Universal Skills and Competencies for Geoscientists

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Results from project sponsored by

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WHERE DISCOVERIES BEGIN

Future of Undergraduate Geoscience Education

2014 Summit:

- ~200 educators representing broad spectrum of undergraduate geoscience education community
  - R1 research universities with undergraduate programs, 4-year and 2-year colleges
  - Faculty, heads & chairs, education researchers
  - Industry, government & professional society representatives (~20)
- 1st step in development a high-level community vision for the geosciences
  - Surprising collective agreement

Ongoing Community Survey

455 respondents

- 354 academics (78%), 76 industry (17%), 13 government (3%), 7 other (1%), 5 professional societies (1%)
- 85% not Summit participants

Geoscience Employers Workshop (May, 2015)

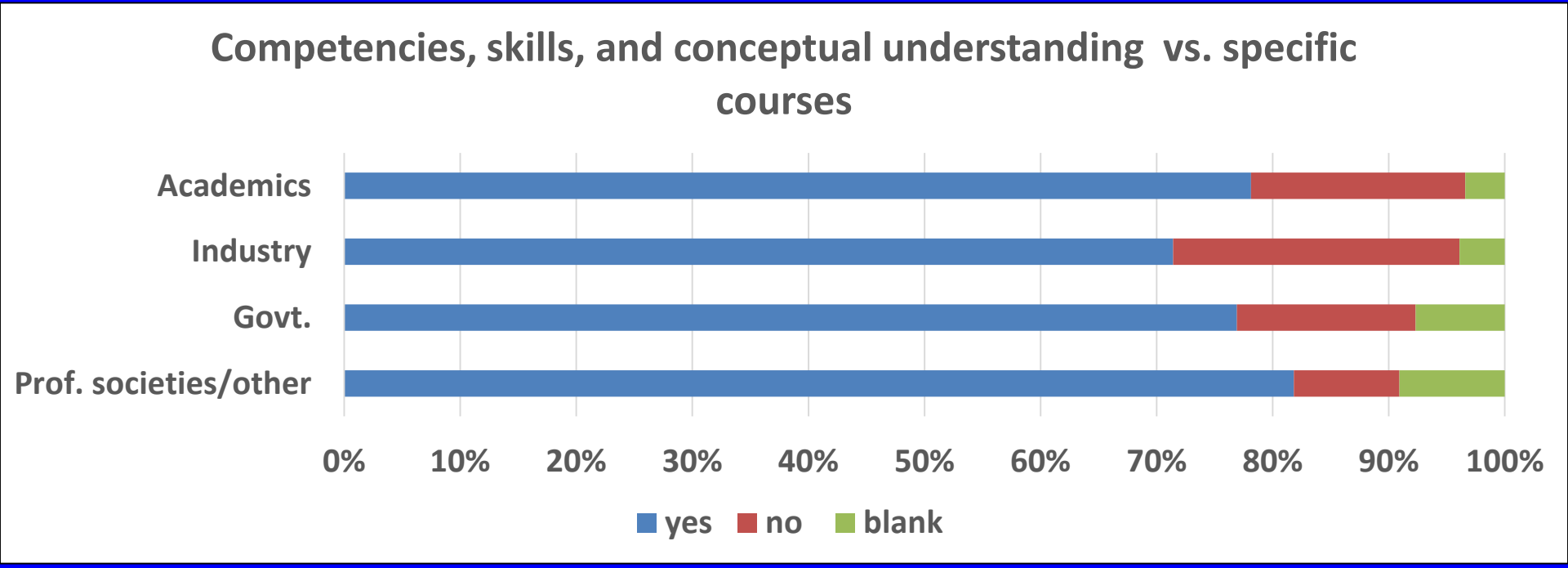
- 46 participants: 6-7 each from energy, hydro/engineering/environmental, govt. agency, prof. societies, academics; 1 mining
- Plus ~13 NSF program directors

Summit for Heads & Chairs – January 8-10, Austin, TX

Concepts, Skills, Competencies

- **Major conclusion of Summit**
  - Developing competencies, skills, and conceptual understanding
  - More important than taking specific courses

Survey Results:



