# Geoscience education in the United States

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The National Academy of Sciences recently published *Rising Above the Gathering Storm* (COSEPUP, 2006), the product of a committee established to investigate the steps the federal government could take to enhance science and technology in the United States. The special committee that produced this report was convened in response to the perceived shortfall of skilled STEM (science, techonology, engineering, and mathematics) workers in the US labour force who could maintain the US's position in the global STEM–based economy. Overall, the report specifically calls for an increase in the number of undergraduates earning 4-year degrees in STEM areas, and proposes that teacher training and professional development in STEM should be a major focus of efforts in STEM education. This report, as with many others, presupposes that STEM departments are well positioned to effectively train scientists and K-12 (elementary and secondary school) teachers. Rather, emerging research in geoscience education suggests that we know little about how people perceive the natural world, how ideas change in response to instruction, and how best to teach diverse populations of students in the geological sciences. Attempts to improve geoscience education at all levels has led to high visibility of geoscience education activities within the US geoscience community, both among traditionally occupied geologists and a new breed of scientists focusing on geoscience education research and activities.

Geoscience education activities within the US are supported at many levels. Earth science activities housed within Colleges of Education generally focus on K-12 programmes. Earth science is also the least active of the four major sciences; for example, over 78% of students enrolled in US secondary school earth science courses were taught by uncertified teachers or teachers without a major in the subject area (McMillen *et al.*, 2003). Within geology and related disciplinary departments, geoscience education activities are mainly focused on college students, and primarily at non-majors enrolled in entry-level geology courses. The concept of geoscience education within geology departments has itself evolved in recent years. 'Geoscience education' encompasses a wide range of activities, from curriculum development, to K-12 and public outreach, to research on student and expert cognition. Each of these activities is supported by funding agencies, such as the National Science Foundation, although the majority of funds go to the former two activities. Although isolated scientists in the US have been engaging in geoscience education research for decades, research in geoscience education as a subdiscipline has only recently gained a foothold in the U.S. geoscience education community.

The majority of geoscience educators in the United States are second career scientists, and generally have already established themselves as experts in a traditional domain. These geoscience educators typically focus on education activities, such as curriculum development and K-12 outreach, rather than research. Recently, some geoscience departments in four-year institutions have begun hiring tenure-track 'Geoscience Education' faculty, typically at the Assistant Professor (pre-tenure) level. This new breed of faculty are responsible for activities typical of other geology faculty, including conducting research. In their case, this research is expected to primarily be in geoscience education. The impetus for the creation of these positions is unclear, although the availability of funding opportunities in science education and the increased attention to school reform, standardized testing, and science content standards may play a role. Currently, at least nine faculty[1] have been hired into tenure-track positions where research in geoscience education is expected, and at the time of writing three additional adverts for geoscience educators had been posted by US geology departments. The role of geoscience educators within US geology departments is evolving as more faculty are hired, and as the growing community of tenure-track researchers grows and communication builds between faculty. At the time of writing, at least two Masters-only departments offer Masters of Science degrees for research in geoscience education, and at least three PhD-granting geology departments are building formal research programmes in geoscience education.

The US National Academy of Science (NAS) recently held a workshop (http://www7.nationalacademies.org/CFE/STEM_Disciplines_Agenda.html) on Education Research Positions in Disciplinary Departments. Scientists and engineers representing core STEM disciplines were invited to discuss the roles and potential of STEM education positions housed within STEM departments. In preparation for this meeting, invitees were asked to gauge the role and function of tenure-track faculty in these positions within their own discipline. In Fall 2005, eight geoscience education faculty with tenure homes in geology departments were queried about their experiences and expectations for these positions (Libarkin, 2005).[2]

