Executive Summary

The *Future of Undergraduate Geoscience Education* initiative, sponsored by the National Science Foundation, addresses three critical questions facing undergraduate geoscience education:

- What concepts, skills, and competencies do undergraduates need to succeed in graduate school and/or the future workforce?
- What are the best teaching practices and most effective use of technology to enhance student learning?
- How do we recruit, retain, and ensure the success of a diverse and inclusive community of geoscience majors and support K–12 science teachers to contribute to a well-informed public and dynamic geoscience workforce?

Since 2014 over 1000 geoscientists in the academic and employer communities have collectively developed a robust vision for the *Future of Undergraduate Geoscience Education*. This report articulates that vision and identifies strategies for transformative change in undergraduate geoscience education. The key strategic findings are summarized below and highlight recommendations that capture the extensive work of the community participants and the initiative's organizing committee. These recommendations are comprehensive, and each department, program, or institution should consider how to appropriately implement them in the context of each institution's educational mission. Geoscience educators have an opportunity to capitalize on an evolving higher education landscape, the role that geoscience plays in addressing issues of importance to society, and changing demographics of the student population. We will lose that opportunity, however, if we insist on grounding our programs in the concepts, skills, and pedagogy of the 20th century.

KEY FINDINGS AND RECOMMENDATIONS

The academic and employer community participants have established a consensus on the broad geoscience concepts, skills, and competencies (i.e., expected student learning outcomes) that need to be developed to prepare graduates for meaningful employment across many occupations and/or for continued education in graduate school. Courses and activities should enable students to develop an understanding of geoscience concepts, including processes and impacts, that creates a strong framework for the future acquisition of knowledge. Activities that develop geoscience skills, building competencies at progressively higher levels, should be integrated into multiple classes so that students can practice, establish mastery, and recognize how these skills are employed. Quantitative reasoning and computational skills required in the workplace and/or

OBSERVATIONS FROM THE COMMUNITY:

Geoscience programs will grow and thrive when their graduates can demonstrate that their knowledge and skills are grounded in innovative thinking and have prepared them well for their role in a dynamic society.

Nick Gilbert for AGI's 2017 Life as a Geoscientist contest

graduate school should be incorporated throughout the curriculum. Professional skills (communication, teamwork, project management, etc.) should also be included in the undergraduate program along with those skills closely aligned with the discipline. The educational focus should be on students developing competencies that are embedded in a robust knowledge framework so that graduates can use these concepts and skills to solve geoscience problems throughout their careers. Authentic experiences, such as fieldwork, research projects, and exercises that involve real data acquisition and analysis foster geoscience habits of mind, systems thinking, and problem solving. Further, geoscientists need to combine critical thinking with a full understanding of accuracy, limitations, and uncertainty.

The community-vetted suite of concepts, skills, and competencies provides the basis for successful curriculum revision, in which student learning outcomes become the foundation of curricula planning. Geoscience faculty within a program and/or department should develop a consensus on course and curricular-level student learning outcomes, accounting for the recommended concepts, skills, and competencies and institutional priorities and capacities. Strategies such as backwards design or similar approaches allow evaluation of how and whether targeted learning outcomes are being met by the current curriculum and can guide redesign of individual courses and/or the curriculum as a whole.

Student learning outcomes for discipline-specific and professional competencies can form the basis for geoscience program evaluation protocols. Each program should develop their own understanding of what defines their program's success, including effective and tractable learning assessments based on key student learning outcomes that incorporate disciplinary, institutional, and program-level goals. Many external assessment instruments and methods are available, such as those by the American Association of Colleges and Universities and *National Association of Colleges and Employers*.

Geoscience educators should further embrace and become adept at active teaching strategies that pedagogical research has shown motivates students and improves learning. Experiential learning courses and inquiry-based activities in laboratory courses emphasize the process of scientific discovery and promote a focus on students' roles in investigating scientific questions and building conceptual understanding. Using current and emerging technology and computational models and simulations with large datasets will increase student understanding of complex geologic structures, features, and spatial relationships and provide insight into processes and global-scale events.