Employer Workshop Overview:
Systems Thinking

How systems work and interact

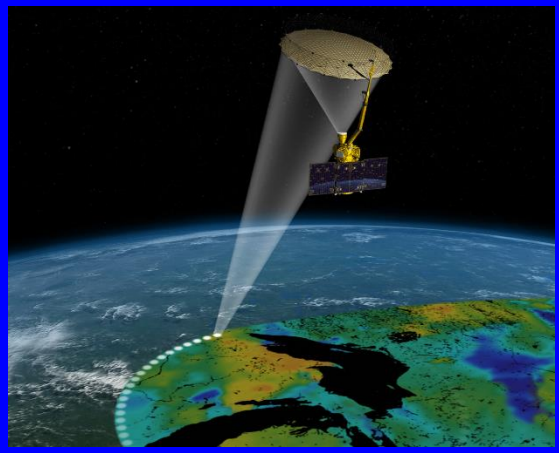
- **Atmosphere** – Climate, Weather, Ocean-atmospheric circulation
- **Hydrosphere** – Ocean, Ice, Surface water, Groundwater
- **Lithosphere** – rock cycle, deformation, structure, tectonics
- **Pedosphere/surface** – Geomorphic, Erosion, and Surface Processes, Landscape evolution
- **Biosphere** - Paleontology, Ecosystems
- **Solar/Earth Interactions** – Tidal, Climate; planetary geology
- **Human/Societal Coupled to Earth** – Natural Resources, Energy, Anthropomorphic Climate Change, Natural Hazards
  - Influence of geology on society
  - Influences of society on earth processes

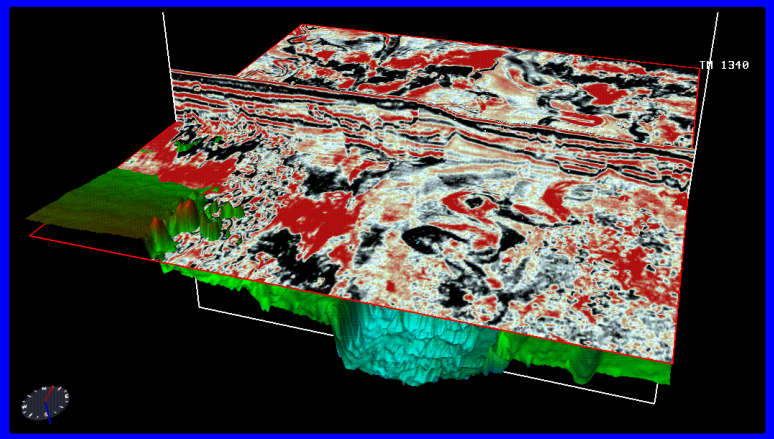
Processes

- **Thermodynamics** – energy, kinetics, diffusion, heat, mass transfer, fluid flow
- **Geochemical Cycles** – C, H_2O, N, P
- **Geomechanics/Stress State/Rheology**
- **Geological Time/Earth Evolution**
- **Plate Tectonics/Geodynamics**
- **Tectonic Processes**
- **Depositional Processes**
- **Crystallization Processes**

Tools

- Statistics/Uncertainty/Probability
- Mathematics (differential equations, linear algebra)
- Field Methods
- Cartography
- Geography and spatial thinking
- Potential Fields
- Remote Sensing
- Age Dating
- Instrumentation
- Analytical/Numerical Modeling
- Seismology/Geophysical sensing

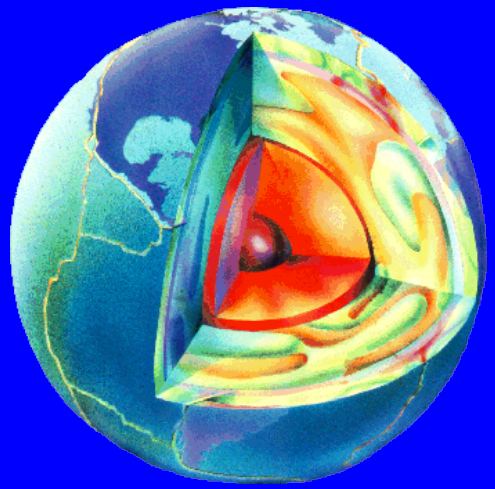




Geoscience Work Requirements

- Spatial & temporal thinking – 3D & 4D
- Understand Earth as an interacting system of parts & processes
- Geoscience reasoning & synthesis

