Geoscience Fundamentals: Teaching the Methods and Philosophies of Science through Writing

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I am suspicious of faculty who, when they begin to converse on curricular planning, open with, “When I was a student…” but this time, it was I who was speaking, and I continued with, “I wish I had been taught how to think like a scientist.” When I graduated with my bachelor’s degree, I had a firm grounding in both didactic and procedural knowledge in the geosciences. I knew the ‘whats’ and the ‘how-tos’ of geology; I could identify rocks, map like a fiend, and reason my way through a phase diagram, but I did not really know how to think like a geoscientist, and I also didn’t know how to write like one either, even though I had written an average of four papers each term for several years. (I recently cleaned out my office and found all of my term papers.) Thus, my weaknesses in writing were not for lack of opportunity to write. Instead, they were for lack of *explicit* opportunity to think about how to think about science and then to think about how to write about my thinking.

As faculty, we are guilty of assuming that our students have developed far more sophisticated knowledge structures than they actually have. And when we misjudge their ability to connect information with concepts, they are disadvantaged. But with more explicit training in the methods, philosophies, historical underpinnings, and communication forums of the geosciences, undergraduates can develop more robust ways of thinking about and working to solve geologic problems. However, in order to develop more sophisticated scientific habits of mind, the methods of science need to be made explicit across an entire program such that students can shift from naïve and disconnected knowledge structures to more connected and apprentice-like ways of thinking about, reasoning through, and doing science.

As I look back on my educational experience, I did not realize that my philosophical naiveté was an issue until I entered graduate school, but as I did so, I found myself negotiating the widest intellectual chasm I had yet faced. Between undergraduate and graduate school, the rules about schooling change. Beginning graduate students are tossed up a few rungs on the ladder of Bloom’s taxonomy with virtually no explicit training in professional-level scientific reasoning, information literacy, authentic problem solving and the importance of writing in clarifying these important learning and research skills. Graduate students are expected to think and communicate like geoscientists, but many have yet to develop these skills. To say that my first year of graduate school was painful is an understatement. And while I do not believe that all beginning graduate students share my experience, 25 years in the faculty trenches has convinced me that many first-year graduate students experience similar and variably prolonged intellectual panic attacks. Thus, to better prepare VT undergraduate geoscience students for graduate school or their first geo-career, I chose to design and teach a geoscience course that explicitly addresses the philosophical, methodological, historical, and communication void that is present in many traditional undergraduate programs. Beginning in 2001, Virginia Tech added “Geoscience Fundamentals” as a required core course for all undergraduate geoscience majors. This essay describes the curriculum and pedagogy of Geoscience Fundamentals, how it has evolved since 2001, and where it is going post-2012.

Geoscience Fundamentals (Fundamentals) is the professional entry point to the geosciences degree wherein majors are introduced to: 1) thinking like a geoscientist by using the methods and philosophies of science in an authentic earth-related project; 2) reading, writing, speaking, and portraying geoscientific concepts using forums of communication common to the profession; and 3) developing a career vision and a professional persona through electronic media. Development toward these outcomes is essential to support the use and integration of content and procedural information offered in subsequent geosciences core coursework, many of which will require that students maintain and update progress toward their degrees by continually updating their electronic portfolios with both formal communication products and other career envisioning and planning materials. The required sub-disciplinary courses that make up the core of the program culminate in a capstone integrative research and communication experience, the Senior Seminar, which gives students an explicit opportunity to revisit and hone philosophical, methodological and communication skills introduced in Fundamentals and used in the sub-disciplinary courses.

