First Steps Toward Synthesizing Geoscience Education Research: Notes from Workshop Discussions May 2016

This document is an outcome from the workshop, *Synthesizing Geoscience Education Research: Where are we? What is the path forward?* The workshop was held at the Earth Educators Rendezvous in Boulder, CO in July 2015.

This document summarizes the findings and results of group discussions at the workshop. The workshop organizers recognize these efforts to be an important first step in an ongoing process to summarize the current status of geoscience education research and prioritize future efforts.

For further information, please contact Heather Macdonald, College of William and Mary.

Tuesday, July 14, 2015 - Working Groups

What do we know, what do we want to know, what do we need to move the field forward? Working towards a community synthesis.

The goal of this activity was to begin to synthesize the 'state of the field' of geoscience education research (GER) in each of the sub-topics within geoscience education. Each group had 2.5 hours to work together to lay the groundwork in addressing three broad questions.

1. What is already known in that field, what methods and types of evidence have shaped these outcomes, and what are the key papers and landmark research results in this area?
2. What are important questions that still need to be addressed?
3. What tools and future research will help to carry the field forward?

The working groups were self-selected and participants signed up for groups where they had the most expertise or interest. The workshop conveners selected the leaders for each group. The group leaders all have significant experience in the topic of their working group.

Seven working groups were formed prior to the workshop, and each was focused on one particular dimension of GER. The list of topics is given below. We recognize that some of these subjects are intertwined and overlap, and that there are several possible ways to organize these themes. Our list was influenced by the structure of the DBER book and how other science disciplines have organized their education research.

1. Students' conceptual understanding
2. Cognitive domain and problem solving
3. Instructional strategies to improve geoscience learning
4. The affective domain and metacognition
5. Access and success
6. Nature of science / nature of geoscience

7. Professional development of college/university educators
8. Elementary, middle, and secondary teacher education (Note – no workshop participants signed up for this topic, so it is not included in the notes below.)

The task assigned was monumental, particularly given the time constraints of the workshop, and the workshop leaders viewed this session as the first step in a larger process. Thus, this session was an opportune way to initiate this work and draw from the expertise present at the workshop, with the expectation that the work done at the workshop would be used as a framework from which other GER synthesis work could build after the workshop.

The content below was generated by each of the working groups. These summaries have been condensed and organized from their original state.

Part I: Overarching outcomes

While the workshop leaders hoped the groups would be able to help identify what is already known in various sub-topics of GER, this task proved to be difficult. Not surprisingly, given the time frame, groups made few firm claims about what is known. This may be due to the social/professional pressure of staking a claim to say authoritatively "this is known." This was especially true because of the spectrum of GER experience among workshop participants; some participants were specialists in geoscience discipline-based education research, while others were scholars on geoscience teaching and learning, and others were primarily practitioners and new to GER in any form Also, it would be easier to make such claims in the context of a literature review, rather than a working group session. An additional factor is the richness of variables when it comes to student learning. Even if one factor is robustly known, can it be transferred to another type of student, a different context, or a related topic?

Nonetheless, a few claims were made.

- Active learning works.
- Professional development workshops are effective in transforming teaching practices.
- The geoscience field is a leader in research on spatial and temporal thinking.
- A metacognitive approach improves student learning; students can be taught metacognition.

In addition, participants recognized progress made by other fields. Geoscience educators and researchers are advised to take advantage of advances that have been made in other disciplines (including K12), so as not to reinvent the wheel. For example, the challenges of dealing with misconceptions, or teaching quantitative reasoning are common research themes in other science disciplines. That said, we should also recognize factors that are particular to the geosciences. For example, geoscience problems are likely to be what educators call "ill-structured problems," which are problems that are complex, and have many possible solutions and paths to solutions. In another example, participants asked if are there specific metacognitive skills and/or affective attributes that are particularly useful for students in the geosciences? It's important to be attentive to the degree to which skills learned in one discipline transfer to another.

While the workshop session was intended as an initial foray into these questions, more thorough review of the literature would help to answer these questions. While participants were hesitant to make claims, they did cite key papers, programs, and researchers that were influential in their sub-discipline.

The working groups were successful in making lists of questions for further work and future needs, and consistent themes emerged among the groups. From this we can generate a consensus-based list of next steps and priorities for the GER field as identified by the workshop participants.

Priorities for new geoscience education research:

- We need to move beyond single-course studies and move toward
  - Multi-institutional studies,
  - Mixed-method studies,
  - Longitudinal studies, for example, across the trajectory of the geoscience major,
  - Extend studies to include diverse populations.
- These priorities are consistent with those in the "strength of evidence" pyramid for evaluating research results.
- Need validated instruments, assessments, and other tools that researchers can use.

