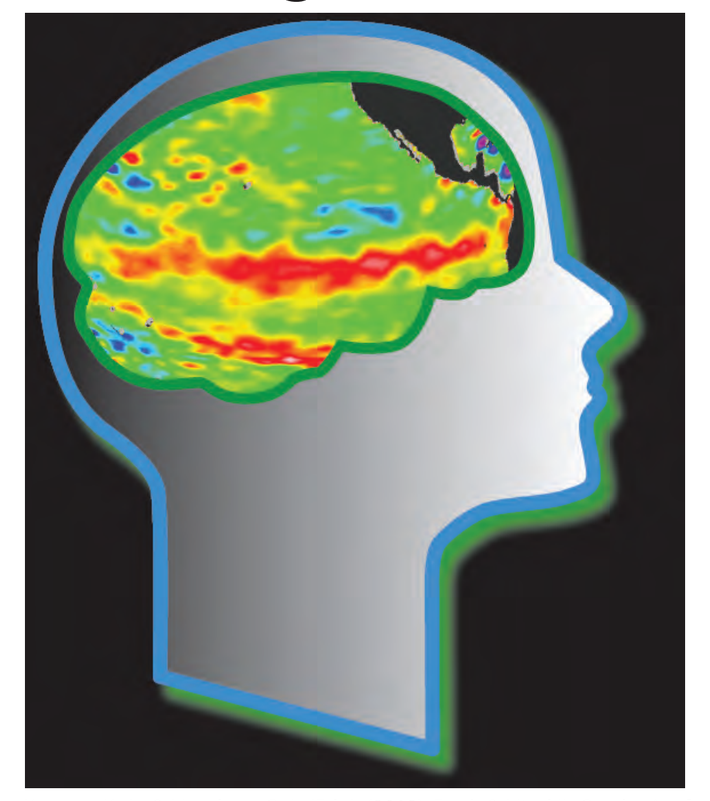


Input-Environment-Output Framework
Pathway analysis of individual in context of lived experience interacting with systems
after Callahan, LaDue, Baber, Sexton, van der Hoeven Kraft and Zamani-Gallaher, 2017, in press, JGE

CG#1: How can we recognize and support the individual identities and personal pathways of students as they are attracted to and thrive in the geosciences?

GC#2: How can the geoscience community capitalize on evidence from different scale efforts to broaden participation?

WG6: Cognitive Domain A - Research on Spatial and Temporal Reasoning



Kastens, K. A., & Manduca, C. A. (Eds.). (2012). Earth & Mind II: Synthesis of Research on Thinking & Leaning in the Geosciences. Boulder, CO: Geological Society of America Special Paper 486.

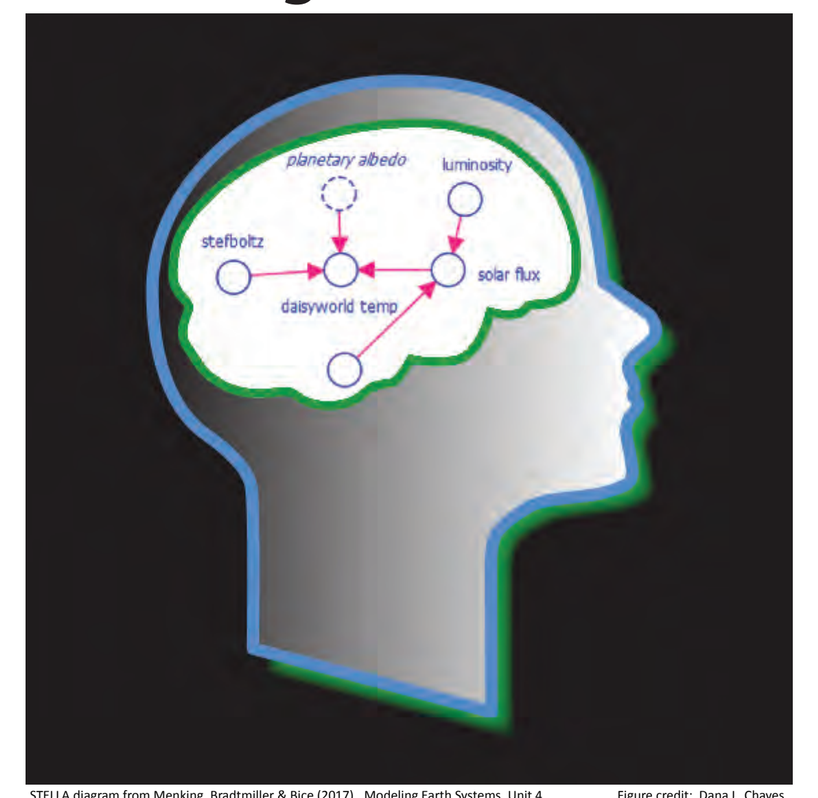
CG#1: What are the types of spatial and temporal reasoning essential to the geosciences, and where do research gaps remain within this domain?

