Universal Skills for Geoscience Graduate Student Success in the Workforce

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WHERE DISCOVERIES BEGIN

AGU/AGI Heads and Chairs Webinar

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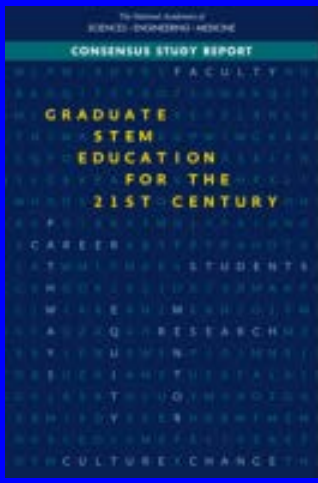
Most PhD & M.S. STEM students will not go to academia!

So, in addition to their specialty,
what do they need to learn in graduate school?






Graduate STEM Education



- **National Academy of Science Engineering & Medicine (NASEM):**
  ***Graduate STEM Education for the 21st Century* (2018)**
  - http://www.jsg.utexas.edu/events/files/nas-graduate-stem-report.pdf

- **Council of Graduate Schools (CGS)**
  ***PROFESSIONAL DEVELOPMENT Shaping Effective Programs for STEM Graduate Students* (2017)**
  - http://www.jsg.utexas.edu/events/files/cgs-profdev-stem-grads16.pdf

- **Future of Undergraduate Geoscience Education initiative (FUGE) (2014-2019)**
  Vision and Change for Undergraduate Geoscience Education: A Call to Action* *(working title)
  - http://www.jsg.utexas.edu/events/future-of-geoscience-undergraduate-education

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Mismatch between Graduate Education & Future Careers

- **Graduate programs: too narrowly focused on academic research**
  - Students need to develop professional and personal skills valued by *both* academic and non-academic employers
  - Teamwork, project management, leadership, communication
- **Students need information to identify career options, necessary skills/competencies, mentoring**
  - Need preparation in skills/competencies needed outside academia *(as well as within)*
- **Transferable skills – for changing world & occupations**
  - Transitioning to interdisciplinary/multidisciplinary/transdisciplinary research → application
  - Increase in societally important research & application
  - Changing research methods & technology
  - Changing demographics – more diverse & global

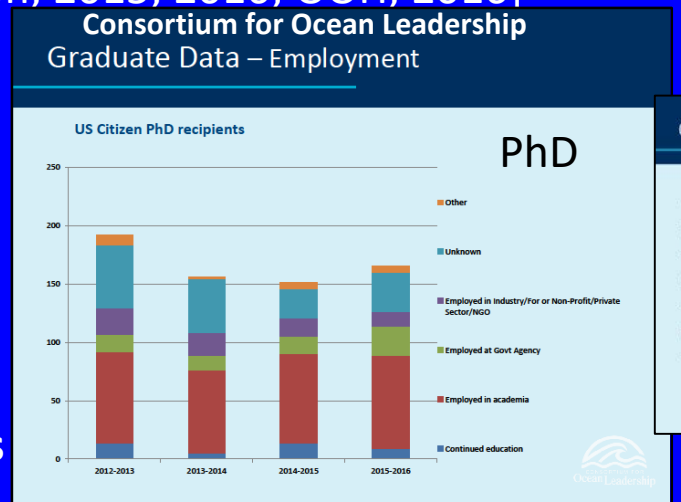
Call from graduate students, professional societies, employers, Council of Graduate Schools, National Academies of Science, etc.

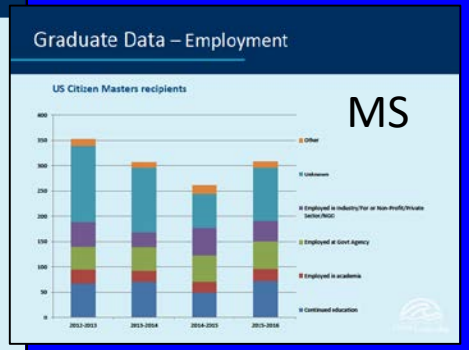
Current Landscape

Graduate STEM Education

- ***Propels societal advancement, innovation and economic growth, strengthens national security, protects environment, improve health & medical care*** [NASEM 2018]

- **STEM PhD students: 45% business; 46% academia** [NSF NCSES, 2013].
- **Geosciences: 51% PhD & ~4% Masters students in academia** [Wilson, 2015]
- **B.S. geoscience graduates plans** [Wilson, 2015, 2016; OOH, 2016]
  - **8-9% Ph.D. and academic career**
  - **20-27% Master's degree**
    - **16% M.S. continue for PhD**