Next steps for supporting the communities of geoscience researchers and educators

- Identify the key papers and results so that others can use these references and move forward without reinventing the wheel. This work can also help to inform the broader community about the conceptual framework behind particular topics.
- Move toward a common language within the research community, and work to define key terms and concepts so that it's easier for non-experts to stay abreast of new developments.
- Need to help departments and institutions understand the importance of GER and research-based instruction.
- To recognize GER as research that is as legitimate as traditional science research (for example, when considering promotion and tenure).
- Need to solidify and clarify the case for why GER is important, and continue to make this case to funding agencies.

Next Steps for Translating GER Results into Practice

- Establish a bank or a library of instructional methods with advice about when/how to use them (such as Pedagogy in Action).
- Promote and disseminate recommended practices for teaching and for instructional design (such as in the *On the Cutting Edge* workshops).
- Engage the broader community of geoscience educators; encourage colleagues to move toward evidence-based instructional methods.

- Acknowledge that the most appropriate methods need to reflect the situation of particular teacher, course, and setting. Emphasize that methods can be adapted and modified to suit the real-world needs of institutions, departments, faculty, and students.
    - Work toward courses, classrooms, teaching assignments, and course evaluations that recognize and support evidence-based instructional design. In other words, remove barriers toward progress.
    - Continued professional development and mentoring about teaching practice that is grounded in GER results.

Part II: Summaries from Working Groups

The content below was generated by each of the working groups. These summaries have been condensed and organized from their original state.

Group 1 - Students' Conceptual Understanding

Group Members

Simone Dumas, Julie Ferguson, Karen Kortz, Karen McNeal (facilitator), Nancy Price, Tim Shipley, Rebecca Teed, Karen Viskupic, Emily Ward

What do we already know?

1. Students' conceptual understanding is challenged by misconceptions.

Misconceptions go by different names and have subtle differences in meaning. Common terms include pre-conceptions, naïve conceptions, and partially-correct conceptions.

2. Misconceptions arise from different causes.

- Lack of exposure to the concept
- Exposure to the idea that resulted in an inaccurate explanation and conception
- Misconception resulting from ineffective teaching materials or methods
    - Textbook figures
    - Teaching methods
- Domain-specific misconceptions arise from using ways of thinking from other disciplines and applying them (incorrectly) to the geosciences.
- Cultural influences

3. Educators and researchers have made lists of common misconceptions.

Misconceptions can be grouped around cognitive themes such as geologic time, scale (very small or very large numbers, particularly when applied to time or distance), change over time, transfer of matter and energy. Misconceptions can also be categorized by topic, such as the cause of Earth's seasons.

4. Some tools exist to uncover misconceptions.

- Concept Inventories
  - Geoscience concept inventory
  - Oceanography concept inventory
  - Meteorology (?)
  - Climate (McNeal, Gold, ongoing development)
- Survey instruments
- Concept sketching and free drawing
- Interviewing

5. Key papers and research
[Note, the workshop organizers recognize that this is not intended to be a complete list of influential work. Rather, it's a brainstormed list.]

- Kortz & Murray, 2009: categorizes misconceptions in the geosciences
- Cheek, 2010 (JGE)
- Francek, 2012 (IJSE)
  - Andy Anderson, Michigan State, K12 carbon cycle

What do we want to know?

1. To what standards are we teaching?
As we focus on improving students' conceptual understanding, it's helpful to have an end goal in mind, particularly one that is standardized and well accepted.

- What are the key concepts that are most important for higher education geoscience?
- Are they Earth Science Literacy Principles?
- Develop standards and key concepts be developed
- Consider the preferred blend of practical skills vs. content
- Field skills – what are students getting out of field experiences?

2. Refine the types, sources, and causes of misconceptions
While the basic issues are known, it is worthwhile to investigate in more detail with regard to topic, origin, and audience.

- The cognitive literature can help with the categorization of geoscience misconceptions.
- Chi's ontologies of misconceptions can help organize misconceptions by type (space, time, force, energy, matter). Worth linking?
- Need to compile a list of misconceptions across the broader geosciences: ocean, atmosphere, and climate.
- How do misconceptions play a role for diverse students? What is the role of different cultural settings?

3. Methods to address misconceptions

The "bottom line" is how to we help students move on from their misconceptions, and how do we know when that has occurred?

- When studying conceptual change, there are many factors to potentially include in the research design:
- Effects of class size, course type, and course setting (large course, online course, upper-level course, field course)
- Multi-institution studies
- Diverse student populations
- Work on assessment design (again, with variations for course type, setting, and audience)
- Developing the assessment: What is an effective assessment? What does it measure?
- Organizing assessment methods: uses, limitations, strengths
- Explore potentially effective methods
- Learning progressions
- Threshold concepts
- Learning transfer
- Practice-based activities

4. Establish best practices for conceptual change and engage the greater community.

As research illuminates a better understanding of misconceptions and ways to create conceptual change, the profession will be well-served by ready access to that information.

