1-2014

Future of Undergraduate Geoscience Education: Summary Report for Summit on Future of Undergraduate Geoscience Education

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Summary Report for Summit on
Future of Undergraduate Geoscience Education

January 10-12, 2014
Sponsored by the National Science Foundation

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May 30, 2014

Summit on the Future of Undergraduate Geoscience Education
Summary Report

The Summit on the *Future of Undergraduate Geoscience Education* made major progress towards developing a collective community vision for the geosciences, focusing on three areas: 1) curriculum, content, competencies, and skills, 2) pedagogy and use of technology, and 3) broadening participation and retention of underrepresented groups and preparation of K-12 science teachers. The summit brought together a broad spectrum of the undergraduate geoscience education community, ~200 educators from R1 research universities with undergraduate programs, four-year private and state colleges (4YC), and 2-year community colleges (2YC) from across the country, as well as representatives from industry and professional geoscience societies. Energized by Keynote presentations and informed by panel discussions, the participants spent most of the 2.5 days in small breakout sessions discussing a series of questions. The results of these sessions were presented to the entire group for discussion and are summarized in the following sections.

Motivation for Summit

Geoscience has become more interdisciplinary, multidisciplinary and transdisciplinary, resulting in the need for students to have strength in their discipline as well as the ability to work across disciplinary boundaries. Complex interactions occur between different parts of the Earth system, including the Earth's interior and surface, hydrosphere, atmosphere, cryosphere, and biosphere, and in the chemical, physical, biological and geological processes that help shape the Earth system. For a successful future, students need to be trained to apply a systems-based approach, as well as have an understanding of deep time, including Earth's history and evolution, present-day processes and future impacts. Increasingly, the public and policy makers recognize that the geosciences have much to contribute in addressing societally important issues, such as natural hazards, water, energy, climate, sustainability, and natural resources, which makes preparation in ethics, economics, risk management, policy, and communication ever more important skills for undergraduate students.

At the same time, a transformation in undergraduate education has taken place. New ways of enhancing student learning and new pedagogies for STEM education, incorporating the results of discipline-based education research (DBER), have been developed. Technology is being used in new ways, including virtual experiences, flipped classrooms, blended learning, Massive Open Online Courses (MOOC's), and crowd-sourcing of open education resources. New opportunities exist for sharing resources and courses with local customization. Major advances have taken place in visualization and geospatial tools, generation and use of massive amounts of quantitative information (big data), and computational modeling and simulation for both predictive capabilities and insight into processes and global-scale events. Undergraduate students must be prepared to use rapidly advancing technologies and big data in the future.

As a large segment of the current workforce begins to retire and geoscience jobs increase in number, we will face a shortage of geoscientists for the future workforce. Additionally, despite continued efforts by educators and industry, the geoscience community still has difficulty recruiting and retaining underrepresented groups in our programs and professions compared to other STEM disciplines. Few students take a geoscience course in middle or high school, the best place to instill an interest in geoscience careers and contribute to development of a scientifically literate society. We need to recruit and retain qualified K-12 geoscience teachers in our undergraduate programs. The new Next Generation Science Standards put Earth and Space Sciences on an equal footing with Physical and Biological Sciences, which is a tremendous opportunity for our programs and profession. We also have a new series of Geoscience Literacy documents available for application in curricular development. Additional motivation for this Summit comes from the National Research Council's report on discipline-based education research focusing on STEM fields, the President's Council of Advisors in Science and Technology (PCAST) prioritization for new funding initiatives focused on improving undergraduate STEM education and retention, and pressure on higher education to improve student learning outcomes.

Sustained change in undergraduate geoscience education requires the combined efforts of departments and programs, led by administrators, individual faculty innovators, geoscience professional societies, and industry. A cultural change from the administration down to the student level will be needed to overcome roadblocks to implementation of our collective vision. We will need to learn how to scale up individual programs and successes while maintaining their quality and address the differences in capacity of our diverse educational institutions to implement change.