- Solve problems
  - Context of open & dynamic system
  - With no clear, unambiguous answers
- Manage uncertainty
  - Work by analogy & inference
  - Make predictions with limited data



Needed Experience

- **Tackle problems using real data**
  - Understand context of problem
  - Identify appropriate questions to ask
  - Determine how to proceed
- **Visualize and solve problems in 3D**
  - Incorporate time
  - Understand importance of scale

Technical Skills Needed

- Integrate quantitative, technical & computational skills
- Be intellectually flexible in applying skills to new situations

  - Need experience using
    - High level math & computational methods to solve geoscience problems
    - Probability and statistics to under stand risk
    - "Big Data" & visualization and modeling tools

Field Skills

- **Field Camp and Field Experiences**
  - **Improves spatial cognition, creative problem solving, teamwork, geoscience synthesis**
  - **Field skills are unique and essential, difficult to replicate or substitute**
- **GIS – Most essential for building large data sets**

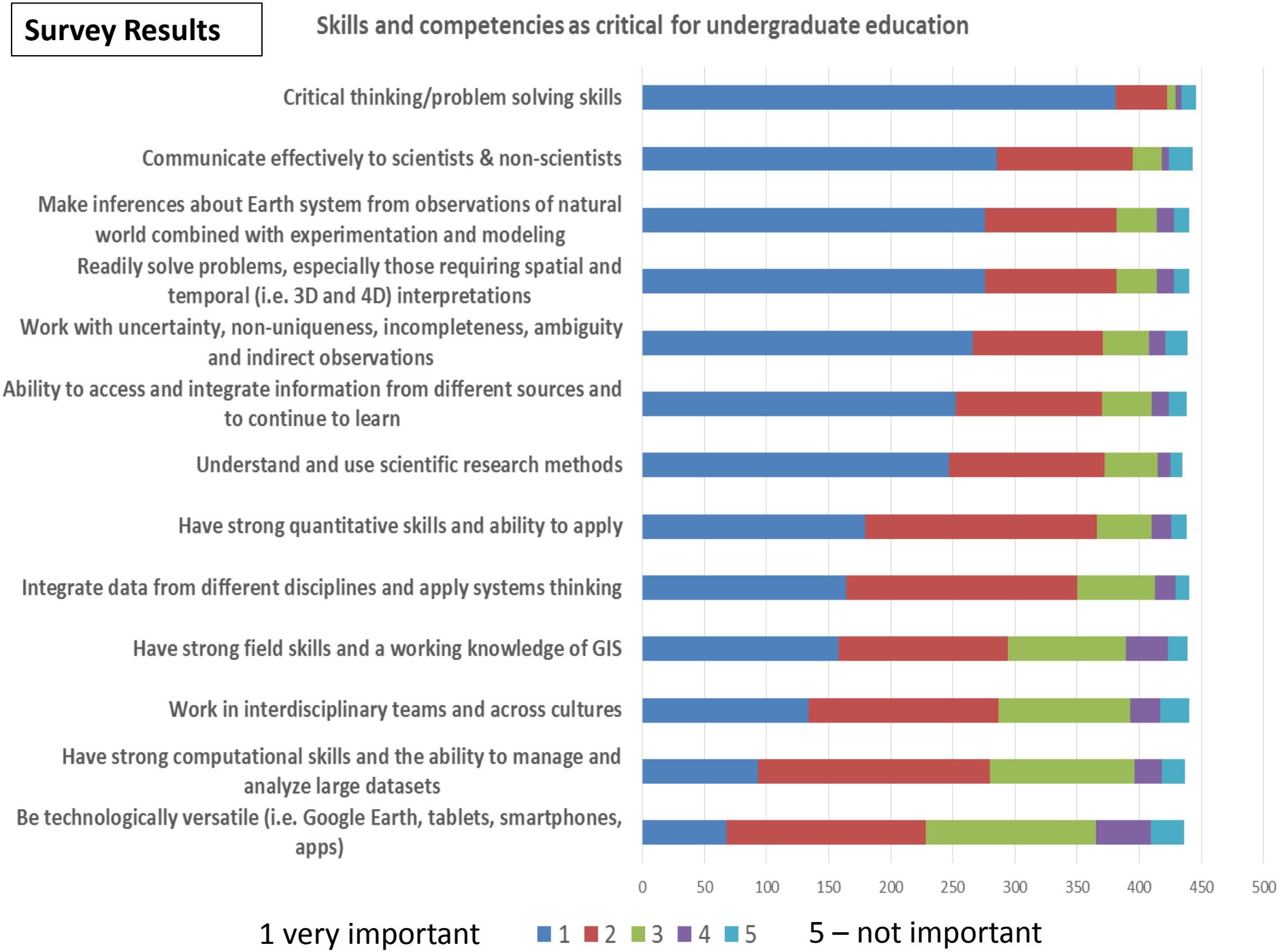
Non-technical Skills Needed

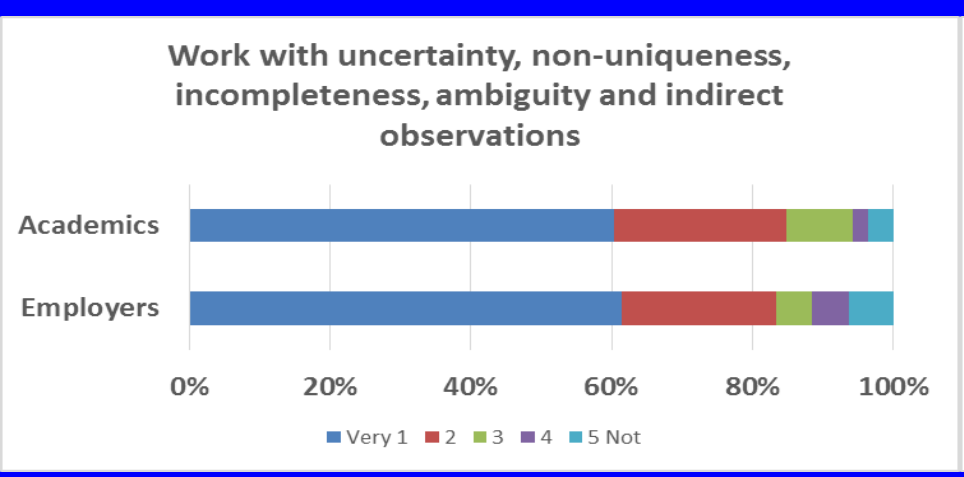
- **Project management in team settings**
  - Goal setting
  - Conflict resolution
  - Time management
  - Being leader and follower
  - Working with people in different disciplines
- **Interpersonal skills**
  - Ethical conduct
  - Awareness of implicit biases & learning styles
  - Emotional literacy
  - Leadership
  - Ability to work with different personalities

Non-technical Skills Needed

- **Communication skills**
  - Written & verbal scientific communication
  - Knowing audience
  - Public speaking
  - Listening skills
- **Professionalism**
  - Business acumen
  - Risk management
  - Career awareness/resume/interview preparation
- **Global perspective**
  - Cultural interactions, cultural literacy
- **Understanding society relevance**

Survey Results




Work with uncertainty, non-uniqueness, incompleteness, ambiguity and indirect observations
Academics
Employers
0%
20%
40%
60%
80%
100%
Very 1
2
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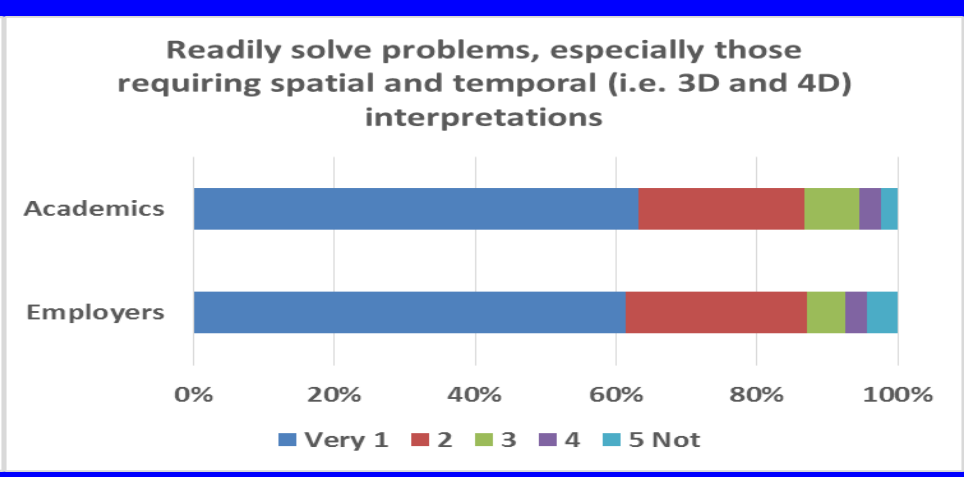
4
5 Not