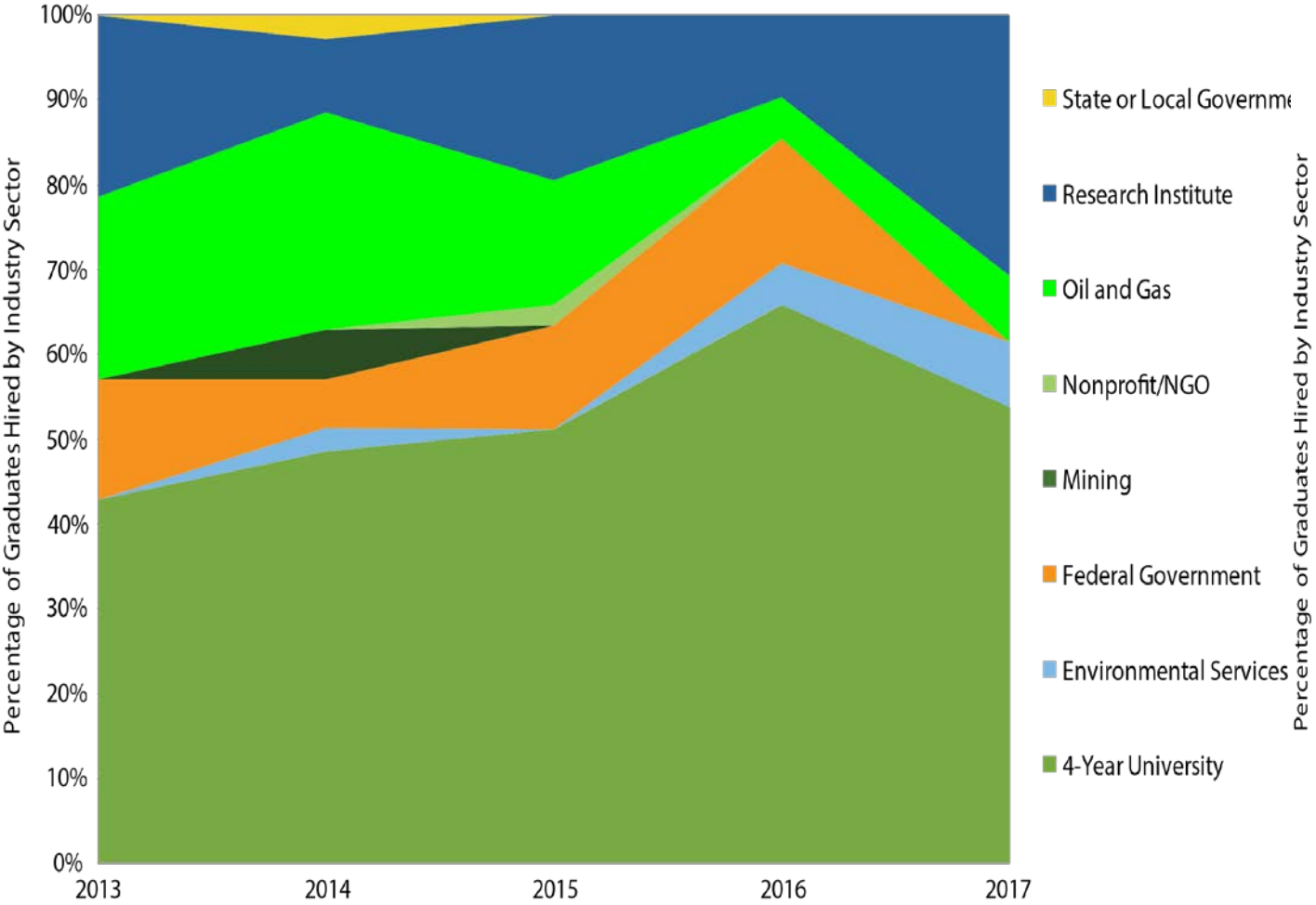


Academics

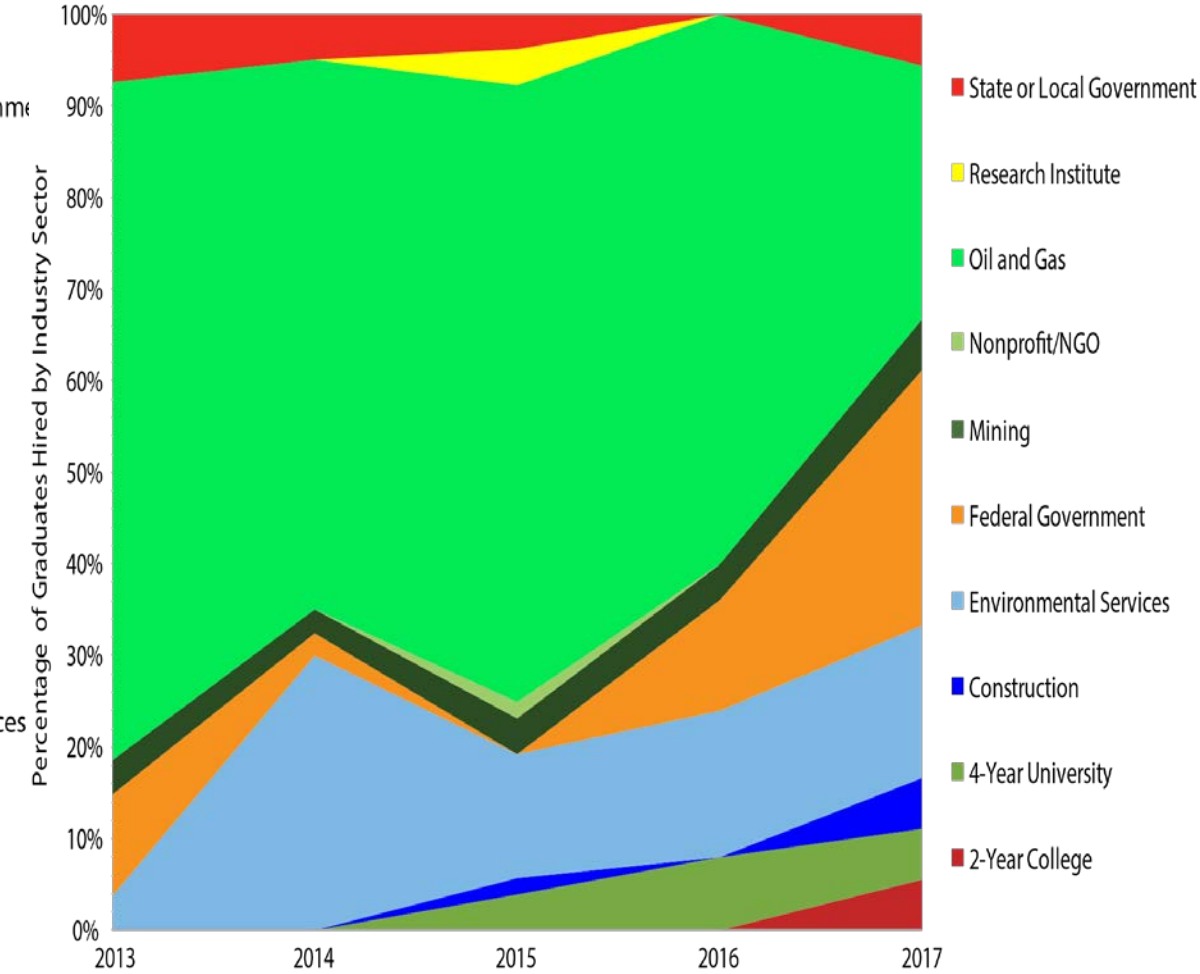
American Geosciences Institute (AGI) Workforce 2018 Report [Wilson, 2018]

Survey of 146 Responding Departments
106 Ph.D. granting
40 Terminal Masters

First Employment of PhD Recipients 2013-2017



First Employment of MS Recipients 2013-2017



Improving Geoscience Graduate Student Preparedness for the Future Workforce

Project Goals:

- Identify the skills and competencies that should be part of graduate geoscience education for PhD & MS students in Earth, Ocean, & Atmospheric Sciences
- Investigate best means of developing these in graduate geoscience programs nationally
- Work with Heads/Chairs and Graduate Program Directors on implementation strategies to develop the skills and competencies identified by the geoscience employers workshop & other studies

Geoscience Employer Workshop
Oct. 2018

- **~52 participants representing broad spectrum of geoscience employers of PhD & MS students in Earth, Ocean & Atmospheric Sciences**
  - Industries, Non-profits, other organizations: Weather/climate, Energy/natural resources, Oceans/fisheries, Environment, Reinsurance/hazards
  - Government agencies – NASA, NOAA
  - Research labs & universities
  - Professional societies

- **Discuss & provide feedback to academia on skills & competencies needed by PhD & MS students for current and future workforce**
  - Build on results of Future of Undergraduate Geoscience Education initiative & National Academy & Council of Graduate Schools Graduate STEM reports
  - Define geoscience skills & competencies needed for MS & PhD graduates
    - Discuss methods for developing skills & competencies & employers role
    - Discuss balance between preparing for workforce, research and general educational goals