Outcomes

Topic 1. Curriculum, content, competencies, and skills needed to prepare undergraduate students for graduate school and/or for future careers in the geosciences

The Summit participants focused on skills, competencies, concepts and learning outcomes rather than specific disciplinary content and were in remarkable agreement on what is needed to prepare undergraduate students for graduate school and/or for future careers in the geosciences. Students need to have skills universally accepted for scientists in general, including critical thinking and problem solving skills; they must be effective communicators and be able to think like a scientist and continue to learn after they complete a degree. As geoscientists, they need to be able to think spatially and temporally, inductively and deductively, make and use indirect observations, engage in complex open and coupled systems thinking, and work with uncertainty, non-uniqueness, and incompleteness. They need to understand how the Earth operates and appreciate the implications of deep time. These skills, competencies and concepts are discussed below along with mechanisms for implementing them and overcoming barriers to implementation.

Thinking

Next generation graduates should be able to think critically and readily solve problems, especially those requiring spatial and temporal (i.e. 3D and 4D) interpretations. They should possess strong quantitative skills and an ability to apply cognate sciences to geoscience problems. Graduates should possess “geo-intuition”, or the ability to make inferences about the Earth system from observations of the natural world combined with the results of experiments and models. They should be able to integrate data from different sources and apply systems thinking, understanding uncertainty and ambiguity. Graduates must understand the societal relevance of geoscience topics as well as their ethical dimensions.

Content/Concepts

Next generation graduates should understand Earth as complex and dynamic with linkages between different parts of the system (e.g., lithosphere, atmosphere, biosphere etc.). They should have a strong grasp of deep time (including the origin and evolution of life), hydrogeology (including water, rock, and microbe interactions), natural resources (including energy), hazards, Earth materials and structure, surface processes, climate change, and the relationship between landscape and process. Graduates should have an understanding of the major areas identified in the Geoscience Literacy documents, a strong grasp of the basic cognate sciences and an ability to manage and analyze large datasets. All graduates must understand that the geosciences are changing rapidly and have an interest in keeping abreast of new discoveries.

Skills

Next generation graduates should be able to engage in effective two-way communication with scientists and non-scientists. They should have very strong computational skills and the ability to manage and analyze large datasets. Graduates should be able to solve problems in a practical fashion, surmounting obstacles and accessing available resources. They should have strong field skills and a working knowledge of GIS. Graduates should be prepared to experiment with new and evolving technologies. Graduates must be able to work with non-uniqueness, incompleteness, and indirect observations. They must work effectively in interdisciplinary teams and across cultures. Finally, graduates must understand scientific research methods.

These skills are best developed through “scaffolding”: i.e. by defining multiple points in the curriculum where specific skills will be continually strengthened. Likewise, skills need to be assessed at multiple points and in a variety of ways.

Experiences

Independent research experience (“doing science”) is one of the best tools for developing the skills described above. Ideally, that experience includes traditional research projects and/or internships, but shorter non-traditional research opportunities are also an excellent vehicle for obtaining experience: e.g. real-time data collection/analysis related to local geoscience issues. Best practices for independent research and internships are needed to facilitate broader use of these opportunities. Experience working in teams is a critical component of a next-generation geoscience education. Coaching/advising, including discussion of the intended teamwork outcomes, helps students to integrate knowledge and build confidence. Teamwork is also a vehicle to build “student hubs” that can energize the broader student population. Field experience plays a key role in 3D visualization skills, community building, and practice in testing hypotheses. Traditional field camp is the preferred capstone experience for geology curricula, but perhaps not for all “geoscience” curricula. When field camp is not a practical option for students, exposure to geology in the field can be accomplished through shorter, alternative experiences, augmented with “virtual” field trips.

Needs and Barriers

Geoscience departments serve multiple constituencies and will need to develop a variety of new strategies to meet the needs of this diverse clientele, especially in light of limits on staff and resources. Incoming students are characterized by diverse ethnic and socio-economic backgrounds and variable levels of preparation for college-level courses especially in the area of quantitative reasoning. Students with a two-year college background are increasingly common. Regional employers also have a stake in the curriculum. Departments will need to develop multiple ways to bring different stakeholders together to inform their decisions regarding curriculum. No one solution will serve all, as departments often serve specific regional needs. Bringing local K-12, two-year college (2YC), and four-year college (4YC) instructors together with prospective employers may help institutions to identify effective paths forward.