- Involve the broader community of geoscience educators in a discussion to prioritize needed topics.
- Create an inventory of research methods and data collection tools.
- Create an inventory of effective teaching methods that are supported by research.
- In both cases, these could be organized by topic, audience, or type of misconception.
- Make the research-driven methods widely available to educators (the "common professor").

Group 2 - Cognitive Domain and Problem Solving

Group Members

Anne Gold, Sara Harris, Bruce Herbert, Ben Maas, Heather Petcovic (facilitator), Stephen Reynolds, Mark Turski

What do we already know?

The following list represents the sub-topics that fall within this larger topic, and the group's "impressions of the status" of each. This group commented that it is really important to look at what has been done in other DBER / science education (including K-12) fields so as not to reinvent the wheel.

Problem-solving

- Geoscience problems are generally "ill-structured," which means there is not a clear solution and/or clear path to the solution. This type of problem solving has been studied in the geosciences.
- We could contextualize problem solving in the geosciences. Engineers have a lot of work in design and problem solving. There is rich literature on authentic inquiry and design research in engineering. Environmental scientists have a particular strategy for solving problems (risk assessment).
- Problem solving is related to problem-based learning (PBL) - this is a huge literature in science education, particularly at K-12.

Quantitative reasoning

- The literature in PER and BER is more robust than that in the geosciences.
- Cognitive science research suggests that temporal reasoning and spatial reasoning are related to quantitative reasoning. Spatial and temporal thinking have been well researched within GER. SILC and the Earth & Mind volumes are good examples. We think the field is pretty advanced in this area, and, for example work in GER has informed the cognitive science community (e.g., disembedding, visual penetrative ability).

Using and understanding models, simulation, and visualizations of Earth processes

Models -

- The literature about Nature of Science has made some advances, particularly in the K12 realm. Similarly, the NGSS Framework document defines models.
- Cognitive science and education research has done a lot of work since the late 90s. One example is DiSessa and others work on mental models.
- Work on gestures can help the development of mental models.
- Note - we use "models" to refer to both mental models (an individual's conception of what something is/ how it works) and the physical model or simulation that represents the mental model. Work on both is important.

Visualizations -

- Existing resources exist at the Cutting Edge website on visualizations; the "Visualizing Oceans of Data" has advice on how to scaffold representations.
- Some teaching materials like PhET simulations try to make the invisible visible.
- Students sometimes have a hard time working with visualizations. Eye tracking work looks at how people interpret visualizations. Advances have been made in the computer science field.

Expert-novice spectrum

- Other domains have done considerable work in this realm (for example, a chapter in How People Learn), and there are many books about expertise in general.

- Some studies in GER use experts as a comparison group to novices (e.g., wanting to know how an expert solves a problem, reads a graph, makes a map, understands a concept).
- There have been few studies of authentic expert practice in the geosciences.

Promoting transfer to new learning situations and settings

- The body of geoscience research in online learning and MOOCs is not extensive.
- Recognize that there is a difference between how people transfer learning in closely related subjects or tasks, compared to transferring learning between contexts that are minimally related. This is called "near and far transfer."
- In an undergrad environment we tend to be focused on near transfer. For example, does a concept from one class transfer to another class?
- Developing skills useful on the job might be an example of far transfer.
- Recognize that there is a different between transfer within a domain and out of a domain - example, can math learned in math class be transferred into geo classes?

GER future directions: What do we want to know?

We think that although the DBER report puts all of these topics into a chapter, this is too complex to be construed as one "field." Each topic on our list could generate a review paper of its own. There is a lot of work done in other fields (and some in GER) but how the work from elsewhere translates into GER is unclear.

- *Problem-solving* - We think that the community has not clearly defined what we mean by "problem solving' in particular contexts. What do we mean by "problem-solving" in the classroom? How do we measure problem-solving success in the classroom? How do classroom approaches differ from those in the working discipline?

- *Quantitative reasoning* - Is there a theoretical basis for understanding quantitative thinking? There probably is, but we don't know where (maybe engineering or math, particularly looking at theory underpinning Common Core at K-12).

- *Temporal reasoning & spatial reasoning* – Much research has been done in the lab. How do we transition this wealth of knowledge to classroom practice?

- *Using and understanding models, simulation, and visualizations of Earth processes* - Earth system models can be complex and large scale as compared to other DBER fields like physics. You can use physical models for discreet processes like aquifers or magma chambers, but large, multi-system processes (like climate) need a different approach. What are the best ways to model these large and complex systems?

- *Expert-novice spectrum* - How do we align employer expectations with program outcomes for majors?

- *Promoting transfer to new learning situations and settings* - What teaching practices work in online settings? For example, how can we teach labs in an online environment? What about (MOOCs)?

What do we need to move the field forward?