- **Determine next steps towards completing & implementing vision**
  - Role for Industry, Government Agencies, Universities & Professional Societies

Heads/Chairs Summit
May, 2019

- 74 participants, primarily Department Heads, Chairs & Graduate Program Directors
  - 59 PhD granting universities/colleges; 5 MS only
  - Earth, Oceans & Atmospheric Science programs
  - 2 NSF, 4 industry, 4 professional society participants

- Discuss input from geoscience employers & other studies on skills & competencies needed by PhD & MS students for current and future workforce
  - *General agreement with employers in terms of what graduating PhD/MS students have and lack*

- Discuss methods for developing skills & competencies
  - Discuss balance between preparing for workforce, research and general educational goals

- Develop implementation strategies for integrating these in graduate programs
  - 60 Action Plans

What skills and competencies make PhD and MS graduates successful in the workplace today (and future)?
And what do they lack?

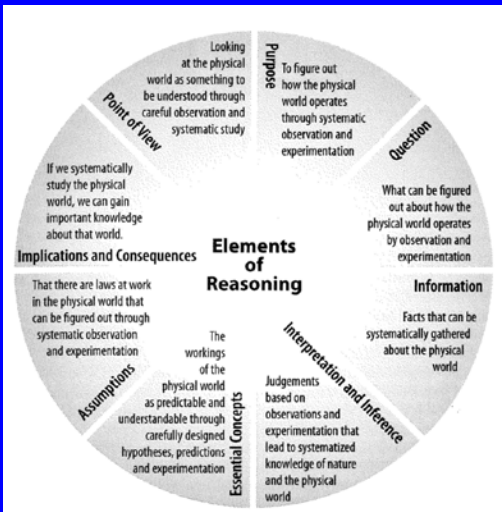
- **Need Expertise/Depth in core area → leads to judgment and confidence**
  - **Core technical skills in relevant area of expertise is absolutely necessary**
  - **Deep understanding of the fundamentals/mechanics of the techniques/methods they are using**
  - **Having foundational skill set – good education in the geosciences**
    - **Breadth in core area, grounding across all sciences**
    - **Course background in their field – even if switched fields from undergrad to grad**
- **Graduates generally are coming with very strong technical skills**
  - **Knowledge in their field of geosciences**
  - **Research skills; field skills**

Most Important Skills – regardless of discipline

- **Problem solving & critical thinking**
  - Pragmatic critical thinking, logical thinking
  - Flexibility, open-mindedness
  - Defining problem and applying an appropriate solution
    - *Establishing what is a sufficient solution vs. a precise and complete solution*
  - Translating the problem to the -- so what?
    - Articulate importance of outcomes
    - *What decisions will be made based on the work you are doing*
  - Understanding the broader impacts of your research & how to communicate those impacts

- ***Independence in critical thinking, and problem development, execution and analysis skills***

Many graduates struggle with being able to define a problem and identifying how to apply the solution
(but could solve the problem)



- **Teamwork, Collaboration** ***(generally lack)*** 😔
  - Ability to work with other scientists & other trained individuals towards your goal
  - Ability to get others to work together; deal with conflict
  - Valuing diversity of thought
  - Developing self-awareness & recognizing skills among ourselves & people around us
  - Evaluating expertise, knowing your own strengths
  - Being coachable, taking directions, leading

- **Leadership** -- in science, education, public policy/politics, business 😔

- **Communication** (common limiting factor) 😔
  - written, verbal; external and internal

  Expressing technical work effectively to appropriate audiences

  - Technical writing & verbal communication
    - within specialty and other science & engineering fields
    - to non-technical audiences, management, pubic, press
  - Be able to convey complex material in a simple way
  - Express ideas logically
  - Be comfortable speaking with people when English is not their first language
  - *Be able to communicate societal and/or financial impacts*
  - **Skill in editing – evaluate critically & accept criticism**
    - Evaluate/recognize credible sources
  - **Listening Skills**
    - High sensitivity to audience – reading the room
    - Pay attention to what others say
    - Answer questions asked & logically

Research Skills

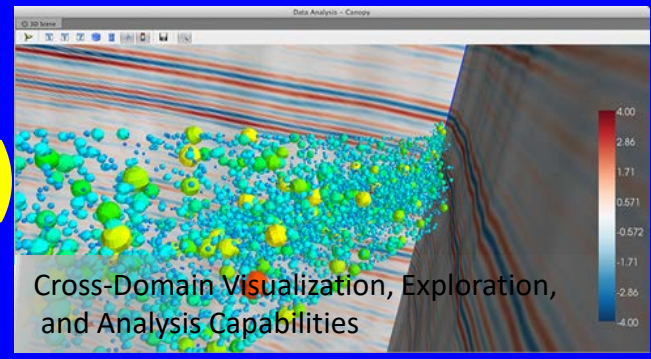
Currently need and increasingly important in the future – across employer spectrum!