Readily solve problems, especially those requiring spatial and temporal (i.e. 3D and 4D) interpretations
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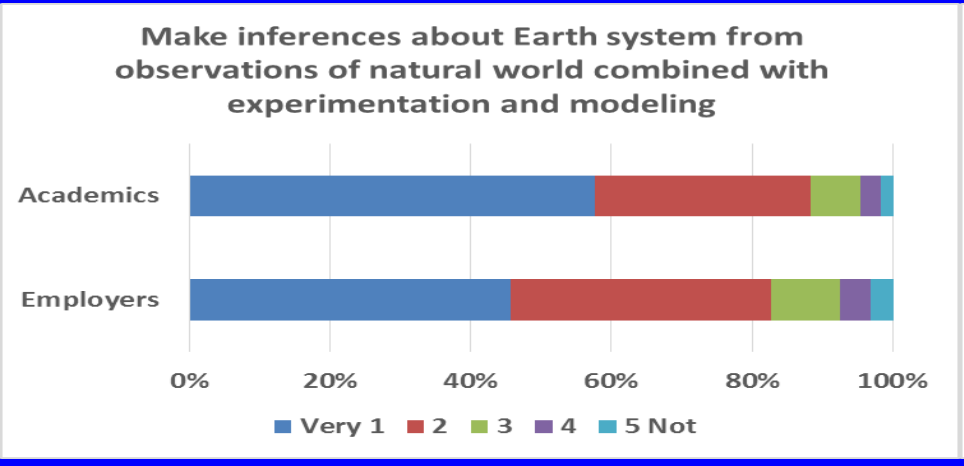
Make inferences about Earth system from observations of natural world combined with experimentation and modeling
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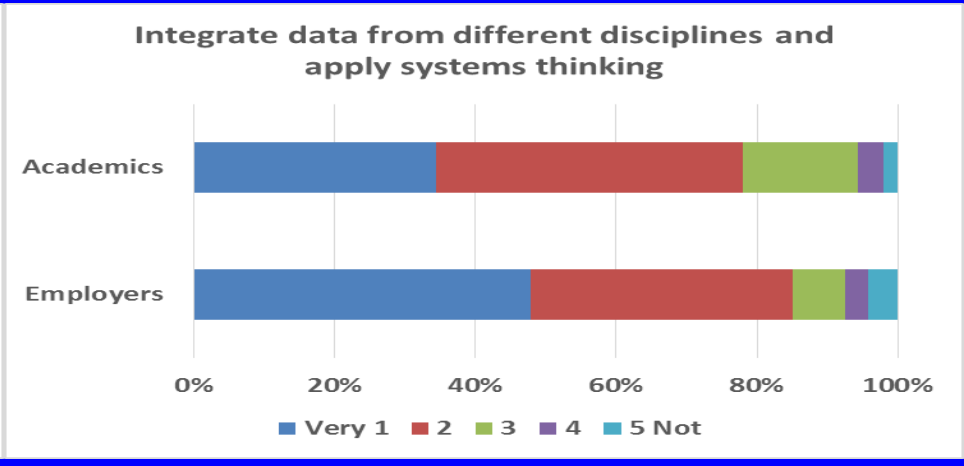
Integrate data from different disciplines and apply systems thinking
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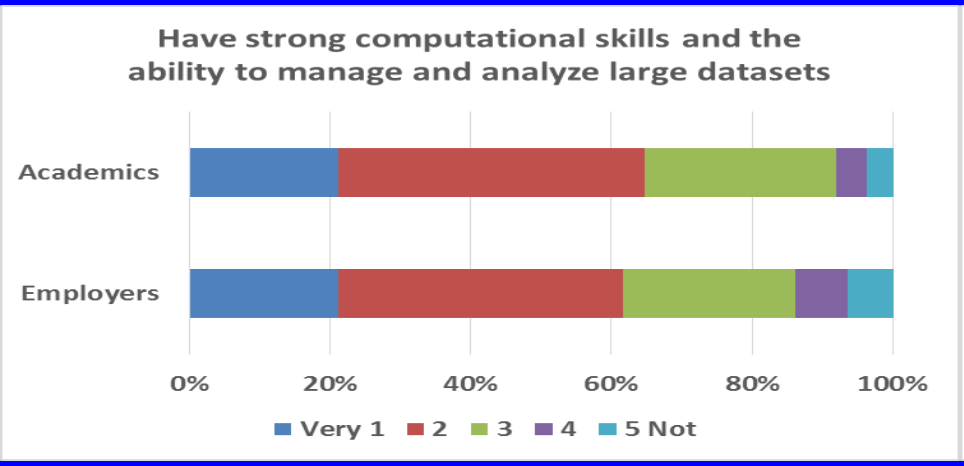
