# Annual Assessment Report

Academic Year: 2013/2014

Department: Earth Sciences

Program(s):All programs

Overview:

The Department of Earth Sciences has undertaken a major curriculum revision (2012/13) which identified central programmatic themes (Earth History, Earth Composition and Architecture, Earth's Surficial Processes, and Human Dimensions of Living on Earth). All course sequences are now aligned to address these themes, and use a cognitive framework based on Bloom's taxonomy to help students develop higher level thinking skills as they progress through our degree programs. This is the "road map" to help students track the required sequence of courses that students must take to successfully complete our degree options. Assessment work continued (2013) through the development of a Student Learning Outcomes and Assessment Plan Matrix (submitted as the 2013 Earth Sciences Assessment Report). This plan identified key program level learning outcomes that include: Mastery of discipline specific concepts and content; Mastery of discipline-specific skills; Discipline-specific "Habits of Mind" (and also Nature of Science); and pre-professional ("soft") skills such as communication, quantitative skills, interpersonal skills and information skills. Individual courses define their own specific learning outcomes (submitted to the Provost's Office December 2013) and these have been aligned with the program-level goals as represented in the SLO matrix. The process used in developing our revised curriculum and the follow-on student learning outcomes and assessment matrix have been presented as a national model at the Geoscience Undergraduate Education "Summit" (University of Texas, Austin, January 2014), and in two blogs posted on the Earth and Mind site: A Curriculum By Design http://serc.carleton.edu/earthandmind/posts/curriculum_desi.html and A Curriculum by Design Part II: Student Learning Outcomes and Program Assessment http://serc.carleton.edu/earthandmind/posts/curriculum_desi2.html . This process will also be presented in a workshop sponsored by the National Association of Geoscience Teachers at the 2014 GSA meeting, and further used by the NAGT "Building Strong Departments Traveling Workshop Series".

This report (2014) follows this foundational work. The Department of Earth Sciences Assessment Plan calls on four courses to be reviewed each year to reflect on 1) Student learning outcomes defined for each course, 2) Example instructional activities that address these SLO's, 3) Metrics or evidence that students are achieving these goals, and 4) Lessons learned (formative assessments to help revise these courses as needed). The responses to these questions are presented by the primary course instructors to the faculty as a whole. This has generated very positive feedback with suggestions about alternative approaches, has provided the opportunity to better articulate learning goals and outcomes between courses In a given degree program or course sequence, and has generally raised awareness among the faculty about the diverse topics and instructional strategies and methods used in our many course offerings. This year the following courses were reviewed: GEO 211 Earth History and Evolution; GEO 302 Mineralogy and Optical Mineralogy, ERTH 303 Weather and Climate; and GPHY 425 Geographic Thought. These courses were selected to represent the breadth of instructional activities in diverse subject areas and at different instructional levels.

There are a couple of general observations that can be made:

- The Department of Earth Sciences is committed to using active learning strategies in instruction in lecture, lab and field settings. Examples of the diverse and creative instructional approaches used by our faculty are demonstrated below. Related to this, the faculty use a variety of assessment strategies to demonstrate student mastery of concepts and skills.
- In addition to content/concept mastery and technical skills development, courses in the Earth Sciences (particularly upper division courses for majors) increasingly a) use an Earth System approach (requiring analytical and synthetic thinking), b) develop students' "scientific habits of mind" (including traditions of thought in the discipline) and c) help students develop pre-professional skills (communication, group work, critical reading of the literature).
- Burgeoning enrollments are having a major impact on the quality of our instructional mission. It is becoming increasingly difficult to engage one-on-one instruction, small group work, critical reading of the literature, and using interactive instructional methods in classes that must now be housed in large lecture halls. Too few TA s are available to support these large section classes, so the number of assignments and degree to which writing or problem-solving activities are being used are significantly reduced.
- Too many under-qualified students are entering our upper division courses. This is particularly evident regarding students who do not have the quantitative skills needed to do the most rudimentary exercises in junior level courses. Many of our courses are required for very diverse student groups beyond Earth Sciences majors (primarily pre-service teachers in Science Education, Ecology, and Land Resources); this results in a very uneven level of preparation by students who enroll in many of our courses. Consequently, we are now enforcing all pre-requisites of our courses, advising students to follow the prescribed course sequences, and will be imposing pre-calculus as a pre-requisite for all 300 level classes in the future. (Note, we advise students to take Math courses from the first day in residence at MSU, but many students put off their Math requirements until the end of the program even though we require a year of calculus for the Geology, Paleontology and Snow Science degree options).