➢Data Management & Data Analytics

- **Awareness of data analytics, the applications, processes for using data** (Answers questions we have not framed yet)
- Dealing with Big Data & Datasets
- Examining datasets to draw conclusions about the information they contain

- **Data Acquisition --**Data collection – different types of data, different data sources – establishing data credibility, familiarity with available tools for access & interpretation
- **Data Management & Analysis**
  - Using data effectively & have proficiency at managing
  - Looking at & synthesizing data from different perspectives (e.g. air, ground, etc.)
  - Using various types of data; Knowing the tools for analysis, how to organize
  - **Data Manipulation** – adding, deleting & modifying data, retrieving data from dataset
  - Learn/develop new ways for data management & analysis & synthesis

➢Data Management & Data Analytics (cont.)


Cross-Domain Visualization, Exploration, and Analysis Capabilities

- **Data Integration**
  - Merging information/data to solve problem
  - Integrating different types of data; synthesize
- **Data assimilation** – sequential updating of model forecast with new observations
- **Data quality** –understanding, evaluating, using data of different qualities
- **Visualization & Modeling --** Data simulation, display; ability to model & know limits of modeling; immersive Virtual Reality data exploration
- **Valuation:** how valuable is the data - monetizing
- **Other data science** - e.g., Machine Learning, AI, computer science, robotics – increasing in future

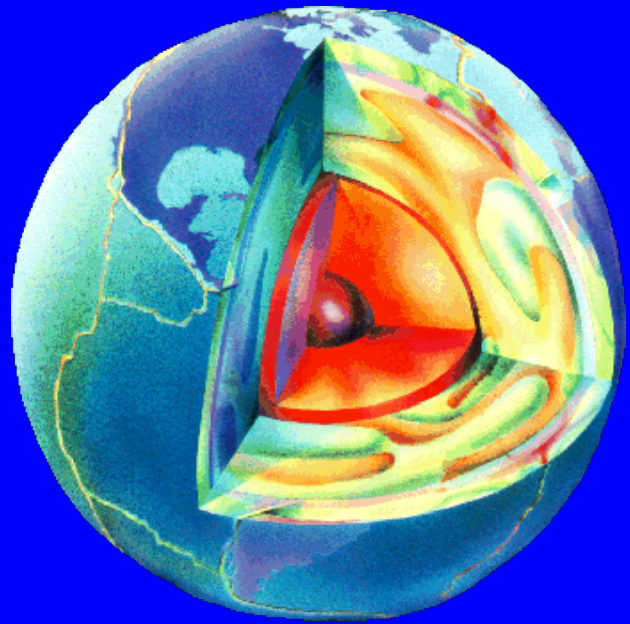
- **Computational skills**
  - More need for computational skills but within the ability to make observations
    - **Basic programming skills**
      - Scripted languages
    - **Coding** - able to code
      - Translate older code to newer codes & systems that are more effective
    - **Ability to analyze algorithms** (with increase in Machine Learning & AI)
    - **Keep up with transition from Supercomputing to Cloud computing**
      - Cloud data manipulation and storage for big data
    - **Modeling** – be able to develop, analyze and evaluate models
  - **Basics of statistics and math** *[should have from undergrad]*
    - **Statistics** - communicating certainty
    - **Higher math** - including calculus, differential equations, linear algebra

- ***Embracing technology not only as users but as creators***
- ***Willingness to step outside of the box to engage in genuine innovation***

Habits of Mind

- **Systems Thinking**
  - Look at entire system - the big picture
    - Parts in isolation may act differently than when within system
    - Go from big to small & back to big to solve problem
  - View whole system and drill down to details, interactions & limitations

- **Earth System Thinking**
  - Earth as a interactive system
  - Complex, non-linear, coupled system
  - Interaction between different processes



Important Concepts & Abilities

- Scientific process
  - Observe, characterize, understand, model, predict, verify
- Importance of simulation
- Good grasp of uncertainty
- Scalability of space and time
- Awareness of risk and impact
- Application driven questions


Credit: Storyblocks

- **Internal drive to do well**
  - Overcome inherent risk aversion in adopting new technology to address major problems
  - Overcome prevalence of fear of failure
- **Willingness to be a life-long learner – learn how to learn**
- **Societal Connection**
  - Understand research needs a purpose
- **Diverse and Adaptable skill set**
  - Specifics less important, but rather evolution potential

Additional Professional Skills

- **Project & Program Management** (generally lack) 😔
  - Understanding budgets, project financials
  - Managing people, multidisciplinary projects
  - What factors are driving the decision-making process?
  - Manage time & resources
  - Know how to run a meeting (agenda, time management, relevance, etc.)
- **Time-value concepts – understand**
- **Business Skills** (needs much improvement) 😔
  - Economic, data-driven decision-making; risk, uncertainty
  - Innovation & entrepreneurship
  - Leadership, teambuilding, finances/budgeting, project management, problem solving
  - Exposure to basics of business, operations, etc.