Have strong computational skills and the ability to manage and analyze large datasets
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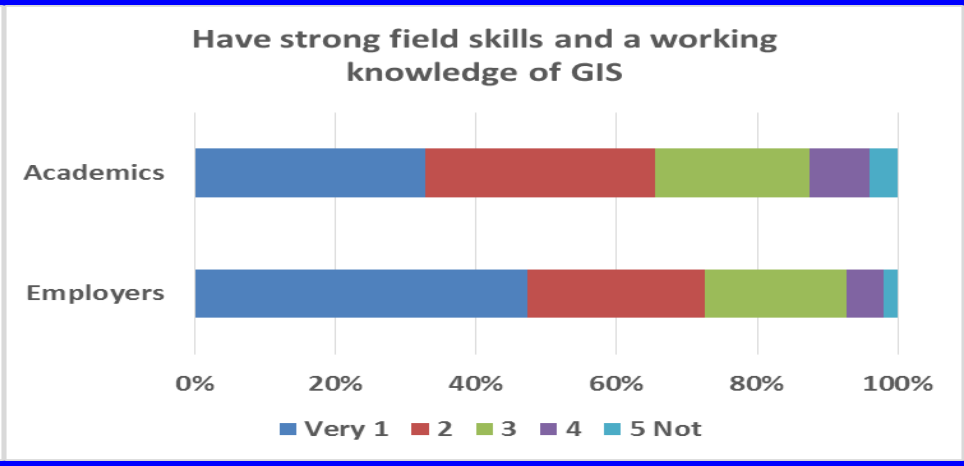
Have strong field skills and a working knowledge of GIS
Academics
Employers
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Very 1
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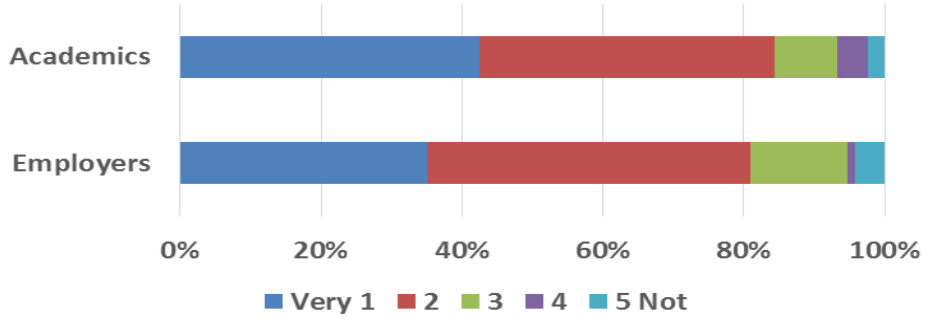
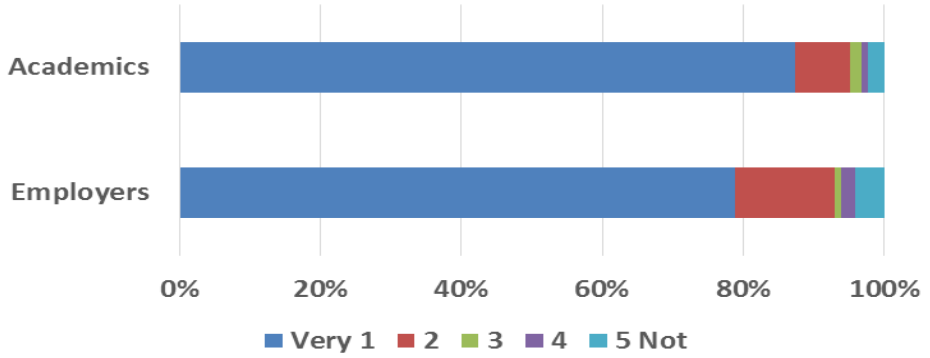
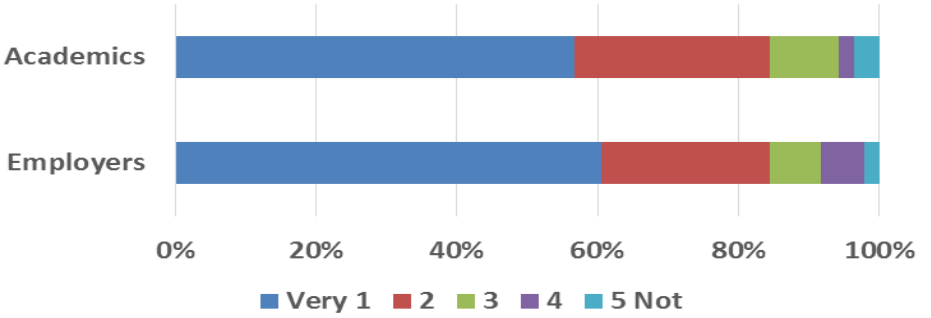
Have strong quantitative skills and ability to apply