Topic 2. Pedagogy and Use of Technology

Summit participants recognized that there are effective methods readily available for use by geoscience educators, but that there were many barriers impeding implementation of these methods. Overall, it was felt that there was a need to increase the understanding and use of effective best practices. Additionally, increasing the knowledge base regarding what works and for whom is a priority. Practices shown to be effective include conducting collaborative and integrative projects involving teams, interdisciplinary projects, fieldwork and research experiences. Also, technology, visualization, simulation, modeling and analysis of big data should be incorporated as appropriate in students’ education.

Pedagogy

The principles underpinning effective, learner-centered classroom practices have been documented in university STEM courses for over 25 years. The geoscience community has generated a unique and robust collection of strategies, materials and resources based on these principles (e.g., http://serc.carleton.edu**)**. Surveys reveal that increasing proportions of geoscience faculty are implementing such active-learning pedagogies over time, but the penetration of such approaches across departments, and even faculty awareness of them is still limited. Hence, our community’s primary pedagogical challenges lie in encouraging the wider adoption of these practices and in characterizing their educational impacts and benefits.

Summit participants considered obstacles to wider adoption of effective pedagogies to include annual performance and tenure and promotion evaluations that commonly do not recognize or reward efforts to improve teaching. Further, space and resource allocations commonly presume lecture-dominated instruction *a priori*. The time and support necessary for developing and piloting new instructional approaches are typically lacking.

Summit participants felt that diffusional approaches to engaging geoscience faculty in educational best practices have had some success in raising awareness in our community, but that more proactive strategies will be required for transformative change. Department Heads and Chairs are seen as critical players in helping establish academic cultures that reward innovative teaching, in advocating for investment in education-focused faculty (both discipline-based education research and instruction-focused) and in improving instructional infrastructure, as well as in making effective teaching an important hiring criterion and a regular part of graduate student professional training. Ongoing professional development efforts for young faculty supported by geoscience professional organizations must continue, augmented by investments that target more experienced faculty and adjuncts. Professional development must also be made available to the growing numbers of contingent faculty at 2-year colleges and other institutions. Innovative approaches may be required to address the needs and constraints faced by this important audience.

Many widely accepted models of effective pedagogy can be implemented in a variety of instructional settings. We should be careful to not delay the adoption of learner-centered practices out of a misplaced desire to identify the “holy grail” of a geoscience-focused pedagogy. However, there is a need for additional research focusing on teaching specific geoscience topics, dealing with growing enrollments across the curriculum, linking science and its impact on society, and the use of online/blended format courses as a part of modern curricula.

Technology

Summit participants discussed the evolution, potential, and challenges of technology in teaching and learning, albeit not as extensively as pedagogy. The Internet and information technologies have evolved as instructional tools from "eye candy" into sophisticated systems that can facilitate student exploration and classroom interactivity. Acknowledging some notable exceptions, the geoscience community as a whole has not yet embraced fully the potential of such approaches, including social networking, educational games and crowdsourcing, to effectively engage with a generation of students that has been immersed in digital information and online social interactions their whole lives. Participants agreed, however, that “technology for technology’s sake” is an insufficient reason for change, and that ongoing research on the impact of technologically mediated instruction will be vital.

Community-wide strategies for developing and integrating appropriate technological advances into future educational efforts (e.g., leveraging the shift to mobile devices, harnessing big data for educational research, or developing virtual communities of practice) were not extensively discussed at the Summit. The place-based nature of much geoscience instruction provides a strong rationale for collaborating across distances, but systemic advances must confront the rapid pace of change and the need to bring on collaborators in cyberlearning from other disciplines.