- **Ethics & Professionalism**
  - Integrity & its importance to science & research process
  - Understanding plagiarism, self-plagiarism
  - Proper attribution to original source
  - Rules for scientific citation & research
  - Knowing how to search for research

Boardeffect.com

- **Social dynamics** (generally lacking; limiting) 😔
  - **People skills** –interpersonal behavioral and cultural
    - Ability to work with people who are different & from different cultures
  - **Corporate skills** – culture clash: academia vs industry, government & business
    - Be able to distill everything down to making it relevant to the CEO or Manager
    - Time - value of money
    - Learning how to take direction – directed work

Professional Development

- Training on how to get a job
  - Resumes, applications, interviews,
  - Where to search
  - Knowledge of careers
  - Knowing options & how to leverage their skills or gain skills/knowledge
- Networking – how to do, what not to do, where to go/be
- Virtual presence/brand
  - Current presence on social media & how that effects hiring/career
  - Self marketing
  - Representing that extra expertise

- Interviewing skills
  - Can be learned
  - Do's & Don'ts
- Ability to move up & transition within organization (1st job not last)

What level of competency is needed?

PhD – Expert; MS – Mastery

- Expertise/depth in core area
- Critical thinking & problem solving

PhD & MS – Mastery

- Communication including written, verbal, external and internal
- Flexibility open-mindedness, collaboration, teamwork, networking

PhD – Mastery; MS – Proficiency/Mastery

- Coding, computer science/programming
- Statistics, data analysis, data display, data analytics
- Higher math including calculus, diff equations, linear algebra

What level of competency is needed?

medium.com

PhD – Mastery; MS – Proficiency

- Systems thinking
- Breadth in core area, grounding across all sciences
- Project management
- Real-world career & applications awareness
- Scientific uncertainty

PhD – Mastery; MS – Aware

- Economics, data-driven decision making , risk, uncertainty, general business skills

PhD – Aware/Proficiency; MS – Aware

- Other data science, e.g., machine learning, computer science, robotics, block chain, etc.

Need for Integration

- **What distinguishes a PhD/strong researcher?**
  - A deep technical dive into one subject
  - Ability to discover, own, and solve a problem independently
  - High level of creativity and innovation
  - Ability to create new knowledge

- **Need to integrate these identified skills without losing the strong research emphasis**
- **Make many of the non-core research skills part of program culture**

Heads/Chairs:
How can we make these opportunities available throughout the graduate experience?

- Deliberate planning & coordination of graduate coursework to include competencies
- Electives or special topics courses
  - Big data, coding, statistics
  - Science communication
  - Project management
- Build open & easily usable databases for students in all fields
- Integrate skills & interests in big data, coding, scientific communication into theses & dissertations
- Reevaluate qualifying/comprehensive exam within the context of broader expectations
  - Press release
  - 3 minute thesis presentation
  - Project plan & budget
- Define expectations & mentoring plan (i.e. paper authorship, timeline, etc.)

- ***Individual development plan (formalize?)***

Individual Development Plans (IDPs)

Customized roadmap for professional training & goals

- Skills assessment: What skills do I currently have?
  - Research, Professional Time Management, Interpersonal, Management & Leadership
- Career Aspirations – what career pathways interest me? What do I like to do?
- Desired Skills – setting goals for the skills I want
  - Specific & Sensible, Measurable, Action-oriented, Help needed, Time-bound
- Professional Development – what support can I take advantage of?

Reflect on self-assessments & career aspirations / professional values

See AAAS Science Careers: my IDP (https://myidp.sciencecareers.org/)
https://www.purdue.edu/science/graduate/idp.html
https://grad.wisc.edu/professional-development/individual-development-plan/
https://www.feinberg.northwestern.edu/sites/ctmh/docs/idp-worksheet.pdf

Hydrology

Career Compass Geosciences

This career compass provides options, tips, suggestions, and strategies for how a student can obtain critical skills, experiences, and competencies in order to launch their geoscience career based on their academic standing. The content herein is based on data from the U.S. Bureau of Labor Statistics, interviews with personnel in the occupation, and research on available student opportunities.

