Committee on Seismology and Geodynamics

COSG Meeting on *Enhancing Quantitative Capacity of Geoscience Programs* April 9, 2020

Resources

As a technical note to complement the meeting presentations discussed at the April 9, 2020, virtual meeting on *Enhancing Quantitative Capacity of Geosciences Programs*, the following programs and selected web resources were compiled from speaker presentations. The original speaker presentations are available in PDF format on the COSG website.

Presentations were provided in two sessions that addressed core analytical skills and best practices. Speakers included Sharon Mosher (University of Texas at Austin), Barbara Tewksbury (Hamilton College), Jonathan Aurnou (UCLA), and Beth Pratt-Sitaula (UNAVCO), with contributions by panelists Pranoti Asher (AGU), Chris Keane (AGI), Michael Hubenthal (IRIS), John Taber (IRIS), and Cathy Manduca (Carleton College/SERC). The main online resources outlined in two sessions are listed below. In addition to those discussed by the speakers, some of these resources derived from comments shared by online meeting attendees during the session.

The presentations identified several ways to boost quantitative skills and reasoning, starting with career pathway materials for high school students, counselors, parents, and pre-major advisors that explain the math and science content of geosciences degrees. It was suggested by several speakers that early communication of geoscience careers may increase representation of under-represented groups in geosciences. Best practices that were discussed included efforts to establish the context and need for quantitative skills in introductory geoscience courses. One way to establish this context and need could be through sharing examples of geoscience problems with math, chemistry, and physics instructors. Visualizations and hands-on experiments were also suggested to be motivating for students to probe complex problems. The presenters also noted that given the diverse backgrounds of geoscience students, providing a variety of examples (rather than just one) may make it easier for students to connect to a question, and that repetition and reinforcement of quantitative skills at all course levels builds students' confidence.

Session 1: What core analytical skills are needed to prepare undergraduate geoscience majors for careers and graduate degrees in the modern world?

Session 1 considered the core analytical skills needed to prepare undergraduate geoscience majors for careers and graduate degrees in the modern world. The speakers noted that industry, government, and academic sectors seek students with strong quantitative and problem-solving skills. However, students commonly avoid math-based courses or majors for a

range of reasons, including lack of preparation in high school to misconceptions regarding level of difficulty or what these courses entail.

Resources:

Career Compass

The American Geosciences Institute and American Geophysical Union have compiled career progression knowledge and skills through surveys of employers and academics. Speakers noted that sharing this information with high school and university students, parents, and career guidance counselors can increase awareness of the geosciences, and the range of career destinations of graduates.
https://www.americangeosciences.org/workforce/compass

Science Education Resource Center (SERC) at Carleton

SERC has worked with math educators to develop and test tools for the instruction of mathematics in geosciences, and to enable their use in problem solving. Teaching resources are based on concepts from mathematics education research, including a focus on:

- Placing concepts in context
- Using multiple representations
- Working in groups
- Using appropriate technology
- Completing in-depth problems that last more than one day

Reference: Teaching Quantitative Skills in the Geosciences, July 2002, based on mathematics research:
https://serc.carleton.edu/quantskills/index.html

Teaching with Geophysical Data

The following resources provide information on using real data and models to explore geoscience processes and study real-world impacts such as climate change. Many include a combination of hands-on activities as well as 3D data visualizations. These teaching materials can be used to supplement existing courses and illustrate the use of quantitative skills in the geosciences.

1. GETSI - GEodesy Tools for Societal Issues - https://serc.carleton.edu/getsi/index.html
2. Teaching with Current Research site guide - https://serc.carleton.edu/serc/site_guides/data.html
   Environmental Data-Driven Inquiry and Exploration – flexible classroom teaching modules using large, publicly available data sets - https://serc.carleton.edu/eddie/index.html
3. Incorporated Research Institutions for Seismology (IRIS) - https://www.iris.edu/hq/inclass/search#type=4/language=1

Computational Skills
Teaching Computation using Matlab
https://serc.carleton.edu/teaching_computation/index.html

Support for Upper Level Courses
https://serc.carleton.edu/quantskills/issues/upper-division.html

Session 2: What are best practices for integrating analytical skills in geoscience curricula?
Faculty in geoscience departments have developed a number of different tools and online instructional material. Best practices for integrating analytical skills include 1) utilization of career videos and inviting visiting professionals into introductory courses, 2) sharing geosciences examples with chemistry, physics, math, and ecology colleagues, and 3) developing demonstrations and videos to engage and motivate students with challenging problems.