Topic 3. Broadening participation and retention of underrepresented groups and preparation of K-12 science teachers to build a robust, diverse and informed future geoscience workforce

Large numbers of geoscientists are projected to retire in the next 10 years, and the number of geoscience-related jobs is predicted to increase over the same time frame[1]. Summit participants focused on ways to increase interest in the geosciences through better preparation of middle and high school teachers and to broaden participation and retention of members from underrepresented groups. The geosciences lag behind all other sciences in terms of minority and first generation college-student participation[2], and only a small percentage of middle and high school students take a geoscience course[3]. Better preparation of teachers is essential so that they are prepared to instill interest in geoscience careers and to educate informed citizens. With the Next Generation Science Standards[4] and Geoscience Literacy documents, new opportunities are available to meet all of these objectives. The following strategic topical areas were identified during discussions on broadening participation and teacher preparation.

Teacher Education at Four-Year Colleges

The education of future teachers can be greatly strengthened by integrating the vision and content of the Next Generation Science Standards[4] into university curricula and preparing future teachers to implement the new standards in K-12 classrooms. Introductory geoscience and general education courses provide the best opportunity to reach future teachers. Additionally, it is important for key faculty members and staff to be aware of state requirements for teacher education and licensure, as well as state expectations for K-12 instruction and assessment of students in the content areas. Encouraging collaborations with K-12 in-service teachers and improvements in pre-service programs should be encouraged and can be used to address "Broader Impacts" objectives for research grants.

Undergraduate Education at Two-Year Colleges

Two-Year Colleges (2YC) are playing an ever more important role in the education of undergraduates, which makes increased collaboration among 2YC and between 2YC and four-year colleges (4YC) and universities imperative. 2YC faculty should be encouraged to reach out to 4YC faculty and vice versa to better serve students. Curriculum alignment

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[1] http://www.americangeosciences.org/workforce/reports/status-report-2014

[2] http://www.americangeosciences.org/sites/default/files/currents/Currents-030-URM_GeoDegrees.pdf

[3] http://geocntr.org/wp-content/uploads/2013/08/ESS_sec_status_report_10_17_13.pdf

[4] http://www.nextgenscience.org/next-generation-science-standards

between local 2YC and nearby 4YC programs will help to reduce challenges for transfer students. Activities that promote increased interest in the geosciences as a major and recruitment of future geoscience teachers include collaborative field trips and research opportunities such as REU experiences. Exposure of 2YC students to research experiences as part of the science curriculum will help prepare them for 4YC programs and future employment. Additionally, 2YC faculty should participate in geoscience networks and professional development opportunities[5].

Undergraduate Education

The Millennial Generation has unique characteristics that need to be understood to promote engagement with the geosciences. Departments need to develop strong mentoring programs, particularly for minority and at-risk students. Faculty need to be informed about and respectful of students' heritage and culture. The undergraduate curriculum should integrate team work, problem solving, critical thinking, and research and incorporate applications of math, chemistry, and physics into introductory geoscience courses and labs. Additionally, the perception of what a geoscientist is and does needs to be broadened.

Recruiting Diverse Students

Summit participants shared information about a number of successful programs that attract and retain minority students. The most successful recruiting programs provide financial support, reach out to students in their communities, involve members of the community (families, high school teachers, guidance counselors), incorporate role models, and include mentoring. Developing or collaborating with programs for minority students in STEM at the pre-high school and high school levels promotes the choice of a geoscience major and college completion. Collaborations among 2YC, Hispanic Serving Institutions (HSI), Historically Black Colleges and Universities (HBCU's), and 4YC faculty help foster communication between faculty and students. One approach is to specifically recruit and provide opportunities for 2YC, HBCU and HSI students to participate in programs such as REUs, and mentor the students before, during, and after to increase retention and ensure success. Departments can incorporate, as well as advertise, programs designed to promote success among underrepresented students[6] and promote minority-serving societies and programs[7] to students. It is also important to continually address the question of why diversity matters and educate faculty and students (particularly minority students) about topics such as "stereotype threat", "imposter syndrome" and take actions to reduce the prevalence of "lonely onlies".