- We need a series of papers that define key terms and concepts, review the literature, identify theory behind a particular topic, and then make recommendations for classroom practice.
- We need a clearer understanding of how problem solving relates to conceptual understanding. Students can't solve problems without a basic conceptual understanding. However solving problems can also help build concepts.
- Research needs to take place across multiple contexts and with multiple student populations (to help with transfer).
- Need for validated assessments and tools/instruments.
- A lot of the work in this area has been done on students. Not much on teaching practices or how to translate findings to instructional design.

Group 3 - Instructional Strategies to Improve Geoscience Learning

Contributors
Vince Cronin, Hillary Hamann, Sara Harris, Daren Nelson, Michael Pelch, Perry Samson, Kristen St. John (facilitator)

What do we know and how do we know it?

- Active learning works. It works in multiple contexts. Many strategies work, but instructors need to find what works best for them in their context. Freeman et al 2014 paper (Acrobat (PDF) 768kB Jul14 15), Also supported by DBER Ch 6 report.
- Professional development workshops are effective in transforming teaching practices.
- There are good observational and anecdotal studies on student learning in field and lab-based settings (DBER Ch 6).
- Some tools exist for measuring what students in geoscience courses do/learn; RTOP (http://serc.carleton.edu/NAGTWorkshops/certop/reformed_teaching.html), COPUS (http://www.cwsei.ubc.ca/resources/COPUS.htm) and the Teaching Practices Inventory (http://www.cwsei.ubc.ca/resources/TeachingPracticesInventory.htm) are three examples.

What do we want to know?

Topics and Questions for further research:

- We want to know how to best (and easily) measure (assess) student learning in our contexts. How can we be better at assessing our students' learning? And how can we best measure student activity in our classes? And what should we be measuring in our assessments of student learning, student engagement? Are engaged students therefore better learners?

- Need to move past observational and anecdotal studies on student learning in field and lab-based settings (DBER Ch 6).
- What can GER learn from the other DBER sciences (e.g., what can we learn from physics teaching and learning) and other fields (e.g., educational psychology) about teaching and student learning? We expect most strategies would transfer, but are there some strategies that won't transfer to our geoscience context? And are there some strategies that are specific only to the geosciences b/c of the learning goals (e.g., penetrative thinking [spatial] and temporal reasoning, visualization of the Earth)?
- What are the best instructional strategies for online learning in the geosciences? Ranging from flipped classes, online, MOOCs?
- If you have two different ways to teach the same thing, is one better than the other? And how do we measure which strategy works best? Is this so situationally dependent that we can't generalize?
- Are active learning instructional strategies also helping recruit and retain students in the geosciences?
- Are active learning instructional strategies actually preparing students for career success?

Questions for the wider educational community:

- Even with active learning do we need to *scaffold* our program learning goals differently to ensure student learning? (short term vs. long term learning gains, and teaching and learning that build on earlier instruction). Is the intro survey-level class more really about engagement as a primary goal, and then upper level classes is where student learning really happens?
- What is the place for lecture? We think lecture still has an important place, but we are concerned that department colleagues may think that it is "either/or" - that it must be active learning OR lecture. How can we better communicate that both have a place?
- What is the place for textbooks in teaching and student learning? Are modern textbooks effective in student engagement and student learning? Are online resources better now? There are new models of textbooks now (online supplements, focus on figures and guided inquiry, more of workbooks than textbooks, tutorials), but are not widespread. Are the ways textbooks are adopted (for large multi-section classes) a barrier to change?
- There are many active learning strategies - how do we best integrate them, and integrate them with lecture, for our particular teaching and learning situation?
- Why doesn't active learning always work? There are good peer-tested teaching modules out there (e.g., some InTeGrate modules), but adopting/adapting/modifying for one's unique context, population, location teaching style is not always successful. How do we, as instructors, learn how adapt/modify sooner, better, with lower stress?

- How can we help colleagues move more towards evidence-based instructional methods?
- What are the incentives for instructors to use active learning? It improves student learning, but there are institutional barriers (administrative evaluation; teaching doesn't matter as much research), and student push-back at times, and more effective measures of student learning (vs student opinion) are needed. How can the larger geoscience community move past these barriers?

What do we need to move the field forward?

- We need continued and more effective professional development (and mentoring) on teaching practice that is grounded in GER results. Ideally, this training would address how to adapt methods to different academic environments. And these programs need to model the methods they are encouraging others to use.
- We need professional development on how to develop testable learning goals, how to develop appropriate assessments that measure student learning in multiple contexts and are easy to use by practitioners.
- We need more tools on how to assess student learning in real time, in short-term (e.g., end of course) and longitudinally (years later).
- We need to increase the effectiveness of the knowledge transfer from researchers to practitioners about instructional strategies.
  - We need to find ways for our geo ed community (practitioners and GER), and individual geoscience faculty to make better use of/and contribute to centers for teaching and learning at their institutions.
  - We need to minimize barriers to adoption of active learning. This may include the way that faculty teaching is evaluated. Because of the role of end of course student "evaluations," faculty can be nervous in tying new active approaches. This is especially true if student evaluation is used in their administrative evaluation (e.g., annual evaluations, P&T). For example, it would be helpful to know how to separate learning gains from student opinion.