The growing demand for geoscientists and the importance of increased workforce diversity requires programs and departments to recruit, retain, and ensure the success of a diverse and inclusive community of undergraduate geoscience majors. A geoscience community that pulls from the greatest breadth of society will gain from diverse life experiences and perspectives that capture unique insights and solutions to geoscience-related problems facing society. By engaging the entire student population, the geosciences can tap a greater range of talent and compete for the best minds.

A crucial first step to increasing geoscience enrollments is significantly improving the public's perception of the geosciences, by promoting it as highly relevant to societal and environmental issues and an economically viable, innovative career. Programs and departments should develop positive recruitment programs for new students, lower division non-majors, transfer students, and students underrepresented in the geosciences, leveraging existing institutional recruitment efforts. Another approach to increasing participation in Science, Technology, Engineering and Mathematics (STEM) majors in college is developing or collaborating with programs for minority students at pre-high school and high school levels to build the pipeline.

Programs should be intentional about the retention and success of recruited students, as part of a broad diversity, equity and inclusion (DEI) plan. Best practices include mentoring, building community, and other supportive actions, with particular focus on students underrepresented in the geosciences. Establishing programs that support students before, during, and after transferring from community colleges to four-year programs promotes student success and can help in increasing enrollments and diversity in four-year institutions. Additionally, geoscience programs can leverage institutional efforts to build partnerships among geoscience programs at two-year colleges, four-year colleges/universities and minority-serving institutions to enhance diversity, equity and inclusion in the geosciences.

Introductory and non-major courses should leverage the Next Generation Science Standards (NGSS) to engage all students and preservice teachers to align the courses with students existing expectations of how science is taught. Programs and departments should revise these courses to focus on processes and systems, integrate other sciences and math, and use active-learning pedagogies and resources. This approach may entice more students who take these courses to major in the geosciences and will prepare proficient geoscience-literate K–12 teachers. Explicitly identifying and using cross-cutting science and math examples in introductory and non-major courses demonstrates the relevance of the geosciences to students, including pre-service teachers for whom an introductory or non-major geoscience course may be their only science course. Societally relevant examples have the potential to be adapted for subsequent use in teachers' classrooms. Faculty teaching these courses should have the opportunity to participate in professional learning experiences that introduce the NGSS and supporting practices. If institutionally appropriate, geoscience departments should consider developing an option for K–12 preservice teachers, which may increase future college-level geoscience enrollments.

Faculty, advisors, programs, and/or departments should guide students to be proactive in their education and support them in identifying co-curricular opportunities for developing skills needed for future careers. Advisors and mentors can help students build customized roadmaps for attaining their educational and career goals. Additionally, students should have access to information on career options and training on how to find and obtain employment through institutional career centers, employers and/or alumni, professional societies, and other professional development resources.

Both geoscience faculty and students should recognize that formal undergraduate education is a robust foundation for lifelong learning in support of a successful career. Geoscience programs can help students become aware of external certifications required for some geoscience employment and the availability of continuing education programs. Moreover, students need to be prepared for changing workforce needs, including

Courtesy of the Jackson School of Geosciences, University of Texas at Austin

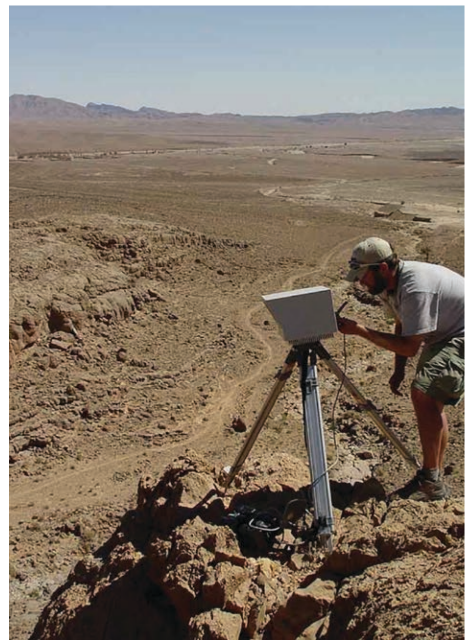
new careers and jobs that require the use of new technologies, strong quantitative and computational skills, data analytics and machine learning, interdisciplinary teamwork and problem solving.