Resources:
Curriculum Design
Several groups have developed tools to assist geoscience departments with augmenting or revising curricula to enable quantitative skill repetition and reinforcement at all course levels. The primary challenge of program design, according to speaker Dr. Cathryn Manduca, is balancing what is needed by all with what is desirable for some. This depends not just on curriculum, but also on advising and mentoring. She noted that this problem has three parts: supporting faculty to incorporate strong teaching of quantitative skills; designing programs that allow quantitative literacy for all and advanced geophysics skills for all who would like to choose that path; and working with all faculty who are advising students about opportunities, their value, and available support.

Building Strong Geoscience Departments
https://serc.carleton.edu/NAGTWorkshops/departments/index.html

CAST Universal Design for Learning Guidelines
http://udlguidelines.cast.org/?utm_medium=web&utm_campagin=none&utm_source=cast-home

Design Patterns
There is limited research into the best practices of supporting students in the application of quantitative skills to geoscience concepts. Kastens and Krumlansl (2017) explored "design patterns" as a mechanism for describing teaching strategies across topics. This concept builds on resource collections such as that available through "Teach the Earth" and analyzes for common instructional design strategies. Examples include data puzzles, pooling data to see the big picture, making a decision or recommendation, predict-observe-explain, nested data sets, and deriving a new data type.

Reference: Kastens, Kim A., and Krumhansl, R., 2017. Identifying Curriculum Design Patterns as a Strategy for Focusing Geoscience Education Research: A Proof of Concept Based on Teaching and Learning With Geoscience Data, *Journal of Geoscience Education,* Vol. 65, no. 4, November 2017, pp. 373-392.

Activities to Strengthen Quantitative Skills

Teaching Quantitative Skills in the Geosciences
https://serc.carleton.edu/quantskills/index.html

This website draws information from a series of NSF-funded workshops about teaching quantitative skills in the geosciences.

Core concepts include:

1. Active involvement
2. Learner independence and choice
3. Confronting misconceptions
4. Social interaction
5. High-challenge, low-threat environments
6. Timely, usable feedback with occasions for reflection
7. Appropriate use of technology
8. Practice and reinforcement

The principles above are drawn from a presentation by Dr. Sam Patterson, Carleton College, at the 2004 Teaching Quantitative Skills in a Geoscience Context workshop (https://serc.carleton.edu/quantskills/workshop/index.html) summarizing the references below, and modified by participants in the 2005 Developing Quantitative Activities for Upper Division Geoscience Students workshop. (https://serc.carleton.edu/quantskills/workshop05/index.html)

References:

Theodore J. Marchese, 2002. The New Conversations About Learning: Insights From Neuroscience and Anthropology, Cognitive Science and Workplace Studies
Joan Garfield, 1992. Principles of Learning Statistics
David L. Potter, 1998. Powerful Partnerships: A Shared Responsibility for Learning
NRC, 2000. How People Learn: Brain, Mind, Experience, and School

InTeGrate – Interdisciplinary Teaching about Earth for a Sustainable Future
https://serc.carleton.edu/integrate/index.html

Virtual Field Work

NAGT 'Designing Remote Fieldwork Experiences' – US-Canada-UK collaboration. Outlines learning objectives of fieldwork, and virtual modules that achieve specific objectives. Examples are geophysics modules that utilize cell phone instrumentation.
https://nagt.org/nagt/about/workspaces/field_workgroup/index.html
https://www.see.leeds.ac.uk/virtual-landscapes/

Career Pipeline and Diversity
Students have a range of backgrounds and talents. Speakers noted that a student's background should not be a barrier to their ability to pursue a career in the geosciences, including seismology and geodynamics. They explained that program design will need to accommodate students who move at different paces and need to learn different quantitative skills. Approaches include shadow courses, tutoring, online support, and multiple offerings that accommodate learning at different paces. One example of this is:

The Math You Need When You Need It https://serc.carleton.edu/mathyouneed/index.html

High School
Local partnerships among individual faculty or departments.

AGU's BrightStars Program
https://education.agu.org/diversity-programs/bright-stars/

GeoForce
http://www.jsg.utexas.edu/geoforce/about-us/staff/

Undergraduates
SERC hosts multiple resources to support the inclusion of quantitative skills in undergraduate courses.
https://serc.carleton.edu/integrate/programs/diversity/whole_student.html