Group 4 - Affect and Metacognition

Group Members

Mary Beck, Jennifer Dixon, Kaatje Kraft, Laura Lukes (facilitator), Elizabeth Nagy-Shadman, Karl Wirth, with substantive comments added by Dexter Perkins

What do we know and how do we know it?

Basic definitions

The affective domain includes:

- Attitudes and motivation
- Values
- Science/math self-efficacy
- Beliefs (e.g., about evolution, climate change)
- Strategies to promote motivation or provide materials and opportunities that students value or find relevant
- We may want to stop using the terms "domains" because there is much overlap between cognitive and affective processes.

Students' self-regulated learning / metacognition includes:

- Encouraging students to think about their learning
- Basic learning assessment methods: minute papers, knowledge surveys, etc.
- Reflective practices
- Developing students' study skills

Selected publications contribute to a baseline understanding of the field

- A metacognitive approach improves student learning. (DBER book)
- Students can be taught metacognition (DBER book).
- There are parts of affective domain that we know to be relevant that DBER does not mention, for example, emotions, test anxiety, emotion regulation, and stereotype threat.
- Lukes (2014) has made important advancements in our understanding of self-regulated learning for introductory geology students in both our understanding what is happening in classrooms and how students are (or aren't) translating that to practice.
- There are many DBER studies but not necessarily consensus. There are only few studies in the geosciences, thus perhaps we do not know too much.
- Karl Wirth's has made important contributions to affect and metacognition, such as, *Learning to Learn* (found at http://www.macalester.edu/academics/geology/wirth/CourseMaterials.html.)

What do we want to know? What are our needs?

Research-driven questions

- Much of the research to date has been classroom studies and populations of convenience. An important next step is to move the research beyond classroom-scale. Broader studies could be at the programmatic level or perhaps involve cohort investigations.

- We need to address reliability and validity concerns as we develop instruments and methodologies.

- "To date, much DBER has treated cognitive and affective outcomes as distinct variables. Future research on the affective domain should avoid this dichotomy and recognize the interdependence of affect and cognitive outcomes." (pg. 161, DBER)
- Longitudinal studies are lacking and would be helpful.
- Tactile/eye tracking affective studies would be good to have.
- Are there specific metacognitive skills/affective attributes that are particularly useful for students in the geosciences? If so, how can we help our students develop those skills?
- Looking at student interest (pre- and post-class) with respect to active learning activities is a way to learn which pedagogies are engaging students.
- Although some educational studies take affective traits into account, many existing do not do meta-analyses for affect. This makes it hard to uncover where affective factors are playing a role in the outcome.
- Many previous studies have examined many variables simultaneously. There is need to focus on specific variables, such as demographics, and to consider additional variables previously lost in an ocean of data.

Community-driven questions

- Issues around motivation, emotion, metacognition, self-regulated learning are all are important to student learning. We need to do much more investigation and to develop some guidelines and suggested practices for geoscience educators.
- There is a great deal of discipline-based literature, from many fields, that we may potentially use to guide our teaching activities. However, not all the important issues have been investigated in detail, and it is sometimes unclear how results from other fields transfer to our geo classes/programs/students
- We need to improve our efforts to communicate what has actually been investigated/found out/concluded in studies already done. We must find a way to get this information to a broad audience of geoscience educators.
- How to translate research into practice? What are the best ways to convince faculty that addressing affective factors is beneficial?
- A sense of community and establishing relationships (with faculty, peers, in general) is important for success for unrepresented student populations (UROP program from U of M).
- We need to clarify the language as other fields have done. We propose moving away from the "domain language." As a community, we need to come to a shared understanding of common language.
- We need to convince funders that these issues are important by building on pre-existing work.

Key References

DBER, beginning at page 155 lists published work up through 2012 (General psychology as well as more focused metacognitive research)

Cooper and Sandi-Urena (2009), Flavell (1979), Craik and Lockhart (1972), McCrindel and Christiansen (1995)

Earth and Mind II - summaries but not original research

Group 5 - Nature of (Geo)Science

Group Members
Kelsey Bitting, LeeAnna Chapman, Kim Kastens, Heather Lehto (facilitator), David Mogk, Sharon Mosher, Carrie Nelms

What do we know and how do we know it?

What do we know?

Prior projects have articulated a first-order vision of what it means to think geoscientifically.

Characteristics of geoscientific thinking are: spatial, geologic time, sequencing, rates, scales, systems, and uncertainty. While these are characteristic, they are not unique to us.

How do we know?