The following sections detail the Student Learning Outcome assessments for the 4 designated courses for 2014:

## 1. Geology 211: History and Evolution of Earth (Todd Feeley)

This class typically has enrollments of 50-60 students. It is required for Earth Science majors in the Geology and Paleontology degree options, and is also attended by Science Education majors (~10-15) and some Ecology majors. The diversity of backgrounds of students entering this class has been identified as a major challenge. This is one of the “foundations” courses in the Earth Sciences curriculum, and plays an important role in introducing students to the nature of geoscience, and the methods of addressing geologic questions (especially the importance of understanding “deep time” and concepts of relative and absolute age dating). Another challenge in teaching this class is found in demonstrating the concept of evolution—of life on Earth, and co-evolution of the Earth system. This course is of particular importance as it provides training in the fundamental concepts of geologic time for future teachers, who must be well-prepared to go into their own classrooms to teach this topic with competence and confidence.

A) Student learning outcomes:

a. Students will understand the methods that Earth scientists use to reconstruct the physical and biological evolution of Earth
b. Understand the development of modern scientific thinking of Earth processes, including the development of the modern geological timescale and the theory of plate tectonics, and
c. Reconstruct the geologic and biologic history of Earth, particularly from the perspective of North America.

B) Example instructional activities that address these SLO’s

a. Homework assignments that require substantial group interaction. Students work in small groups to write a weekly essay on an assigned topic. On Wednesdays they “rough out” the major lines of evidence to be addressed, and on Fridays work towards a more comprehensive and complete essay. All students hand in their individual essays on Monday, and one of the essays is selected to be graded using a scoring rubric. All students in the group are awarded the grade of this chosen essay which means that it is in all students’ best interest to make sure that all the essays submitted by the group are of high quality.

b. Graded examinations and homework assignments; 2 midterm examinations and a final exam which is half multiple choice, and half short essay/short answer to demonstrate fundamental concepts.

C) Metrics or evidence that students are achieving these goals

a. Student performance in this class has traditionally been very strong, with median scores of 78/100 (recorded over many years) and a Gaussian distribution of grades. Overall class performance has increased now that course pre-requisites are being enforced

D) Lessons Learned

a. Overall, the weekly group writing assignments have proven to be very useful in achieving course goals, as all students are invested in helping other students in their groups achieve mastery of the basic concepts. The ability to work in groups is important pre-professional training (even though some students protest that they prefer to work independently).

b. The writing assignments provide an important focus for mastery of these concepts.

c. Writing is an important professional skill, and writing requirements early in our curriculum sets an important standard of expectations for the students, and provides good preparation for students moving through our course work and into life.

## 2. Geology 302: Mineralogy and Optical Mineralogy (David Mogk)

Mineralogy and Optical Mineralogy were central to our recent curriculum revision. It is a required course for students in the Geology and Paleontology degree options. Hand sample identification of minerals, and interpretation of their occurrences in Nature, geologic processes and environments of formation have been moved into a new course, Earth Materials (GEO 208). This has provided more time to explore in depth theoretical aspects of the discipline (crystallography and crystal chemistry), to introduce analytical methods (use of the petrographic microscope, X-ray powder diffraction, and SEM/EDS), and to demonstrate ways in which mineral analysis can be used to interpret geologic processes, history, and environments. The course format approaches a "studio" course, where there is little distinction between "lecture" and "laboratory" sessions to the extent possible. Lectures are minimized, small group work and exploration of laboratory materials is optimized.

A) Student Learning Outcomes

a. Content and concept mastery (Principles of crystallography, crystal chemistry, analytical methods)

b. Skill Development (Use of the petrographic microscope; introduction to X-ray powder diffraction and electron beam methods (SEM/EDS)

c. Hand sample identification reinforced (a second exposure, following introduction in GEO 208)
d. Applications of analytical methods to solve geologic questions; engaging authentic research as a individual problem in the context of this class;
e. Development of Professional Skills (Report writing, critical evaluation of the literature; application of quantitative skills).

