What are the critical, transferrable skills for (geo)scientists? Insights from recent STEM-wide and Geoscience efforts

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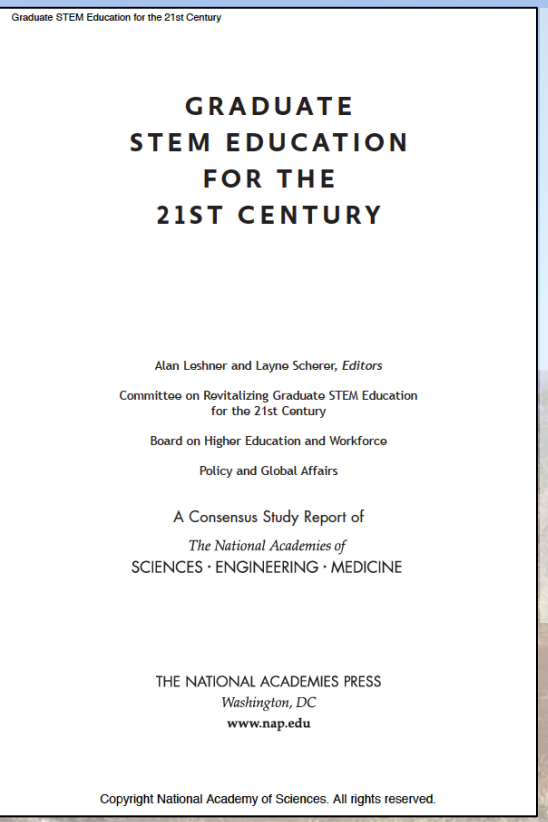
Longstanding Issue: Graduate education/training and needs of M.S./Ph.D. graduates are mis-aligned (or perceived to be so)…

- *Cassuto, L. (2015). The Graduate School Mess*
- *Council of Graduate Schools and Educational Testing Service. (2012). Pathways Through Graduate School and Into Careers*
- *Council of Graduate Schools and Educational Testing Service. (2010). The Path Forward: The Future of Graduate Education in the United States*
- *Golde. C.M., & Dore, T.M. (2001). At cross purposes: What the experiences of today's doctoral students reveal about doctoral education*
- *Re-envisioning the PhD Initiative, 2000*
- *Etc.*

Building on a foundation of previous efforts…


Graduate STEM Education for the 21st Century

GRADUATE
STEM EDUCATION
FOR THE
21ST CENTURY

Alan Leshner and Layne Scherer, *Editors*

Committee on Revitalizing Graduate STEM Education for the 21st Century

Board on Higher Education and Workforce

Policy and Global Affairs

A Consensus Study Report of

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

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Washington, DC
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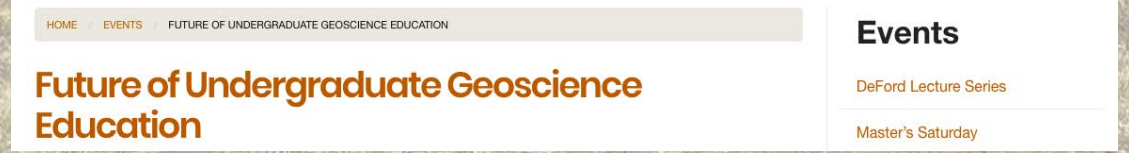
Caveats:

- STEM-wide reports and analyses bias toward where most of the graduate students are (i.e., biomedical, engineering, chemistry, physics)
  - We need to consider their findings in the context of the demographics and cultures of geoscience graduate programs (earth/ocean/atmospheres)
- We need to consider their recommendations in the context of the financial/logistical realities of geoscience departments and graduate programs
  - Primary difference – our departments and programs are smaller, our funding structures are different/more modest!



Council of Graduate Schools: "Professional Development: Shaping Effective Programs for STEM Graduate Students" (2017)

- NSF-funded effort
- Data collection
  - Survey of graduate deans
  - Interviews with “employer” representatives
  - 2015 workshop (Deans, employers, students, faculty)
- Focus: Student-targeted professional development activities for Ph.D. candidates aiming to broaden their preparation for non-academic opportunities.
  - What activities are occurring?
  - How effective are they?
  - Adaptable/adoptable models?