- Reflections, discussion, help reflecting from collaborations with other disciplinary perspectives.
- For example, a collaboration with an anthropologist and a philosopher on "professional vision" in the sciences and in geoscience.
- Observational, inferential, historical discipline.
- Bringing Research on Learning to the Geosciences.
- National Geographic- K12 geography workshop- "SPWATS" Skills, practices, ways of thinking
- Working with SILC to hold up a mirror to help us see our work
- The Science Teachers - "Multiple Modes of Inquiry in the Earth Sciences"

Critical references:

- Cathy Manduca and Kim Kastens Article- "Manduca and Kastens (2012) Geoscience and Geoscientists: Uniquely equipped to study Earth (Earth and Mind II)
- How Geologists Think and Learn, EOS article
- Synthesis of Thinking and Learning in the Geosciences Project – temporal thinking, spatial reasoning, systems thinking, thinking in the field.
- Teaching Geoscience Methods – InTeGrate Workshop and web module on the "habits of mind" that are essential to succeed as a geoscientist

- Mogk and Goodwin (2012) Learning in the field: Synthesis of research on thinking and learning in the geosciences
- Dott, Robert (1988) What is Unique About Geological Reasoning?
- Frodeman, 1995, Bob Fodeman, Geological Reasoning; Geology as an Interpretive and Geological Science GSA Bulletin 1995. Historical, interpretive science, observational work to create theoretical framework

Next step would be having geoscientists be the subject of study by others, nothing done that we know of. Similar work has been done in particle physics, one paper on soil science (Bruno Latour), work on oceanographic vessel, archaeology education, ontology paper about iterative process of defining units in field geology (Northern Canada).

SILC Instruments page- Inventory of Map attitudes (example of good instrument to be used/developed)

What do we want to know?

- What do we mean by the "nature of geoscience?"
- Need to distinguish differences between ways of knowing in various geoscience disciplines (not just commonalities) - atmospheric science, geophysics, etc. What are the geoscience habits of mind that should be universal vs. discipline-specific?
- What counts as evidence for us vs. our students? Modeling, analytical, experimental, etc. Ways to collect, process, and represent data have embedded assumptions that present difficulties for teaching. Might benefit from reaching out to other communities for help on this.
- How do students/human beings manage/cope with/interpret data and datasets? How do we see data/evidence differently from our students?
- How do we represent the ambiguity, probability and uncertainty, causality, risk (perception, resilience, preparedness, etc.) and teach those ideas to students? We can learn much from other DBERs on this topic.
- Decision-making and reasoning, how to unpack the expert perspective, help students transfer "book learning" to the field/data, metacognition. Extend to public domain- how do decide whether to pursue a project- organization/behavior/management literature. How to decide what to research.
- How to inculcate values and habits of mind? How does role-playing help students understand various habits of mind? Look at InTeGrate activity with rubric for various roles.
- How do we get students to the point of being able to recognize model outputs/readings/answers are "geologically reasonable"? Good information on this related to weather forecasting.
- Correlation between new ideas and old experiences, facilitating that transfer of ideas
- How do we get faculty to accept, adopt, and respect education research? Use research-based, experiential-based orientation to play to people's strengths?

What do we need to move the field forward?

- Increased and broadened collaborations with people from other fields.

- Follow up on articles that explicitly try to define the nature of geoscience with some self-reflection- create inventory that can be mapped onto teaching responsibilities. Likert scale? I always use this, I sometimes use this, I am comfortable using this...
- Comparative interventions that might look at decision making in geoscientists vs. lawyers, etc.
- Use existing teaching interventions as raw material for research studies.
- Longitudinal studies within departments to see how knowledge/mastery develops across the trajectory of a major, with comparisons across sub-disciplines.
- Instruments are needed to measure (student and expert) abilities, thought processes, etc.
- Expert vs. novice studies- problem solving with incomplete data, like what Heather Petcovic has done with mapping.

Summary

We know some general characteristics about geoscientists as experts and the nature of geoscience expertise through reflection, discussion, and some studies in conjunction with other disciplinary specialists

Moving forward, we see a need for:

- More collaborations with other disciplinary professionals (anthropologists, philosophers, etc.) who can examine our practice and habits of mind.
- Need to move beyond overall geoscience thinking to distinguish sub-disciplinary differences in thinking.
- Need for more expert-novice studies and longitudinal studies of how skill sets develop across the trajectory of a curriculum.
- More instruments to measure skill sets, habits of mind, and propensity to use specific approaches.
- Ways to measure proficiency in analytic and synthetic reasoning.
- There may be space to begin using existing teaching activities as the raw materials for research studies (Sharon Mosher's example of comparing expert vs. novice maps, role playing of different stakeholders in InTeGrate workshop)

Group 6 - Access and Success

Group Members
Caitlin Callahan, Eric Riggs (facilitator), Julie Sexton, Ben Wolfe

What do we know and how do we know it?