Needs and Barriers

Perception of geology and limited career options reduces some students' interest in the geosciences. We need to address the image problem by emphasizing societal relevance

[5] http://nagt.org/nagt/divisions/2yc/index.html, http://serc.carleton.edu/NAGTWorkshops/index.html, http://serc.carleton.edu/sage2yc/index.html

[6] URECAS-AGU, MSPHD, IBP, Geoscience Alliance, LS-AMP, AGEP, GEM, etc.

[7] NABG, SACNAS, AISES, AWG, GEM, etc.

and career prospects[8], developing community service activities, and building a robust STEM advising and support system for students. Efforts should be made to obtain funding to initiate and test new programs to address minority and nontraditional student issues in the geosciences. The Broader Impact review criterion for federal grants can be used as a way to encourage actions to increase minority participation and retention. Robust communications need to be developed between 2YC and 4YC to promote transfer articulation agreements, joint advising strategies, clear pathways to successful completion of degrees for students, and partnerships that offer opportunities to a broader segment of the student population at 2YCs and 4YCs.

Summary

Geosciences research and applications have changed, which requires changes in education. Technology and data have changed, which necessitates changes in how or what we teach. Culture and motivations have changed, particularly for higher education. We must change the way we educate students to increase student learning and preparedness for the future (not the present) workforce. A major outcome of the summit was an agreement that we need to concentrate on skills, competencies, and concepts, not on disciplinary content or specific courses. The geosciences are too broad to be covered in an undergraduate curriculum. The challenge for educators going forward will be to build deep understanding of the nature of the geosciences while still promoting an appreciation of the breadth of the discipline. What is important is that students are prepared to continue to learn as the geosciences grow and change and as the students' interests and employment change. Students need to learn to think critically and solve complex problems, to work in teams within and across disciplines, to visualize the world in 3D (and 4D), to work with uncertainty, incomplete data, and non-uniqueness, use deductive and inductive reasoning, and make interpretation based on indirect observations. They need to understand how the Earth works, that it is a complex dynamic, open and coupled system. They need to understand deep time, present-day processes, and future impacts. Moreover, they need to be able to communicate effectively with other scientists and non-scientists. The key is to integrate these skills, competencies and concepts into the curriculum at multiple stages.

Flipped classrooms, blended learning, and use of visualizations, simulations, modeling and analysis of big data facilitate student understanding and can strengthen learning outcomes. Active student learning through project-based activities, research projects or experiences, and field courses or projects are well suited to developing desired outcomes. Having students work in teams on interdisciplinary, collaborative projects is important for building the skills needed in the future workforce. Faculty need to learn about proven active learning methods and effective pedagogy and be rewarded for experimenting and implementing new techniques in their classrooms in order to assure improved educational outcomes for all students. On average, geoscience departments are struggling in their efforts to adapt the newer pedagogical methods known to be effective in deepening student learning. Similarly, implementing outcomes-based learning assessments is challenging to many. Administrators will need to provide faculty with performance-based

[8] Salaries, employment rates, diverse fields of study, etc. Earth is Calling: www.beageo.com

incentives and to make investments in professional development activities. Availability of web-based resources, such as repositories of data and curricula are, and will continue to be, important for helping departments implement new pedagogy effectively and efficiently. Strategies for building faculty awareness of the availability of these resources need to be made widely available

Effective programs that broaden the demographics of the future geoscience workforce must be scaled up and successful elements replicated elsewhere. Professional societies and industry have a critical role to play in this regard. Sustaining the geoscience workforce and improving scientific literacy of citizens are best met by high quality preparation of K-12 teachers in the geosciences and other STEM fields.

Next Steps and Roadmap for the Future

Our first step is to disseminate results of the Summit and receive input from the broader community. We have presented results of the summit at many of the Geological Society of America sectional meetings this spring, in a March AGU/AGI Webinar for Heads and Chairs (http://www.youtube.com/watch?v=QmCYaATD4eo), and in articles in EOS and other society magazines and newsletters. We also intend to hold town meetings at GSA and AGU annual meetings this fall. A participant survey will collect additional thoughts on the summit outcomes. Participants were enthusiastic about returning to their departments and incorporating new strategies. All participants were encouraged to be ambassadors and tell others about the emerging community vision for undergraduate geoscience education and to help implement that vision.