Currently, Fundamentals is a three-credit course intended for sophomores and transfer students who have completed one year of introductory geoscience coursework (in essence, physical, historical, and a field observations course). Once students have whet their content appetite for the geosciences, Fundamentals introduces them to how geoscientists think, reason, and act. But Fundamentals did not start out this way. Beginning in 2001, it was offered as a 1-credit, first-year experience course for beginning geoscience students. But students vote with their feet and that was not the population the course actually served. Instead, Fundamentals was populated with students from first through fourth year; many of whom were transfers who had completed at least one and perhaps more geoscience courses. I soon recognized that this range in preparation made the course too challenging for first-year students who were not yet grounded in the kinds of problems that geoscientists study. This recognition necessitated adding pre-requisites in 2003, which moved the course entry point to the sophomore year. By doing so, Fundamentals served as an introduction to the ways of thinking and writing about geoscientific problems once students had some idea of what constituted a geoscientific problem.

In 2007, VTs Department of Geosciences agreed upon and adopted five learning outcomes for the Bachelor’s program in geosciences. Fundamentals supports two of the five departmental learning outcomes:

* Use conventions for communication and information-searching common to the geosciences to: 1) search for and evaluate geoscientific and related information, 2) write a geoscientific proposal and report, 3) write a geoscientific abstract and give a companion oral presentation, and 4) design a geoscientific poster.
* Propose a means for studying a typical geoscientific problem; select and apply appropriate scientific methods and tools to generate data, analyze and interpret those data, and describe findings according to the conventions appropriate to the problem.

Assessment of students’ performance on independent research project design, development, action, and communication indicates a marked improvement of approximately one letter grade over the decade in which Fundamentals has been offered. Most of this improvement is fairly recent and is attributed to a pedagogical shift in the course toward more collaborative, problem-focused, and learner-centered.

Beginning in fall, 2012, Geosciences will require that all undergraduate majors participate in the formerly optional career-planning course that was offered as a follow-up to early versions of Fundamentals. Because the career-planning course (formerly Geoscience Fundamentals II) was not part of the required core, too few students took advantage of it. That changed in spring 2012. Geoscience Fundamentals will now explicitly encourage undergraduate majors to become more cognizant of both the variety of career options available to them, and the skills and habits of mind they need to compete for geoscientific and related careers.

Following construction of a new Scale-UP style classroom in 2009, Fundamentals has used a largely collaborative problem-based learning pedagogy in class, which requires that students prepare in advance of class. Using a workshop format, the collaborative environment provides a platform for students to carry out limited team-based research projects on an authentic problem and engage with diverse geoscience professionals. We attribute recent gains in writing and speaking to this new classroom-learning environment.

From its inception, Fundamentals has been writing intensive but more recently has used an inverted classroom format in which students acquire and are quizzed on basic information prior to attending workshop meetings. During workshop, they apply this information to in-class activities. These activities emphasize using the methods, philosophies, and communication forums of the geosciences. The activities range from debating whether facts are separate from values, to researching and writing about an authentic geoscience problem, to developing a compelling electronic portfolio that demonstrates learning, mastery, and a career plan, to engaging with geoscience professionals about the knowledge, approach, and skills they use to address their daily activities and challenges. By the end of Fundamentals, students will have completed weekly formal pre-meeting responses and post-meeting reflections, a collaborative written research project including a poster and a formal oral presentation, built an electronic portfolio that will be expanded upon in subsequent coursework, and created electronic promotional career materials (e.g., resume, career envisioning statement and plan, and sample cover letter). Throughout all of these activities, students are asked to engage with and reflect on whether and how the way they think about doing science has evolved or is evolving. Indeed, our pre-/post-assessments indicate that students’ ways of thinking about the act of doing science has evolved over the years that Fundamentals has been a required part of the undergraduate curriculum. Students report that the course “makes them think”, and “challenges their assumptions about science” in ways that traditional content courses do not. While anecdotal, these statements are encouraging, especially when coupled with increasing performance scores on graded assignments over the course of the program. These data suggest that making the methods and philosophies of science increasingly explicit in our teaching and requiring that students not only write and revise, but be held accountable for writing according to the appropriate forums and protocols for scientific communication reaps significant benefits in student learning and thinking over the course of the program and beyond. As the course continues to evolve, it is my fervent hope that no student graduating from VT feels significantly disadvantaged when they embark on their first job or undertake graduate work.