Tenure-track positions in geoscience education are relatively new, with all faculty having been hired within the past seven years, and at the time of the NAS workshop all but one were still pre-tenure. The majority of the hiring institutions were teaching-oriented schools or schools working towards a stronger research emphasis; only one school would be considered a 'research-intensive' institution. The faculty (three men and five women) hired into these positions had surprisingly similar backgrounds. Seven held PhDs in geology and had conducted research in traditional areas, while one held an MSc in geology and a PhD in science education. Two other faculty were also certified to teach in K-12 classrooms, and one had several years of secondary school teaching experience. Although all of these positions required research in geoscience education, only two faculty had any experience conducting research in this area; the PhD in science education and one faculty member with a three-year postdoctoral fellowship in science education. This means that the remaining faculty were forced to learn how to conduct science education research on the job. This puts these faculty at a disadvantage to peers within their departments with relation to achieving tenure. The tenure clock, typically five to seven years, is not stopped to allow faculty time to learn about science education research, nor are teaching or service loads reduced to accommodate faculty hired to do unfamiliar research.

This inconsistency in faculty preparation and position guidelines leads to a dichotomy within the small community of tenure-track geoscience educators. Geoscience education faculty in geology departments have mixed perspectives about the role of geoscience education, reflecting the larger geological community. Some faculty felt that geoscience education is a research discipline that explored fundamental questions about cognition or assessment of learning environments and pedagogies.

In fact, two respondents specifically called for increased rigour in geoscience education research. Other faculty felt that the primary role of geoscience education is the dissemination of effective teaching strategies through new faculty workshops. These faculty held a strong sense that alternative strategies such as inquiry and collaborative learning needed to be adopted by the larger geologic community. The intellectual divide between faculty in tenure-track geoscience education positions is reflected by their discourse. For example, one respondent lamented that, "presentations at professional meetings are almost all pedagogical in nature ... and many of the publications traditional geologists see are non-research based", perhaps adding to the perception of "many traditional geologists [who] do not recognize that geoscience education (or science education in general) is a rigorous field of scholarly research" as suggested by another respondent. Another faculty member indicated, "I see geoscience education (and science education in general) as more consciously trying to use and promote teaching methods that are shown in educational research to be most effective for science learning". Reports prepared for the NAS workshop by researchers in other STEM disciplines suggest that experiences across the STEM disciplines are surprisingly similar. In general, STEM departments are becoming increasingly interested in STEM education research, although the role of science education research in STEM disciplines is still unclear.

The experiences of geoscience education faculty, as well as the diversity of backgrounds and perspectives, suggests several questions that the community of geoscience educators must ask. An international dialogue informed by the range of experiences of geoscience educators would be extremely valuable to individual faculty and departments active in geoscience education, as well as to the community at large. I see three primary questions: (1) What is 'geoscience education'?; (2) What role should geoscience educators play in colleges of science, and what roles are they capable of playing?; and (3) Can geoscience education become an accepted sub-discipline within geology?

## What is geoscience education?

As discussed earlier, geoscience educators in the U.S., both those who have moved into the discipline and those hired into geoscience education positions, predominantly engage in education and outreach activities. The community is very active, as evidenced by participation in the Geological Society of America (GSA; http://www.geosociety.org/) annual meeting. Special topical sessions at GSA have covered a wide range of

**Table 1. Topics of special sessions in geoscience education hosted at the annual Geological Society of America meeting from 2001-2005**