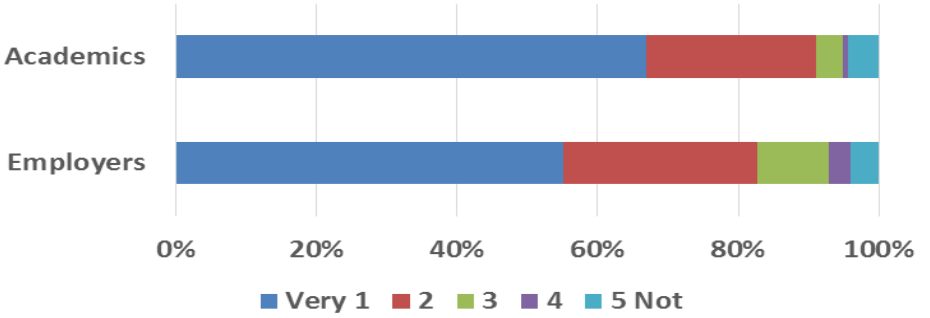
Critical thinking/problem solving skills



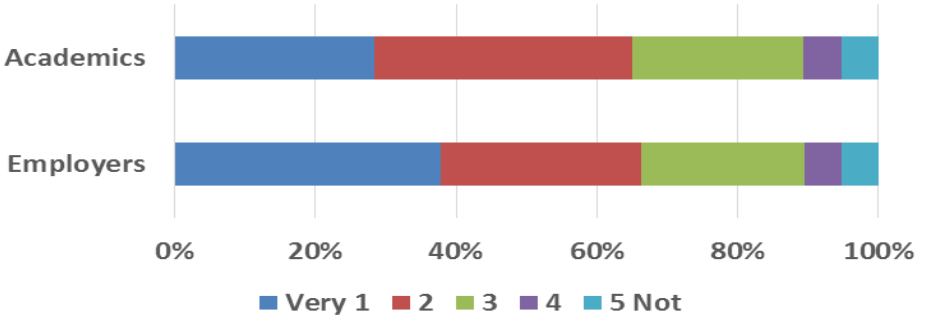
Ability to access and integrate information from different sources and to continue to learn