Job Summary

Hydrologists study how water moves across and through the Earth's crust. They use their expertise to solve problems in the areas of water quality or availability. Hydrologists work in offices and in the field. In offices, hydrologists spend much of their time using computers to analyze data and model their findings. In the field, hydrologists may have to wade into lakes and streams to collect samples or to read and inspect monitoring equipment.

Build Grow Connect

Undergraduate

- Clubs, student government, or geoscience professional societies
- Hone skills through courses, community involvement, and conference presentations
- Geoscience professional society conference
- First Aid/ AED/CPR training
- OSHA HAZWOPER training
- Geologist in Training Certification (ASBOG Fundamentals Exam)
- Geoscience internship with a non-profit, for profit organization or company, research institution, or federal agency
- Degree in earth science, geosciences, or other natural science major
- Proficiency in using and understanding GIS
- Writing class outside the discipline (business or environmental law)
- Course work in math, chemistry, or microbiology
- Research experience
- Field experience
- Write a senior thesis

Graduate/Master's

- Present research at conference
- Publish research
- Events, activities, and technical sessions at professional society conference
- Departmental committee, clubs, geoscience professional societies

Also applicable at Ph.D. level

- First Aid/ AED/CPR training
- OSHA HAZWOPER training
- Geologist in Training Certification or Professional Geologist license (ASBOG Fundamentals of Geology Exam and/or the Practice of Geology Exam)
- Geoscience internship with a non-profit, for profit organization or company, research institution, or federal agency
- Degree in geosciences
- Coursework in advanced math
- Map creation software or groundwater modeling software
- Master's thesis related to groundwater/surface water interaction

Ph.D./Post-doc

- Develop interpersonal skills
- Present complex scientific concepts to nontechnical audiences
- First Aid/ AED/CPR training
- OSHA HAZWOPER training
- Geologist in Training Certification or Professional Geologist license (ASBOG Fundamentals of Geology Exam and/or the Practice of Geology Exam)
- Geoscience internship with a non-profit, for profit organization or company, research institution, or federal agency
- Degree in geosciences
- Coursework in advanced math
- Map creation software or groundwater modeling software
- Take a more focused approach in a discipline related to your career aspirations
- Dissertation topic(s) related to groundwater/surface water interaction

Symbol Key

- Attend
- Communicate
- Network
- Participate
- Leadership
- Internship
- Scholarship
- Fellowship
- Academics

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Heads/Chairs analysis:
Where to best develop competencies? *Research*

- **Focused disciplinary & technical knowledge**
  - Field and/or lab skills
  - Computational skills, Big data – Data Analytics, Data Management
- **Communication: Written & Oral communication**
  - Thesis/dissertation, publications, proposals & conference presentation
  - Presentations to research group, department, undergraduate classes
  - Writing press releases before the full proposal & publications -- societal impact, diverse audiences
- **Critical Thinking & Problem solving**
  - Reading & evaluating literature
  - Identifying reliable data sources
  - Analyzing & evaluating data/results
  - Characterizing, managing, communicating uncertainty
  - *Learning to formulate problems & solutions; recognizing societally important problems*
- **Project & time management --** dissertation/thesis research project
- **Team work (as part of research group)**
  - Project & time management
  - Conflict resolution
  - Diversity sensitivity
- **Ethical (research) behavior & standards of practice**
- **Learn to take calculated risks, manage criticism & failure**

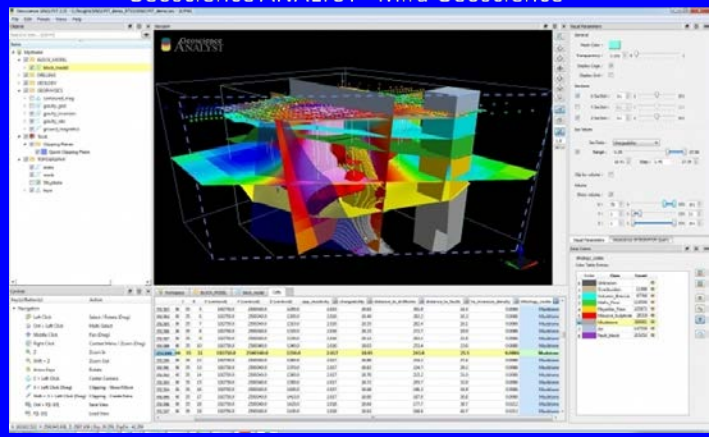
From: Diane Doser (UT El Paso) & Joshua Villalobos (El Paso Community College)