Access
Defining access:

- Access to the "pipeline" in terms of time and space? Break into milestones: K-12, 2YC, 4YC, and career/grad school. The factors that are relevant at each stage are different, as are the strategies at helping students into and through the geosciences at each level.
- This is the traditional way of thinking about it is often limited to easily defined dimensions of diversity related to race or ethnicity, but are there are other ways that are relevant that need to be included in a broader discussion, such as disability, SES, gender, etc. The issue is really one of educational and workplace climate and supporting the whole student through the pathway to the geosciences.
- Access in terms of communities – we have an uneven reach and perception in many communities of interest in the nation, and the strategy for reaching students differs substantially based on community, economic and historical circumstances.

Access is not a linear path to reaching a destination. A linear conception of the geoscience “pipeline” can constrain and exclude individuals. Communities that encourage access can allow for different things to occur at different times - not necessarily chronological. A metaphor of a pathway is more useful, especially looking at the wide range of professional outcomes and styles of education possible within the geosciences.

What role does sense of self and development of identity play? Stage of conforming/acculturating to the norms and practices of the new community - in our case the geoscience community and geoscience workforce. Work is needed on understanding the culture of the geosciences (and subcultures) and then working to map the needs and interests of students to that culture where appropriate.

There is considerable literature on college students, identity, and culture. The geoscience education community has made great strides in the past decade in programmatic and curricular advances, but much of this work has not always kept abreast of developments in social science in diversity, identity and culture theory. There is a need and opportunity to incorporate current research into our programmatic efforts.

There is rich literature on STEM access in higher education, which also has evolved substantially in recent years and which needs to be incorporated into geoscience diversity efforts.

There is a need for meta-studies and some generalization as possible. The geoscience discipline-level literature is mostly programmatic or single institution/program case studies. Some of these case studies may be built around one key person, which limits its usefulness.

Success: What is success?

- Degree completion. Career entry. Feel including/belonging in the community.
- The role of student academic preparedness (academic capital) including study skills, time management, etc., is growing relative to a content-only centric approach.
- Student-centered versus faculty centered curricula and programs
- Academic engagement is key (for example, learning communities, undergraduate research, faculty-student interaction).
- Social involvement (co-curricular, student organizations, sense of belonging)
- Integration (feeling a part of the community).

- Expert/novice – evidence of movement along the novice to expert trajectory needs to be couched in the context of broadening participation with relevant metrics and intent

Often used Conceptual Frameworks

- Grounded in Capital Theories (Cultural, Social, Human, Transfer, etc.).
- Student Involvement (Astin, 1999)
- Integration/Departure Theory (Tinto, 199x)
- Student Engagement Theory (Kuh)
- Academic preparedness (Bahr)
- Microagression/Stereotype threat (many authors)
- Impostor syndrome
- Learning communities literature
- Intersectionality
- Organizational change/Organization theory
- Social cognitive career theory
- Socially mediated cognition
- Culturally relevant pedagogy

What do we want to know?

- How do we create an environment (or community) that is open and welcoming to all individuals?
- What about students with physical, sensory, learning disabilities and how do they fit into the definition of access?
- Balance between access for large groups versus individual groups or individuals? (ie. access for women versus access for African American women).
- Expectations of workforce versus expectation of faculty/curriculum design at the college/university.
- Identifying other types of diversity in terms of access.
- Is field work necessary for what is defined as a successful geoscience student, and if so, how do we make that available for all students?
- What are the parts of the geoscience culture that require social and academic capital?
- Map the various needs of the entire geoscience community - aligning student interests with those needs. Building pathways for students to reach those needs.
- How do we get past the "icon" phase (i.e., who is a famous woman geoscientist)? Instead can we broaden to thinking about the community of geosciences - and focus on interests aligning with workforce. No longer about being just like "this person."
- Intentional partnerships with groups and communities - meeting people where they are and their cultural reference/framework. What does success mean for different communities - maybe beyond the "Academy" expectations for success. How do we design recruiting programs along these lines?
- Moving towards a partnership mentality - entering into partnership with whatever population you are wanted to engage (be it gender, disability, rural, SES, etc.).

- Moving beyond "matching" gender/race/ethnicity in mentorship. Existing literature has shown that internships and strong mentorship regardless of like gender/race leads to success.
- Combating the "token" faculty effect in which minority faculty member by default handles all the diversity aspects of a department (i.e., advising all the minority students in a program)- negative impacts on underrepresented faculty's ability to be successful (make tenure).
- Students from urban/lower SES/lack of nature access - how does this fit into cultural norms of geoscience - should it?
- How do we use social justice - environmental justice - to bring potential underrepresented minorities to geosciences and bring back to their communities?
- How do rural institutions implement access models from large urban or minority serving institutions?
- Paying attention to the language that we use in terms of inclusivity versus exclusivity?

What do we need to move the field forward?

