Intentional Learning for Career Success

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Abstract

Many students must be trained in how to be intentional in their learning of principles of geology and this is made more difficult because geology is a multi-disciplinary science supported by allied science. Students must be able to apply basic principles, laws and procedures in multiple ways to address problem solving in myriad sub-disciplines. We identify typical challenges students face which can be as basic as not fully understanding that seemingly disparate topics are inherently connected. Such understanding is critical for initial employment as well as professional advancement. We present curriculum ideas that have been successful for us and our students which entail students actively doing geology and not just learning about it. This includes students becoming involved as peer mentors, engaging in professional conferences in a meaningful way, tapping into the knowledge of industry professionals, and conducting independent research through hands-on experiences in analytical and field methods.

Key words – Learning, Geoscience Careers, Mentoring, Peer Mentors, Analytical Methods, Environmental Geology, Field Methods

Figure 1. Analytical expertise is best developed in the lab, examining issues of contamination, proper sample preparation, calibration, precision and accuracy, and data interpretation. Senior majors serve as peer mentors, not only explaining instrumentation and Standard Operating Procedures, but giving context from their own research (and mistakes!). Here a student demonstrates a Standard Operating Procedure for the Raman Microscope.

Introduction

Mentoring of undergraduate students by both faculty and peers is being emphasized at many universities and colleges, partly because of the importance of context in enabling real learning to occur. Retention of material diminishes over the duration of typical lecture periods such that very little is retained by the end of a period. Much of this loss appears to be because students are not driven to learn the material out of a sense of its importance, but rather by grades. Faculty who can articulate the practical importance of the material may do so through case studies, journal articles and anecdotal experiences. Hands-on activities in instrumental analysis of earth materials coupled with determining detection limits, calibrations, evaluating the validity of data sets, and careful sample preparation model professional responsibilities and can be offered in courses in analytical techniques. Early immersion in geological mapping and field research, instead of static learning on "field trips", demonstrate the natural variability and ambiguity inherent in field-based science, in addition to providing context for diagrams, graphs, and images used in lectures. The practice of mapping requires close inspection coupled with integration into a larger scale map. In these ways, students may learn the context for the material and become more intentional in their approach, knowing that they are building skills for their career. Realizing that they will be working twice as long as they have been alive (at 20-25 years old) can provide profound context for the importance of learning.

Peer Mentoring

Courses in Analytical Techniques and Field Methods, research experiences for undergraduates (REUs), and elective courses all build an environment of exploration/research in which students learn the expectations of academic excellence from those that went before. Upper class students are used as peer mentors in many of the classes, not only serving as *ad hoc* Teaching Assistants, but also offering anecdotal and practical experience from their own experience.(Figure 1) Students are encouraged to seek opportunities to peer mentor; after all, to teach is to learn. Furthermore, the capacity to listen, but also contribute in a team setting is a critical skill for industry, that needs to be developed amongst your peers, instead of the normal hierarchy of academic settings. Start now to expand your academic experience and develop trustworthy contacts through intense study groups, "language circles" to apply foreign languages during lunch or breaks, and deliberately seek creative solutions to class assignments.

Course Connections

Students commonly ask how best to study myriad geologic topics and how to master the essentials of geology. Our experience is that to truly learn anything you have to see, read or hear about a given topic but to obtain "content ownership" a student really has to do some geology. Students are advised to seek out courses offered by faculty who themselves have professionally practiced geology beyond the academy. Look for professors offering courses that include as many exercises, labs or field trips as possible because this is a packaged deal for students who are intentional about learning as much geology as possible by doing it. Another piece of advice is to learn how to study. We suggest starting out with a blank sheet and writing down bulleted items you have mastered from each of your classes – this will take some thinking. Then the big challenge comes next – try to see linkages between each of your bulleted sheets.