Another important step is to increase awareness and use of already developed community resources, effective pedagogy and techniques, and technology. Participants varied from fully informed and involved in developing resources and best practices to unaware and unsure of what exists or has been proven effective. We will put links to specific research papers on the website demonstrating the effectiveness of different methods, links to resources and workshops (especially to Cutting Edge, Integrate, and other SERC web resources and workshops), examples of curricula, and other helpful information.

To fully develop and implement a community vision, we need to further refine the answers to the questions discussed during the summit, generate more specific strategies with finer resolution, and provide examples of successful implementation. We also need follow-on activities involving employers who can provide input on the emerging community vision and articulate future workforce needs in terms of skills, competencies, and critical concepts. Employers should be encouraged to work with department faculty to provide practical applications, projects, and research experiences for undergraduates. Professional societies should play an important role in spearheading follow-on activities and disseminating the results of the Summit. They should be strong advocates for a community vision for geoscience undergraduate education and must be instrumental in organizing professional development efforts for young faculty and experienced faculty.

Heads and chairs, deans, and other administrators have a significant role to play in stimulating change. They have the ability to establish academic cultures that reward innovative teaching. They are in a position to work towards improving instructional infrastructure and can allocate time and support for faculty developing and piloting new instructional approaches. To encourage faculty, they need to provide performance-based incentives to change teaching methods and invest in professional development for faculty. Administrators are also in a position to make effective teaching an important hiring criterion and to include teaching as part of graduate student professional training.

To have a sustained change in geoscience undergraduate education, we need to change our culture from the administration down to the student level. Overcoming roadblocks to implementation will take the combined efforts of departments and programs, administrators, and individual faculty innovators. Geoscience professional societies and future workforce employers have a major role to play in insuring these changes are implemented.

Involvement in Summit, post-meeting*:* Most of the Summit is archived online (see links on **http://www.jsg.utexas.edu/events/future-of-geoscience-undergraduate-education/**) and available for non-participants to view. Archived Keynote talks, panel discussions, and workgroup presentations followed by whole-group discussions cover many of the above topics in more detail and provide numerous examples and suggestions for further action. The following are linked on the webpage**:**

- The Summit began with an overview of goals, issues to be discussed and motivations for the summit by Dr. Sharon Mosher, Dean of the Jackson School of Geosciences.
- The opening Keynote Address was by Dr. Robert Frodeman, Director of the Center for the Study of Interdisciplinarity and Professor of Philosophy University of North Texas, on “The End of Disciplinarity”.
- The first panel discussion on Topic 1, Curriculum, content, competencies, and skills needed to prepare undergraduate students for graduate school and/or for future careers in the geosciences was led by Steve Marshak (University of Illinois at Urbana), Dave Mogk (Montana State University), Lyndsey LeMay (Thomas Nelson Community College) and Chris Keane (American Geoscience Institute). After small, 10-12-person breakout sessions and 20-14-person intermediate workgroup sessions (not archived), each intermediate group gave 5-minute presentations of their results followed by a group discussion, all of which was taped and available online.
- The second Keynote talk was by Dr. James Collins, Virginia M. Ullman Professor of Natural History and the Environment in the School of Life Science, Arizona State University, on “Undergraduate science education early in the 21st century: No miracles needed, but we do need leaders”.
- The second panel discussion on Topic 2, Pedagogy and use of technology was led by Cathy Manduca (SERC), David McConnell (North Carolina State University), and Steven Whitmeyer (James Madison University). Again, after small 10-12-person breakout sessions and 20-14-person intermediate workgroup sessions (not archived), each intermediate group gave 5-minute presentations of their results followed by a group discussion, all of which was taped and available online.

- The third panel discussion on Topic 3, Broadening participation and retention and preparation of K-12 science teachers to build a robust, diverse and informed future geoscience workforce was led by Stephen Mattox (Grand Valley State), Ashanti Johnson (Institute for Broadening Participation; University of Texas at Arlington), and Anne Egger (Central Washington University). Again, after small 10-12-person breakout sessions and 20-14-person intermediate workgroup sessions (not archived), each intermediate group gave 5-minute presentations of their results followed by a group discussion, all of which was taped and available online.
- The Summit ended with a summary of the Summit's progress, next steps and roadmap for future by Sharon Mosher and a final whole-group discussion (available online).