- Modernize language and discourse related to access and success. Educate ourselves more on diversity literature in general. Need to elevate discourse in the geosciences.
- Most literature of geoscience education is programmatic and single institution case studies.
- More mixed methods studies - across the pools of studies that occur. Capture that diversity is not checkbox research. Multidimensional areas of this research.
- More multisite studies. Primarily literature is single institution/program studies.
- Diversify studies on multiple institution type - what does access look like for rural institutions for example.
- How do we do research with small pools of individuals and make that work useful to the broader community?
- Research that can impact at a local classroom level all the way to institutional and disciplinary policy.
- What does the research say about factors that support access and success and what are the policy implications that come out from this?

How do we disseminate all this to appropriate constituents, administrators, policy makers, etc.?

Group 7 - Professional Development of College/University Educators

Group Members

Eric Baer, LeeAnna Chapman, Sara Cina, Jennifer Dixon, Anthony Feig (facilitator), Susan Lynds, Alison Rockwell, Katherine Ryker

What do we know and how do we know it?

Key papers and programs (this list is unsorted, but later work can categorize it)

- DBER report: Translating teaching into research practice

- Caulkins (RI) & Gilley (UBC): Course re-design
- Henderson & Dancy: efficacy of translating research into practice (physics)
- Borrego & Henderson: change strategies
- Carl Wieman: science education transformation initiatives
- Marbach-Ad: graduate student professional development (STEM)
- Czjaka: situational instructional coaching for dinosaur course
- Casey Davenport- atmospheric
- GeoScape-K-12 professional development (Stanford)
- www.theiagd.org
- Seymour & Hewitt 1997
- SOARS- UCAR
- On the Cutting Edge/ SERC
- PFF- Preparing Future Faculty
- Informal conversations - Dancy, Turpin, & Henderson 2010; Borrego & Henderson 2014

What do we want to know?

- How do personal beliefs and attitudes towards teaching influence teaching practice (and does professional development influence this)? Longitudinal study.
- How do we get people involved with effective professional development? What incentives work? Innovation adoption- early, late adopters (get involved AND use the strategies).
- Content development - developing needed materials for professional development to assist in teaching/research efforts (what do people want?).
- Clearing house for validated instruments - models, pilot studies– ways to find what's out there
- Anthropological longitudinal study of us as a practice - how our field grows, how practices/beliefs change over time (due to professional development programs, videos, etc.).
- Longitudinal study of terminal degrees- what did students do after their degree (placement tracking)?
- Tie professional development to student learning and professional outcomes.
- How does departmental/institutional/advisor culture impact teaching practice or professional development?
- Historical sketch of professional development (change over decades) — Literature review? Look at JGE to see what instructional methods are encouraged and how that has changed (cycles/themes of teaching methods).
- Survey of advanced career professors to see if there were any experiences that shaped their careers.
- Long term tracking of professional development (what is effective) - create future PD based on findings.

- What has influenced our personal teaching styles? Why do people teach the way they do?

- Misconceptions/assumptions about professional development ("all lecture is bad").

- What amount of professional development is needed to have an impact and cause a change in teaching practice? (For example, in a 2YC with high turnover) What are the most important PD strategies (demonstrations, videos)?

Professional development audiences – each has different needs

- Graduate TAs
- Full-time faculty
- 2YC instructors
- Independent instructors
- Adjunct
- Informal education / outreach
- New faculty
- Tenured faculty
- Pre-tenure (but not new) faculty

What do we need to move the field forward?

Research:

- History of professional development

- Implementation of long-term professional development. And what does this look like at different institutions (2YC, 4YC, R1)

- How to incentivize PD

- How to tailor PD toward different audiences (tiered approach to fit different audiences)

- Do we need a new instrument? Valid data for self-report (current instruments: TBI correlates with practice; BARSTL; Carl Wieman- Teaching Practices Inventory; COPUS; RTOP; TDOP)
    - TBI: http://connection.ebscohost.com/c/articles/25999504/capturing-science-teachers-epistemological-beliefs-development-teacher-beliefs-interview
    - BARSTL: http://onlinelibrary.wiley.com/doi/10.1111/j.1949-8594.2013.00175.x/abstract
    - Teaching Practices Inventory: http://www.cwsei.ubc.ca/resources/TeachingPracticesInventory.htm
    - COPUS: http://www.lifescied.org/content/12/4/618.abstract
    - RTOP: https://mathed.asu.edu/instruments/rtop/RTOP_Reference_Manual.pdf
    - Applicability to existing instruments?
    - Separate this list into self-report vs. not self report

- Talk to people who teach

- Who are leaders/experts in each educational specialty?

- Is there an instrument to measure student perceptions/resistance to active learning strategies?

Tools:

- Professional Development Synthesis
- Longitudinal studies & history- practices, beliefs and professional development.
- Formal and informal professional development and what that looks like.
- How successful/effective is professional development for faculty and student.
- Audience specific (multifaceted approach?) approach to professional development and what is it.
- Generating meaningful evaluative output.
- Effective modes of PD dissemination outside of workshops and literature?