Exhortation to Students to Intentionally Seek Connections of Material

We earnestly advise and encourage students to challenge themselves to take their core and elective courses in geology and review important principles, laws, theories, or Standard Operating Procedures (SOPs) to see how certain items reappear in various sub-disciplines of geology. Take for example that students commonly learn about Stokes' Law, Bragg's Law, and Snell's Law but it should be recognized that the introduction of these laws in a given sub-discipline does not inherently mean that there is only one application of the law or procedure. Stoke's Law can be used in classic hydrometer analysis for determining fine-grained sizes in soil or sediment samples and it can also be applied to phenocrysts moving in cooling magma chambers. The principle is the same but the modifications make it applicable in different scenarios! Bragg's Law, which states that an incident X-ray has a corresponding and predictable diffracted X-ray in a crystal, is akin to a similar phenomenon recognized in Snell's law which helps us understand seismic wave travel pathways that are refracted along variable stratigraphic interfaces. In short, each student should think of the possible multiple applications of a given law or principle.

Make Connections to Math, Physics, Chemistry, Biology, GIS and Writing Courses

Students need to be aware of the importance of not 'putting off' allied science classes because they are foundational for geology, permitting a better understanding of topics such as the chemical interaction between water and rocks, how seismic energy is propagated, how we use seismic surveys to find hydrocarbons, how we use geophysics to delineate hazardous waste sites, and how we use GIS to manage data such as stratigraphic tops, mineral trends, and the progress of aquifer and soil remediation.

Calculus, physics, and chemistry can be learned in a "just-in-time" fashion for a course (e.g., chemistry as a co-requisite for mineralogy), but provide foundational material for geology coursework, and should be taken sooner rather than later. Students are also encouraged to look at journal articles noting that papers are commonly the communication vehicle for practicing geologists. This also takes effort on the part of the student but limiting yourself to mere textbook learning does not provide an avenue of understanding communication between scientists and how to write a journal article or necessarily how to do science. Use of journal articles in classes not only augments a given text required for a lecture class, but journal reading permits a student to get familiar with technical jargon, see how to focus a research topic, define the scope of work, and state project significance. This exercise also forces students to see that it is not possible to study all aspects of a given topic as published papers are limited by the stated hypothesis or problem statement.

Learning by Doing

Faculty are generally quite conscientious about preparing material for lectures to prepare students for success. As a professor it is always interesting to deliver important material, material you know the students will absolutely need, and watch as they sit passively waiting to be told it will be on an exam. Realize that your professors are intentional about what they are trying to teach. They know the connections between the different courses in the major. They use these connections in their research and projects all the time. Make one of your intentions as a student to seek connections inherent in a multi-disciplinary science such as geology and to do the science first hand.

Select Courses in Which to Do Geology

The Geology Program at WKU has modified its program to provide select courses characterized by immersive experiences:

Analytical Techniques

Science, and most importantly earth science, is usually treated descriptively in secondary education. There are big concepts (geologic time, plate tectonics, volcanoes and earthquakes, stratigraphy, etc.) that are difficult to explain by numbers. However, university and industry science is more quantitative. To that end, WKU initiated a course in Analytical Techniques offered after the introductory geology course, but prior to most of the core geology courses. This course is an intensive introduction to basic analytical/research techniques, which are then used to model research in later courses. Students make thin sections and are trained in polarized light microscopy (PLM), magnetic and heavy liquid separations, x-ray diffraction (XRD), x-ray fluorescence (XRF), Raman microscopy, scanning electron microscopy (SEM), and other techniques. The students in turn can use these techniques during mineralogy to independently identify unknown minerals. They may generate their own geochemical data sets during igneous petrology, sieve and analyze sediments they collected during sedimentology-stratigraphy, identify ore minerals in economic geology, and do field work for their own research, starting their sophomore year!