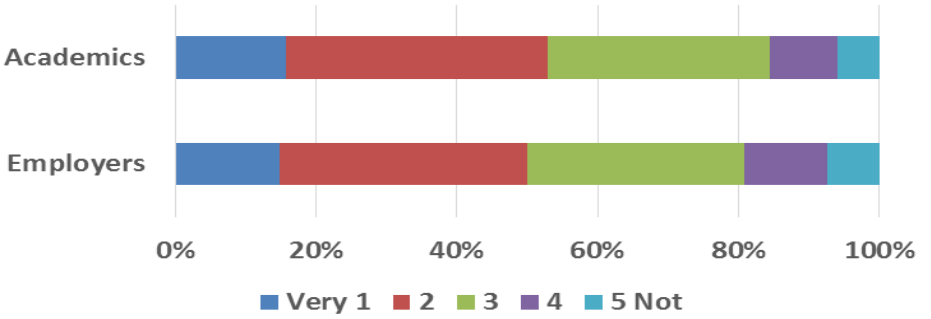
Communicate effectively to scientists & non-scientists



Work in interdisciplinary teams and across cultures



Be technologically versatile (i.e. Google Earth, tablets, smartphones, apps)



Employers Workshop

Skill List (A-awareness (had in class); P-proficiency (had to use/apply); M-mastery (project, etc. requiring demonstration of ability); E-expert (MS or PHD)	Level of Mastery
Critical thinking/problem solving skills	P
Communicate effectively to scientists & non-scientists	P
Readily solve problems, especially those requiring spatial and temporal (i.e. 3D and 4D) interpretations	M
Make inferences about Earth system from observations of natural world combined with experimentation and modeling	M
Work with uncertainty, non-uniqueness, incompleteness, ambiguity and indirect observations	M
Ability to access and integrate information from different sources and to continue to learn	M
Understand and use scientific research methods	P
Have strong quantitative skills and ability to apply	P
Integrate data from different disciplines and apply systems thinking	P
Have strong field skills and a working knowledge of GIS	M, P
Work in interdisciplinary teams and across cultures	P
Have strong computational skills and the ability to manage and analyze large datasets	P
Be technologically versatile (i.e. Google Earth, tablets, smartphones, apps)	M

Effective Ways of Developing Skills/Competencies/Concepts

- **Experiential learning**
- Constant engagement in opportunities to practice skills and use concepts
  - Collaborative, interdisciplinary, integrative team projects
  - Fieldwork and field experiences
  - Exercises using and analyzing real data
  - Research experiences/projects/theses
  - Internships
  - Integration and interactive use of technology
    - Visualization, simulation, modeling of real data
- **More active collaboration between academia and the outside employers**

Geoscience Workforce today & in the future…

- **Need for multi-disciplinary approaches to problems**
  - **More integration of different types of datasets**
  - **Cross disciplinarily teamwork**
- **Different paradigms – thinking about rocks in fundamentally different ways**
- **Different types of jobs for geoscientists**
- **Technological advances – changing skill sets**
  - **More digital & modeling skills**
  - **Black box mentality without understanding how works**
- **BIG DATA – manage, use, model; statistical analysis**
- **More interaction between business & society**
  - **Economics/law/business practices/ethics/risk/environment**
- **Cultural diversity**

As the workforce changes – student learning must change

Project Outcomes at:

http://www.jsg.utexas.edu/events/future-of-geoscience-undergraduate-education/

- Summit Summary Report
- Survey - ongoing
- Archived Summit webcasts
- AGU/AGI Heads/Chairs Webinars
- PPT slides

Contact smosher@jsg.utexas.edu

Or organizing committee:

- Tim Bralower, Pennsylvania State University
- Jacqueline Huntoon, Michigan Technological University
- Peter Lea, Bowdoin College
- David McConnell, North Carolina State University
- Kate Miller, Texas A&M University
- Sharon Mosher, University of Texas at Austin
- Jeff Ryan, University of South Florida
- Lori Summa, ExxonMobil Upstream Research
- Joshua Villalobos, El Paso Community College
- Lisa White, University of California – Berkeley