| | |
|---|---|
| ***Higher education*** | ***Pressing Questions and Resources*** |
| *Pre-service teacher training and professional development of in-service teachers* | What can geologists learn from teacher training programmes in other disciplines? Do teachers' ideas and beliefs impact their conceptions? What impact does teacher involvement in scientific research have on K-12 classrooms?<br>• U.S. National Academies of Science publication on the role that scientists can play in teacher training (CBTIP, 1996) |
| *Non-science majors* | How effective is instruction? What are the goals of non-major courses (Conceptual change, attitudes, logical thinking skills, etc.,)? How do non-majors become majors? |
| *Undergraduate majors* | How effective is instruction? What are the goals of majors courses? What skill sets should majors have? |
| *Graduate students and faculty development* | How effective is instruction? What are the goals of graduate courses? Is graduate training aligned with career opportunities? How can we balance research programmes with training in teaching and/or education research? |
| ***K-20 and informal education*** | ***Pressing Questions and Resources*** |
| *Conceptual change/mental models* | What ideas do students and adults bring to the classroom and life? How do ideas originate? How do classroom, informal, and other experiences influence ideas?<br>• September 2005 issue of *Journal of Geoscience Education* on conceptions [http://nagt.org/nagt/jge/abstracts/sep05.html]<br>• Geoscience Concept Inventory [http://newton.bhsu.edu/eps/gci.html] |
| *Quantitative skills* | What quantitative skills are necessary for understanding geologic phenomena? Where do students at all levels fall on skills continuum? Is quantitative instruction in geosciences effective? What unique characteristics does 'geoscience/geography' have with respect to visualization?<br>• September 2000 issue of *Journal of Geoscience Education* focuses on quantitative skills |
| *Field and research experiences* | How do we teach field observation skills?; Does engaging in geosciences research change geologic understanding?<br>• Burnely et al. (2002) discuss effect of research experiences on attitudes |
| *Temporal/spatial skills* | How are understanding of time and space related? What do students know about relative and absolute time? How can we teach deep time concepts?<br>• The January 2006 issue of *Journal of Geoscience Education* will focus on geologic time. |
| *Experts versus novices* | How do experts 'understand' the landscape? What do expert geoscience models look like? How does a novice become an expert in geosciences? |
| *Diversity* | Does conceptual understanding differ across gender, ethnicity, or background? Does a 'Glass Ceiling' still exist in academia? How do different cultures interpret Earth processes? |

*research into geological cognition should follow established theories and methodologies from cognitive sciences, psychology, and science education.*

topics (Table 1), focusing both on specific groups, such as pre-service teachers, and cognitive skills, such as conceptions and visualization. Table 1 synthesizes the major questions that are beginning to be addressed in research in these areas, and some example products stemming from work in the US. Geoscience education is not well-defined, and both practitioners and outsiders have diverse perspectives about what geoscience education is and the role it should play in geoscience.

## What role should geoscience educators play in colleges of science, and what roles are they capable of playing?

The creation of tenure-track positions in geoscience education in the U.S. is a relatively new phenomenon, although geology faculty have a long history of transitioning into geoscience education activities. The advent of geoscience education research as an area of scholarship has brought with it a variety of problems and potentials. For example, it is unclear how these geoscience educators will be evaluated for tenure, and whether or not colleagues will be able to judge quality work. One geoscience educator responding to the survey for the National Academies of Science workshop on Education Research Positions in Disciplinary Departments wrote:

> "Although I have written and spoken about the similarities between science education research methods and traditional geology research, I find that it is really difficult to convince traditional geologists that education research can be rigorous. For example, I recently gave a talk at a departmental colloquium and an old friend from graduate school was perplexed by my talk. He wanted to hear more about what he should be doing in the classroom, and was frankly bored by the qualitative and quantitative data I presented in making an argument about learning. Some of his colleagues were more interested, but the overall impression I received was that a talk about my own anecdotal experiences would be more palatable than a research talk. I can't imagine a mineralogist, for example, being asked to talk about his mineral collection instead of his traditional research!"

This experience illustrates an identity crisis that is emerging in geoscience education. Should geoscience educators work to improve instruction at all educational levels, or should geoscience educators work to answer fundamental questions about cognition and cognitive processes? These two domains are not mutually exclusive, but the geoscience education community needs to evaluate how best to use its limited personnel and resources, and needs to evaluate how best to portray itself to the larger geological community.