Exploration of these techniques is done either independently and as teams, supervised by faculty and peer mentors. Students compose a generalized research flow chart over the course of the semester, and then write a research proposal based on their flow chart, employing techniques learned during the course. These can be submitted for internal funding, or external funding from scientific societies. Each must keep a daily lab notebook, including ALL notes, ideas and speculations, procedures, results, and even mistakes as they learn about chain of custody, and the reality that their notes may be subpoenaed as legal documents! Clear, concise, and illustrated Standard Operating Procedures (SOPs) are created for each technique. Students use the SOPs throughout their academic career – and commonly email after graduation that they find these SOPs indispensable in their jobs. In short, we advise that students get immersed early in active, hands-on learning projects. There is no need to wait for graduate school. If your institution doesn't offer such a course, you may still prepare your own SOPs and explore the possibility of getting training in instrumentation available to you.

Field Methods

Based on our faculty experience from their *alma maters* and investigation of curricula in Kentucky and the region it is not that common in undergraduate education for students to have had numerous hours of field study prior to field camp with the latter generally being the capstone experience for students. Field camp is the last item on their list to graduate or as they transition to graduate school. At WKU, students are immersed in field situations relatively early in their academic careers. Most of these hours spent in the field (3 hours per week for at least 11 weeks in the semester plus a long day or full week field trip) provide students with extended periods of structured learning. Toward the end of the semester, students conduct independent research within small groups of two or three, and this is when more formal peer teaching and interaction occurs. Students then present their research before the class and they are evaluated by not only faculty but by their peers as well. (Figure 2) Students make advances in developing organizational and presentation skills by the end of Field Methods class.

Figure 2. Field-based learning brings context to material presented in lecture and classroom activities. During focused field activities, each student is the on-site "expert" presenting material in class before the trip, in addition to leading that segment of the field activity. This compels students to see and explain natural variability, but also builds leadership and presentation skills.

Environmental Geology

Small to large environmental consulting companies provide ample employment opportunities for students at the BS level who choose not to immediately go to graduate school or seek employment elsewhere. When students ask what kind of work they will do it is an easy response – you will be conducting sample collection, mapping contaminant plumes and subsurface geology, and summarizing your results in report form for a client and/or a regulatory agency such as the U.S. Environmental Protection Agency (EPA). In environmental geology, students actually create site characterization reports simulating a real job situation. If your university does not offer such opportunities then we would suggest you contact the Underground Storage Tank (UST) branch of your state environmental regulatory agency, get some of these reports, and create your own self-instruction from them. This provides a wonderful opportunity to 'do geology.' Students who have taken this course have reported that once they got to an environmental job they actually knew what to do! Employers have responded quite positively, calling or e-mailing about students who have had such case study experience as well as the 40-hr HAZWOPER training (also advised for students to have).

Strength in Elective Courses

Professors who offer these courses provide vehicles for students to see real world application of various topics. For example, we have faculty who have worked for major oil companies who are versed in sequence stratigraphy. Students can also learn that the basic construct of sequence stratigraphic principles is also applicable to environmental site characterization and hydrogeology employment ranging from small UST sites to the largest of CERCLA (Superfund) sites. Other faculty possess experience in the mining industry, worked as consultants and contractors for the EPA and State Surveys, have done litigation/arbitration support, or have worked at high-tech national laboratories. Students should seek out these faculty members and ask questions in and outside of the classroom.

Focused Undergraduate Research

In addition to intentional opportunities for research and practical training embedded in courses, WKU Geology has developed a number of ways whereby students can get focused, practical training by actively applying field and analytical techniques to research topics. A good example of this is students engaging in topics associated with the extractive minerals industry including examples of metallic ore mining and oil and gas (most via Geology 399 – independent research for undergraduates). Students dealing with economic geology topics obtain a suite of samples from a mine, and model typical tasks of a mine geologist in characterizing the ore. Many of these samples were donated by alumni in the mining/minerals industry. Students analyze samples using powder XRD and Raman microscopy to establish the equilibrium mineral assemblage (paragenesis) for the ore. When possible, cuttings or core are characterized as a proxy for logging done on site. Models of ore genesis are discussed and students prepare and deliver presentations on their research at conferences. In this way, students are executing research while learning firsthand about styles of mineralization and how to investigate mineral assemblages. Two students recently obtained grants from WKU to go further in their investigations of gold mineralization in Nevada and South Dakota. The program has recently developed a computing facility with site licenses for various industry software used in the mining and petroleum industry, including Vulcan® and Petra®. Experience in modeling ore deposits and mines, and oil and gas reservoirs, using industry software provides training that is less common in academic environments. Students will graduate with classroom knowledge, but more importantly, with practical experience in the methods required to work as a mining or petroleum geologist.