- **Organizational Management Skills**
  - How to run a meeting (agenda, time management, relevance, etc.)
    - Students rotate to run lab meetings (or TA meetings)?
  - Give concise and organized communications to a group
    - AGU-style talks; elevator speeches
  - Exposure to a chain of command and business culture
    - Foreign in academic settings but need to explore
  - Time management for self and in interaction with colleagues

Where to best develop competencies? *Graduate Course Work*

- **Technical skills & core disciplinary knowledge**
  - Integrate systems thinking
- **Written & oral communication**
  - Need intentional instruction & significant feedback
  - Abstracts, papers, 1-pagers, presentations
  - Writing proposals as the class project -- integration of data from the literature, identify problem & societal impact, project management plan, budgeting, & communication
  - Writing peer review (works better than faculty editing)
- **Case studies – within courses & entire courses**
  - Synthesis, data analysis, decision making, & communication
  - Characterizing, communicating uncertainty
  - Identifying problems & sufficient solutions
- **Computational skills, Big data – Data Analytics & Data Management**
  - Include large datasets in classes
- **Project & time management**
- **Team work** -- with instruction & expectations for group interactions
- **Service - learning courses**
  - Identifying problems, sufficient solutions, communication, team work, diverse communities
- **Direct discussion of ethics, standards of practice, biases & equity in science & work force**

Geoscience ANALYST - Mira Geoscience



Where to best develop competencies? *Co-Curricular*

Departmental activities, clubs, outreach programs, internships, professional organizations, public engagement, etc.

- Leadership & project management skills
- Oral communication
  - Presentations, brown bag talks, and competitions
  - Diverse audiences
- Written communication
  - Reports, fliers, news articles
- Interpersonal skills
  - Conflict Resolution,
  - Ability to work with people who are different & from different cultures
- Teamwork with diverse groups
- International experiences
- Field Experiences
- Peer mentoring/feedback, informal faculty/staff mentoring
- Entrepreneurship

Other co-curricular options:

Short Courses, online courses; 1 credit courses, non-departmental courses, certificate programs, presentations, etc.

- Career development or geoscience professionalism courses
- Alumni, returning interns & other "real world" speakers
- Communicating to different audiences (Toastmasters, etc.)
- Teaching training (NAGT, university Centers for Teaching Excellence, TA training workshops)
- Business/Commercial Acumen/Leadership
  - Within existing courses – Economic Geology, Petroleum & Mining Geology, Environmental Geology, Hydrogeology
  - Business schools, alumni, industry collaborators, etc.
  - Dual degrees
- True Teamwork (not group work or collaboration) – partnerships with industry, agencies & societies
  - Corporate challenge in partnership with corporations and government partners
  - Team-based cross-disciplinary, longer-term projects for student groups to work on together (e.g. AAPG's Imperial Barrel)
- Case studies - involve industry partners; industry retirees
- Ethics (Institutional training)
- Professional development
  - Scientific writing, scientific methods, presentation boot camp

Workshops & Websites

- Diversity, equity, and inclusion training
- Mentorship training for current and future faculty
- Standards of professional practice
- Conflict management
- Time management
- Pedagogy
- Grant Writing
- Breadth of career tracks available for geoscientists
- For faculty: skills & competencies needed by students for career success
- For Students: resources available on campus & through professional societies

AGU100 ADVANCING EARTH AND SPACE SCIENCE

GSA RISE
Respectful Inclusive Scientific Events

AAAS
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

SERC the Science Education Resource Center at Carleton College

EARTH EDUCATORS' RENDEZVOUS
NASHVILLE, TN, JULY 15-19, 2019
VIEW THE PROGRAM | SEARCH THE PROGRAM

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Expectation of Employers

- **What employers expect?**
  - Written and oral communication
  - Capacity for learning/adaptable
  - Systems approach
  - Programming, simulation, data skills, etc.
  - Problem solving & critical thinking
- **Employers will provide:**
  - Specialized job training as needed
    - In house or professional programs outside of the company
- **Workforce of the Future (10 years)**
  - Different programming languages
  - More data centric in all fields, changing algorithms and emphasis
  - Visualization and simulations

Image Via: acsundergrad.wordpress.com

Advice for Students

- **Be ready for dynamic job experiences**
  - Jobs/careers undergoing rapid change/growth
  - Be able to apply what you learned outside your field of expertise
  - Be able to talk to/work with people outside your field (e.g. physical oceanographer and biologist)
- **Show Interest in enterprise**
  - Step out of comfort zone, demonstrate enthusiasm
  - Getting something great done

  …it is not having things perfect, it is about getting something great done