GC#2: How can geoscience education foster spatial and temporal reasoning?

GC#3: How can assessment measure spatial and temporal reasoning?

GC #4: How can we reach out to other domains and communities to explore spatial and temporal reasoning?

WG7: Cognitive Domain B - Research on Quantitative Thinking, Problem-solving, Models & Modelling



STELLA diagram from Menking, Bradtmiller & Bice (2017). Modeling Earth Systems, Unit 4. https://serc.carleton.edu/integrate/teaching_materials/earth_modeling/unit4.html Figure credit: Dana L. Chayes

CG#1: Quantitative Thinking: How does quantitative thinking help geoscientists and citizens better understand the Earth, and how can geoscience education move students toward these competencies?

GC#2: Problem-finding and Problem-solving: How can we help students find and solve problems they care about concerning the Earth, in an information-rich society (big data, emerging technologies, access to a wide-variety of tools, rich multimedia)?

GC#3: Models & Modeling: How can we help students understand the process by which geoscientists create and validate physical, computational, mental, systems, and feedback models and use those models to generate new knowledge about the Earth?

WG8: Research on Instructional Strategies for Geoscience Learning

CG#1: How can research and evaluation keep pace with, and effectively inform, innovations in strategies for teaching geoscience knowledge, skills, and dispositions?

GC#2: How can undergraduate geoscience instruction benefit from effective research-based practices in other domains?

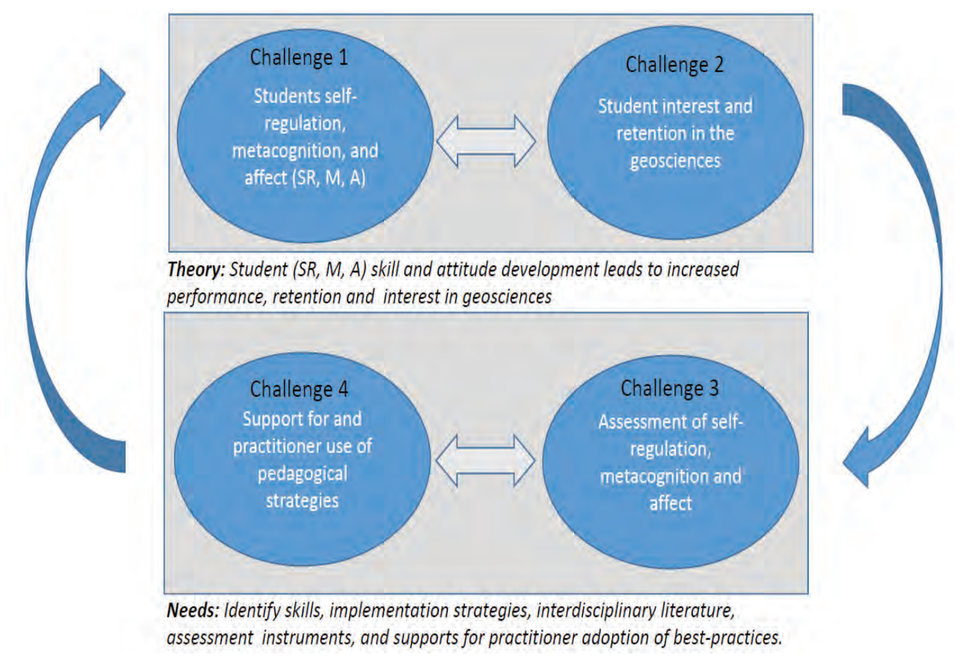
GC#3: What instructional practices and settings are most effective for the greatest range of geoscience learners?

GC#4: How do we overcome structural barriers that impede effective teaching and learning of geoscience?

GC#5: How can we better engage learners as co-creators and colleagues in teaching?

GC#6: How do we most effectively disseminate and promote relevant research findings and best practices in geoscience instruction?