Breakout Sessions: Each of the breakout sessions were given a series of questions to address for each topic.

Curriculum

- What content, competencies, and skills are needed to prepare undergraduate students for graduate school and/or for future careers in the geosciences?
- What should the next-generation undergraduate geoscience curricula include? Given the change in scope of the geosciences, how can we balance more traditional geoscience courses and topics (e.g. mineralogy, paleontology, etc.) with newer ones (e.g. climate, hydrogeology, etc.)?
- What level of math, other basics sciences, and computational competencies for dealing with large datasets, geospatial data, and modeling is needed?
- How can we integrate field experiences into the curricula at diverse institutions?
- How do we ensure students develop critical-thinking and problem solving skills and the ability to be life-long learners?
- How do we successfully teach students to work well in a team environment? What other skills and types of courses will be critical to students' success in the workforce of the future?
- How do we make sure that students graduate with the communication skills and understanding of social science that will make them effective in their chosen careers? How do we infuse curricula with an appreciation for ethics and personal responsibility?
- What should geoscience departments and faculty do to prepare undergraduates for rapidly advancing technologies that they will need to use in the future? What place does computational modeling and simulation, analysis of large datasets, and new visualization and geospatial tools and programs (e.g. Google Earth, Arc GIS) have in undergraduate education?

Pedagogy and Use of Technology

- What should next-generation undergraduate geoscience pedagogies look like? What are the best practices for providing student-centered, interactive instruction?
- What have we learned from educational and design-based education research (DBER) about student learning? What are effective ways of using the results of this

research in different size classes, educational settings, and diverse institutions? What further educational research is needed for the geosciences?

- How do we get geoscience faculty to move from traditional, lecture-style instruction to more effective methods of student learning? What factors keep faculty from adopting new pedagogies and how can these be overcome?
- How do we get the wider geoscience educational community to assess and adopt evidence-based practices? How do we successfully implement sustainable changes in pedagogy?
- How have technological advances changed pedagogy for the geosciences? What are the implications of rapidly advancing technology for undergraduate education, both in terms of how and what students are taught? How should geoscience departments and faculty respond positively to the challenges and opportunities inherent in potentially disruptive technologies?
- How can new modes of teaching, such as hybrid or blended learning (traditional face-to-face classroom instruction combined with online learning), flipped classrooms, MOOCs, and the availability large open-source datasets, crowd-sourced and other distributed open education resources, be used effectively?
- How can we develop more shared resources and courses that allow institutions with limited faculty and resources to customize external instruction to meet their needs? How can virtual experiences be used to effectively augment, or in some cases replace, field and other "real" experiences?

<u>Broadening Participation/Retention and Preparing Science Teachers of the Future</u>

- What are challenges to developing a robust and diverse future geoscience workforce? What are proven best practices for engaging and retaining traditionally unrepresented and first generation college students in the geosciences?
- What roles can 2-year colleges, minority serving institutions, employers and professional societies play? What pathways would improve the transition from 2-year associates degrees in geoscience or science to 4-year bachelor's degree geoscience programs?
- How do we ensure that courses are taught in ways that contribute to success for all students, including low-income, first-generation, and underrepresented minorities?
- What are effective models for attracting and developing middle and high school geoscience teachers? What geoscience content should be included in a curriculum for future geoscience teachers and for all K-12 teachers?
- How can we effectively integrate the Geoscience Literacy documents into introductory and lower level geoscience courses? How will the Next Generation Science Standards effect what future geoscience and science teachers should learn and how they teach?
- How do teacher certification rules impact geoscience teaching at K-12 levels?
- In introductory and lower level geoscience courses, what are effective ways to demonstrate the use of all sciences and math to solve geoscience problems, thereby providing future science teachers geoscience examples to use in their science and math classes?