As illustrated by the NAS workshop, very few tenure-track faculty in geoscience education are trained in research methodologies relevant to science education and related fields. As a consequence, many faculty are forced to learn how to do research while engaging in other core teaching and service activities. This lack of training may be one reason for the dichotomous perspective about geoscience education held by the community, and would suggest that more training opportunities for geosciecne educators need to be made available. While the US community of geoscience educators is slowly building an expertise in geological cognition research, relatively little of the work published in journals such as the *Journal of Geoscience Education* follow established methodologies that would be recognizable to scholars in related fields (education, psychology, cognitive science). It is clear that we are at a critical juncture in geoscience education in the US. With the emergence of new PhD programmes in geology with specialization in geoscience education (most recently at Michigan State University, Purdue University, and Arizona State University), graduate students will have the opportunity to train for positions where facility with education research methods is a pre-requisite. The next generation of geoscience educators may look vastly different from those of in tenure-track positions today. This new paradigm for training in geoscience education bodes well for its acceptance as a sub-discipline.

## Can geoscience education become an accepted sub-discipline within geology?

> "Our experiences with faculty indicate that most are extremely interested in their teaching, most recognize when their teaching leads to learning, and most know when their students are not engaged in a course."
>
> Macdonald *et al.* (2005, p. 252)

This sentiment illustrates a perception in the U.S. that teaching experience is directly correlated with an ability to ascertain whether or not students are learning. Research in a wide range of disciplines, including geology (e.g., Libarkin and Anderson, 2005), suggests that faculty are often unaware of the relationship between learning and teaching in their own classrooms. Understanding the cognitive processes related to learning is a complex undertaking, and can be greatly informed by work in related fields. I argue that research into geological cognition should follow established theories and methodologies from cognitive sciences, psychology, and science education. Most importantly, geoscience education needs to establish itself as a 'serious' research discipline, mirroring research paradigms used in all STEM fields. First, the geoscience education community needs to agree on what constitutes scholarly activity, and which methods should be used to inform research. Research should begin with a question, whether related to fundamental questions or effects of instruction, and should carefully match research methods with that question. Ultimately, as researchers, we need to be concerned with providing an unbiased answer, rather than, for example, proving the effectiveness of a new curricular reform. As scientists, we need to pay careful attention to validity and reliability in research, and should rely upon existing criteria for qualitative and quantitative data collection, analysis, and reporting (e.g., Lincoln and Gubba, 1985; Maxwell, 2005; Patton, 1990; Trochim, 2006). Ultimately, we must agree upon the research methods and theoretical foundations that reinforce our work, and it is still unclear how the community will reach consensus and define the domain of 'geoscience education'.

In this light, I wonder if the term 'geoscience education' hinders the field's ability to change its perception within the larger community. Education means "the act or process of

imparting or acquiring particular knowledge or skills" (www.dictionary.com). Geoscience education conjures up images of teaching about the geosciences, and a geoscience educator is someone who teaches about the Earth. In this context, any geologist engaged in instruction, whether in a formal classroom or informal public setting, is a geoscience educator. Simply adding 'research' to the end of the name does not necessarily change the perception that geoscience education is not a research discipline. Capitalizing on the fact that geoscience educators are studying how people perceive and think about the Earth, whether fundamentally or in response to instruction, the community might consider a name that more accurately describes the discipline. Cognition refers to "the mental process of knowing, including aspects such as awareness, perception, reasoning, and judgment" (American Heritage Dictionary), and therefore encompasses the broad range of conceptual, affective, cultural, and epistemological questions being asked by geoscience education researchers. The terms 'geocognition' and 'geological cognition' effectively blend the domains of geoscience and cognition.

I encourage geoscience educators to consider whether or not a name change would impact how geologists perceive geoscience education research.

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### *Footnotes*

1. At this writing I am aware of tenure-track or tenured geoscience education faculty with primary appointments in science departments at: Arizona State University, Bowling Green University, Central Washington University, Georgia State University, James Madison University, Kansas State University, Michigan State University, Purdue University, and Western Michigan University.
2. To clarify, I participated in the NAS meeting and prepared the report, and also included my own experiences as a tenure-track geoscience educator.

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