WG9: Research on Geoscience Students' Self-Regulated Learning/Metacognition and Affective Domain


Challenge 1
Students self-regulation, metacognition, and affect (SR, M, A)
Challenge 2
Student interest and retention in the geosciences
Theory: Student (SR, M, A) skill and attitude development leads to increased performance, retention and interest in geosciences
Challenge 4
Support for and practitioner use of pedagogical strategies
Challenge 3
Assessment of self-regulation, metacognition and affect
Needs: Identify skills, implementation strategies, interdisciplinary literature, assessment instruments, and supports for practitioner adoption of best-practices.

CG#1: Student Skills: How do we support students in developing their ability to learn, regulate, and apply the skills and ways of thinking in the geosciences along the expert-novice continuum?

GC#2: Inclusion: What are effective strategies in engaging a diverse population of students in their learning and sustaining their interest in the geosciences?

GC#3: Assessment: How can we measure student experiences in the geosciences through the lens of self-regulation, motivation and other components using the most cutting edge research technology and methodologies?

GC#4: Educators: How to support the geoscience community in learning and implementing classroom strategies that research identified as effective in supporting students affect, metacognition and self-regulation of learning?

WG10: Research on Institutional Change and Professional Development

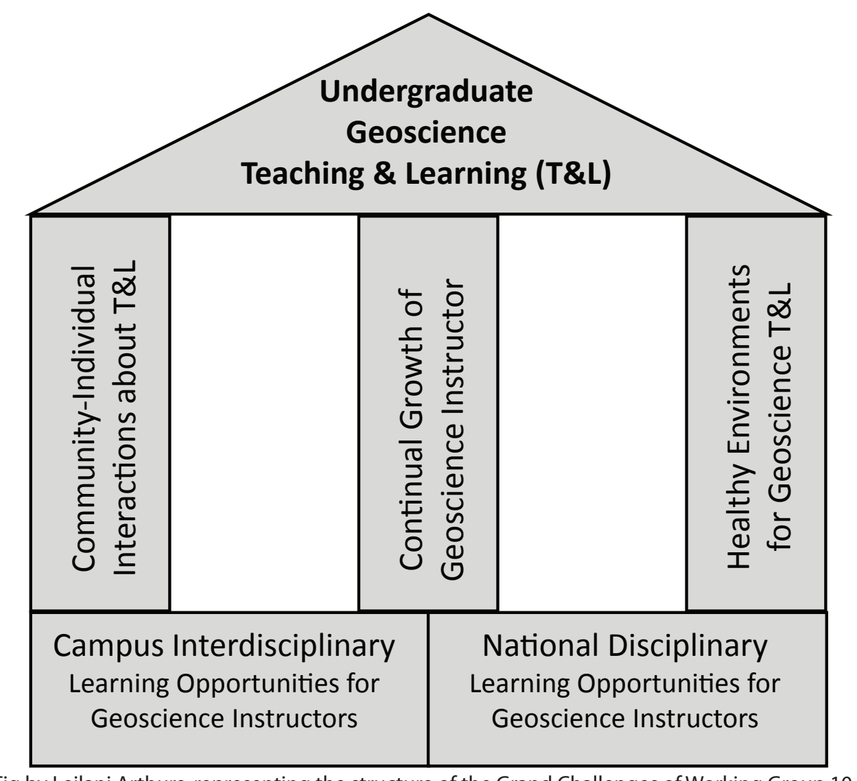

Undergraduate Geoscience Teaching & Learning (T&L)
Community-Individual Interactions about T&L
Continual Growth of Geoscience Instructor
Healthy Environments for Geoscience T&L
Campus Interdisciplinary Learning Opportunities for Geoscience Instructors
National Disciplinary Learning Opportunities for Geoscience Instructors

Fig by Leilani Arthurs, representing the structure of the Grand Challenges of Working Group 10.

CG#1: How can we best support the continual growth of geoscience instructors' ability to teach effectively and to progress professionally? How does the individual's cumulative experience, position type, institutional context, and the nature of the desired learning impact the type of learning opportunities that are most effective?

GC#2: What is the interplay between on campus interdisciplinary learning opportunities and national disciplinary opportunities in promoting geoscience instructor learning?

GC#3: What supports the health of the programmatic environments in which geoscience learning occurs?

GC#4: How do community-individual interactions inform and enable changes in undergraduate geoscience teaching and learning?