Key skills for MS and Ph.D. graduates, per STEM employers (CGS, 2017)

General Skills:

- Communication, writing and presentation (powerpoint)
- Mentoring
- Leadership
  - Cultural competency
  - Teamwork

STEM-specific skills:

- Research development
  - Technology commercialization
  - Entrepeneurship
- Data science (Big Data skills)
- Science policy
- Research ethics
  - Governance, risk and compliance
- Time management/project management

Red means common among the reports!

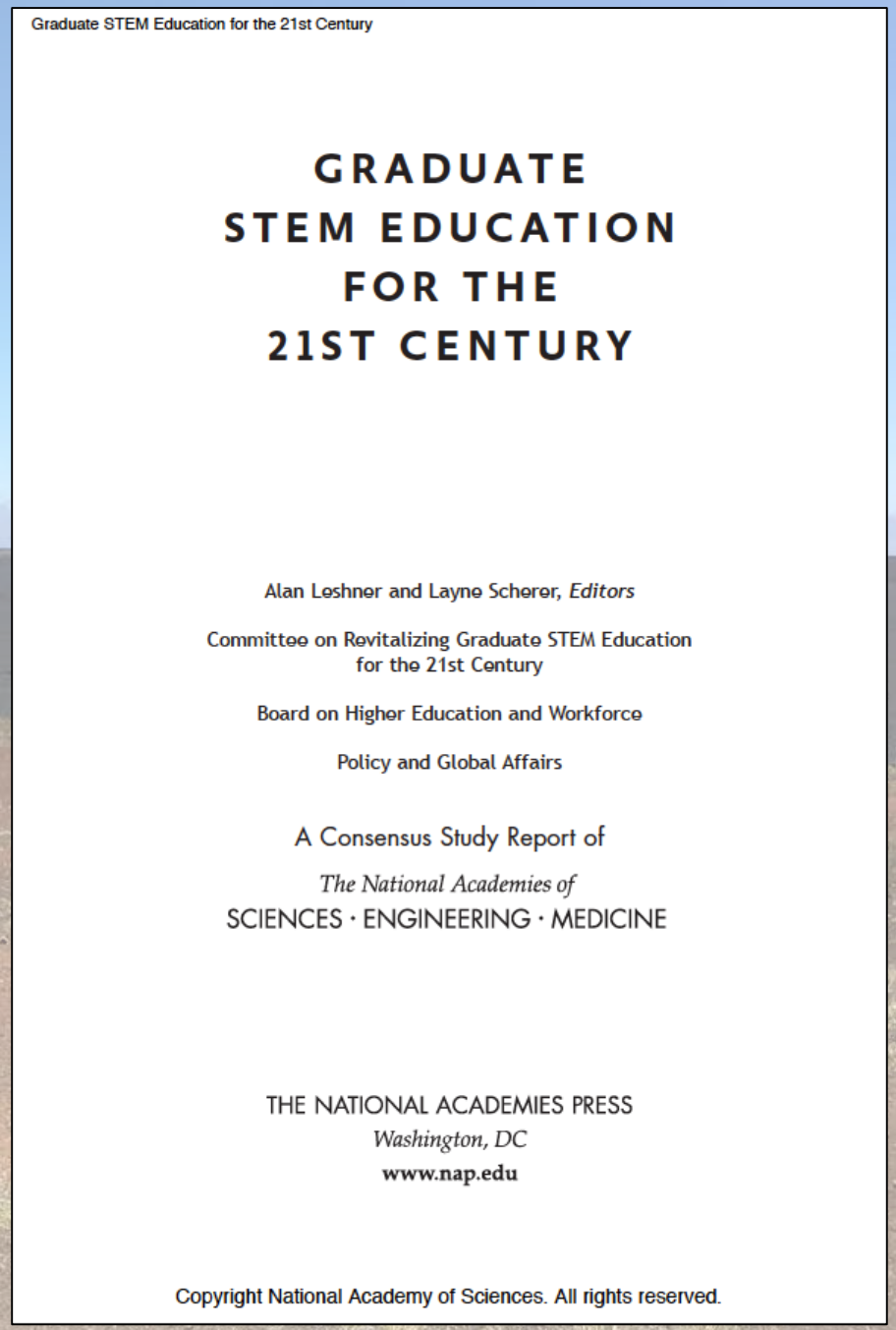
Professional Development: Activities, Examples… (CGS)