In another example, several undergraduates approached faculty asking "how will we look better than all those other Geology majors?" Get practical expertise in industry practices was one of the answers. These students found a local driller who agreed to provide training, and they worked during the summer to get familiar with an air rotary drill rig, best practices, and procedures. After meeting with faculty, they developed an SOP for the rig, which is now available for all future undergraduates, and for faculty to use in the classroom. They then drafted a research proposal using their new knowledge of the rig to drill at least two holes through five stratigraphic units at one of the university field sites. They will obtain gamma ray logs by combining down-hole measurements with outcrop measurements several hundred meters away as a comparison. As part of the learning process, they developed grant submissions for internal WKU grants, AAPG, and even solicited support from industry-based WKU alumni to cover costs associated with drilling the holes. These students volunteered to make a presentation of their project to representatives of an energy company who were recruiting for internships in the department. The students saw this as an opportunity to stand out from the crowd. The recruiters saw undergraduates who were very intentionally preparing for successful careers in oil and gas exploration by making opportunities for training. All these activities made these students much better prepared for careers in industry, and demonstrated their commitment to excellence. It's no surprise that students were asked to provide CVs to the company.

Importance of Professional Meetings

Scientific conferences are where research is disseminated, contacts are made, and synergies are developed leading to the creation of new ideas. It is important to not just attend but to actively participate in conferences in order to gain context for how professionals deal with each other and present their research. At WKU, we have developed courses specific to annual meetings in order to train undergraduates. Students identify specific oral technical sessions that they will attend. They are required to read all abstracts for the two chosen oral sessions, and develop and submit to faculty a number of questions that they might ask presenters at the sessions. While at the conference, students must participate in their chosen sessions and document their participation in at least one more meeting-related activity. These could include a faculty led field trip, other sessions, a sponsored mentoring session, or interviews at graduate program tables. They are required to send follow-up emails to each graduate program, and to each presenter with whom they speak. After they return from the conference, students must submit a summary of their active participation. The department and college have provided support funds as incentives for active participation in the conferences. This intentional approach to participating in conferences is considered appropriate training for a successful career. Practices such as the timely (and articulate) response to emails, the careful nurturing of professional contacts and the intentional approach to participation in a conference are all training for successful professionals.

Scientific advances depend upon dissemination of research results to the scientific community for peer review and discussion. Active participation includes consideration of the broad range of research presented, the validity of data sets, analytical techniques, and being witness to the discourse common among peers. When membership in professional societies is considered a strong "resume-builder," it is because of the assumption that the student is now more familiar with professional vernacular, activities, behavior, and priorities. These come from the active participation in a professional society, and not just membership. In the same fashion, a student's GPA is a fairly accurate index of their commitment to academic success, even though many students don't think that they accurately reflect a student's "smarts."

Summary

Intentionally taking charge of your education and training as an undergraduate student prepares you for a successful career that will last the rest of your life. But it is difficult to know What to do, How to do it, and even Why is this important? Geology departments have developed curricula that offer solid training in core material, and many go well beyond to offer opportunities for research and training in more specific aspects of career preparation. To take full advantage, students need to not just attend, but intentionally seek connections between courses, between coursework and research, and between research and professional behavior. Learning by doing should include how to maximize participation at professional meetings and writing thoughtful and timely communications, in addition to developing expertise in analytical and field methods. Understand the differences between the academic and commercial worlds, and develop a sense of how you can contribute to a corporate vision. Take some control over your preparation, and you'll be prepared when the opportunities come!

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