An ongoing initiative investigating the skills and competencies needed by graduate students for successful careers in Earth, ocean, and atmospheric sciences underscores the need for undergraduate programs to build the educational foundations essential for students who will pursue graduate degrees. Most identified skills and competencies are similar, requiring a higher level of accomplishment, along with some additional skills related to research, problem solving, and future technological trends. Student success can be strengthened by supporting the career goals of students and working with them to build the competencies they need for the future.

Case studies captured by this initiative demonstrate that efforts to revise undergraduate programs are multi-year processes requiring patience, persistence, and steady leadership to maintain engagement and sustain momentum. Heads and chairs need to encourage, facilitate, and support those faculty tasked with making changes to undergraduate programs; they need to allocate necessary resources, assure alignment of curricular efforts with institution-level priorities, and keep the upper administration informed of progress in these activities and of the national effort that necessitates these changes. Review, revision and changes to undergraduate programs and teaching are best accomplished through bottom-up efforts and identifying key individuals or teams of faculty to drive the effort while maintaining full transparency with the rest of the department. Successful implementation of active and experiential learning and other research-based strategies that improve student learning and motivation are greatly facilitated by professional development opportunities and other incentives for faculty, such as release time, redistribution of workload, or reduction of non-instructional assignments, as allowed by each institution.

A wide range of stakeholders, including academics, employers, and organizations, have vested interests in the success of undergraduate geoscience education and bear a responsibility for accomplishing this vision for the future. Heads and chairs should encourage and support faculty in completing necessary curricular review and revision efforts and in adopting new instructional approaches. They should also advocate to their Dean for support of these efforts related to meeting community educational standards and articulate their relationships to institutional measures of student success. Faculty should participate in and leverage relevant professional development experiences, the more specific to the geosciences and to their courses the better. Funding agencies, professional societies, and other stakeholder groups should support and/or offer a broad array of relevant professional development experiences for faculty to learn how to adopt innovative teaching practices and understand curricular enhancement and revision efforts. Academic departments and geoscience employers should establish and maintain interactive professional relationships with one another, focusing ultimately on improving the abilities and accomplishment of bachelor's level geoscience graduates.

Sustained change in geoscience undergraduate education will require the combined and coordinated efforts of departments and programs, administrators, individual faculty, geoscience employers, and professional societies. To prepare geoscience undergraduates for success requires cultural change, from the administration down to the students. This report is a roadmap and resource for deans, heads and chairs, undergraduate program directors, faculty, other educators, current and future employers, and professional societies in shaping the future of undergraduate geoscience education.



Courtesy of the Jackson School of Geosciences, University of Texas at Austin

Annotated Table of Contents

Courtesy of the Jackson School of Geosciences, University of Texas at Austin

Courtesy of the Jackson School of Geosciences, University of Texas at Austin

8. Recruiting, Retaining, and Promoting Success of Undergraduate Students with Emphasis on Students Underrepresented in the Geosciences

Summarizes best practices compiled from Summit participants and other community advice

9. Leveraging the *Next Generation Science Standards* in Introductory and Non-Major Courses to Recruit Majors and Prepare K–12 Science or Geoscience Teachers

Outlines the impact of the *Next Generation of Science Standards* on undergraduate education and how to use it for recruiting majors and preparing the next generation of K–12 teachers

10. Building a Learning Continuum for Life — Undergraduate Geoscience Education as Part of the Continuum of Career and Lifelong Learning

Discusses the importance of and how best to accomplish lifelong learning

11. What Graduate Geoscience Education Should Accomplish

Summarizes the outcomes of the 2018 Geoscience Employers Workshop for graduate education in Earth, atmospheric and ocean sciences

12. Fostering Change in the Academic Community: Case Studies

Provides results of heads and chairs efforts to implement change using the information outlined in this report

13. Engaging Stakeholders

Discusses what stakeholders need to do to accomplish change to undergraduate geoscience education to prepare students for the future