Core Competencies focus:

- Communication
  - "Three Minute Thesis"
  - Communication training/Community Engagement
  - Improvisational theater (Alan Alda Foundation)
  - Presentation Bootcamp (NSF-COSEE Network)
- Academic Development
- Leadership and Professionalism
  - Project Management
  - Entrepeneurship
  - Business Skills development
- Career Development

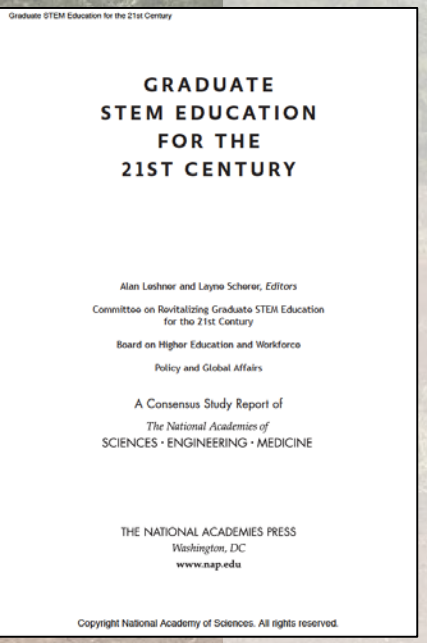
- **Strategies:**
  - Needs assessment
  - Individual Development Plans (specifics not defined…)
  - Partnerships (with employers, alumni, and among campus offices/services for events

The National Academies: "Graduate STEM Education for the 21st Century" (2018)



NAS "Graduate STEM Education for the 21st Century"

- 18 month study
  - "Blue skies" approach (i.e., what would an ideal STEM Graduate Education ecosystem look like, assuming infinite resources (including faculty time!))
    - 5 committee meetings (17 members; 14 NAS staff; 5 consultants)
    - 5 focus groups of stakeholders (run and analyzed by Research Triangle International).
    - Feedback from attendees at ACS, AAAS, CGS, CSSP, FASEB, Grad Career Consortium, etc.
      - 19 different meetings/events across STEM and STEM education
    - Stakeholder feedback on prepared discussion document
    - Student feedback (as committee members and from students at large)
    - Reviews of academic literature on graduate student learning, and on interdisciplinary STEM program frameworks
      - Limitations related to comparatively small bodies of literature on graduate STEM education



Criteria for the Masters Degree (NAS, 2018)

- Disciplinary and interdisciplinary knowledge
- Professional competencies
  - Foundational and Transferrable Skills:
    - Communication
    - Leadership
    - Working in teams
  - Research skills:
    - Scientific skills
    - Quantitative/computational skills
    - Research responsibility and integrity

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Criteria for the Doctoral Degree (NAS, 2018)

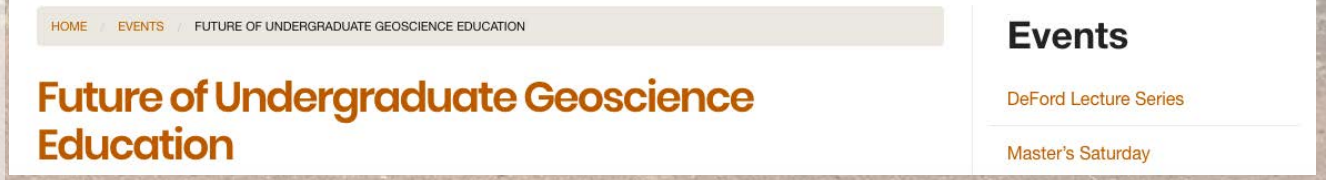
- Develop scientific and technological literacy and conduct original research
  - Deep, specialized STEM expertise
  - Transdisciplinary literacy re: problem solving
    - Identify an important problem and define a strategy to attack it; Rigorous investigative standards
    - Research design (skills in theory, analytical, quantitative approaches); Critically evaluate outcomes
  - Professional norms and practices
- Develop Leadership, Communication, and Professional competencies
  - Working in teams across disciplines and cultures
  - Oral and written communication skills to STEM and non-STEM audiences, incl. general public.
  - Interpersonal communication skills
  - Budgeting/project management
  - Pedagogical skills

Recommendations (for MS and PhD programs):

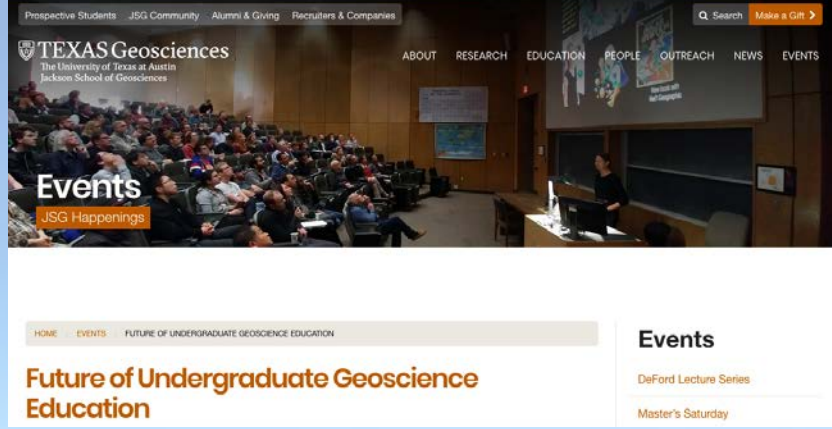
- Verify that graduate programs provide these competencies and students achieve them (?!?!… How does one measure, for example, "transdisciplinary literacy" or working in collaborative teams…?)
- Graduate departments should publicly post how their programs reflect MS/PhD core competencies, including milestones and metrics used in evaluation and assessment.
- Funders should adapt criteria to ensure that all supported students are in programs that develop, measure, and report student progress toward acquiring their key scientific and professional competencies.
- "Universities should scrutinize their curricula and program requirements for features that lie outside of these core competencies and learning objectives and that may be adding time to degree without providing enough additional value to students, such as a first-author publication requirement, and eliminate those features or requirements." (i.e., make degree program requirements about the degree and not other productivity measures)
- Graduate students should create "individual development plans" w/ the MS/PhD core competencies and their own learning and career goals, using resources provided by institutions and relevant professional societies (??).

Summit on the Future of Undergraduate Geoscience Education (2014-2018)

- Two meetings (300+ attendees), a survey (>450 respondents), and several follow-on implementation/informational events
- Targeted the undergraduate experience, but many of the skills and competencies identified (and the discussions thereof) carried into the geoscience graduate education experience.



Summit on the Future of Undergraduate Geoscience Education (2014-2018) (desired skills for undergraduates (shared in red))



Non-technical Skills

- Oral and written communication competency
  - Science writing and verbal communication; public speaking; knowing your audience
- Project management/Time management
- Ability to work in teams
- Professionalism, interpersonal skills
  - Ethics, ethical awareness, codes of conduct, awareness of implicit biases
  - Leadership
  - Understand societal relevance
  - risk management
- Cultural interactions, cultural literacy, emotional literacy, learning styles, Global perspective
- Career awareness

Red means common among the reports!

Summit on the Future of Undergraduate Geoscience Education (2014-2018) (desired skills for undergraduates (shared in red))

Selected STEM Skills:

- **Data Analysis Skills**
  - problem solving with data
  - Ability to handle and analyze Big Data
  - Use of visual models, modeling tools (Stella, Modflow, Matlab, etc.);
  - Data collection and interpretation, use and application of data
  - Computer programming (how to solve a problem computationally)
  - Technological diversity (need skills and training beyond point, click, and type
  - Probability and statistics; Quantitative/mathematical skills
- Experience with authentic research, collection of new information; Critically evaluate literature, critical thinking
- Preparation for life-long learning

Key Inference: Views on key, transferrable skills for geoscience students are shared across STEM fields and across geoscience education!

- NAS and CGS report bases: All of STEM (not geoscience specific…)
  - Big NAS/CGS key concern: perceived resistance in the academe to non-academic professional trajectories
  - NAS/CGS recommendations: Professional Development for graduate students (at the University level), and "culture change…(?)" with leverage from funders
    - No discussion of disciplinary professional development efforts or strategies(??)
- Questions for us:
  - Of the concerns identified, which are Geoscience concerns?
  - What are good geoscience-specific strategies to foster graduate student professional development and growth?
  - What "culture change" is necessary and tractable for geoscience graduate programs?