B) Example instructional activities that address these SLO's

a. Guided Discovery: Individual and small group explorations are used in a constructivist manner to allow students to self-discover the principles of crystallography and crystal chemistry. This often includes the use of models (crystal structures), computer software (animated visualizations of symmetry elements), physical samples, and use of analogous resources (e.g. Escher art prints to demonstrate symmetry relations).
b. Technical skill development—the most important skill developed in this course is in the use of the petrographic microscope to identify minerals in thin sections. Basic principles and methods are systematically presented, a flow-path of tests and interpretations has been developed as a guide for students, students are encouraged to interpret their results in terms of geologic systems (i.e. what minerals are most likely to occur together, or are never associated in Nature); ultimately, optical mineralogy is a premier example of using the scientific method to form hypotheses about possible identification and applying appropriate tests to confirm or reject possible minerals.
c. Research project: Students work with faculty or graduate student mentors to apply their knowledge of mineralogy to solve an authentic research question. Students define the problem with their mentors, design a series of analytical experiments to characterize the mineralogy of their samples (e.g. thin section identification, use of XRD to identify minerals and especially clay minerals, use of SEM/EDS to characterize grain size and texture, elemental composition of minerals), prepare appropriate representations of their data, and write an interpretive report for their mentors. Students are engaged with all stages of this research project including formulation of the question, sample selection and preparation, selection of appropriate methods to address the question, data acquisition, data reduction and representation, and interpretation and report writing.

C) Metrics or evidence that students are achieving these goals

a. Mastery of Content/Concepts is demonstrated through a series of practicum problem sets that demonstrate students' ability to transfer basic concepts to new (but similar) applications;

b. The applications in this course are carefully scaffolded as more complex exercises later in the course require mastery of concepts introduced at an earlier stage (e.g. a knowledge of the basic crystal systems must be obtained before minerals in thin section can be appropriately identified);
c. A lab practical exam requires students to successfully identify the major rock-forming minerals in thin sections of three distinct rock types. Students who do poorly on this practical lab exam have the opportunity to revisit the thin sections (with some guidance) to re-do the exam to demonstrate proficiency. Students must be able to identify minerals in thin section to succeed in following courses in Igneous, Sedimentary and Metamorphic Petrology.
d. Quality of written report: Students must present the results of their research in a final written report that includes: Statement of the problem (including geologic context), methods, sample selection and preparation, results (petrographic, XRD, SEM images, EDS spectra), interpretations, and references.

D) Lessons Learned

a. Becoming a geologist takes a long apprenticeship; Students must stay engaged and take responsibility for their learning. This class is designed to give students the latitude to expand their geologic knowledge using the "guided discovery" approach.
b. Collaborative and cooperative learning helps all students excel.
c. Scaffolding of assignments is necessary; in the early stages of the course a lot of guidance is required; eventually support structures can be removed
d. Expectations need to be clearly defined and demonstrated—this is particularly true for the month-long research project at the end of the semester. This is often the first exposure that students will have to doing authentic research, and they need to be carefully guided towards appropriate methods, timelines, budgets (their time, material and instrument costs), etc. They also need to be reassured that a null answer is still a perfectly acceptable result (it's not a failure), and that we work in an open, ambiguous and complex earth system that often has much of the evidence missing—so being accurate in expressing uncertainties is important. Welcome to becoming a scientist!

## 3. Earth Sciences 303: Climate and Weather (Jordy Hendrikx)

Weather and Climate is a required course for ALL Earth Sciences majors, and is also taken by Science Education, Ecology and LRES majors; this resulted in a significant expansion of enrollments over the past couple of years from 60 students to 96 this semester. As society confronts the challenges of climate change, it is our conviction that all of our majors should be able to speak cogently about the causes, processes and implications.  A challenge of this class is working with students who enter with a mindset that "I don't believe in climate change"; this provides an excellent opportunity to explore the nature of science and the importance of evidence. The format of the course has also undergone significant revision as the all-lecture format has been replaced by weekly practical problem-solving sessions done individually or in small groups in class on Fridays.

A) Student Learning Outcomes: Students will be able to
   a. Analyze, describe, and plot the major atmospheric processes controlling weather and climate, including radiation budgets, pressure gradients, frontal movement, and air masses.
   b. Make use of on-line weather and climate resources to assist in planning daily activities.
   c. Describe the methods used to reconstruct past climates and predict future climates.
   d. Develop and express an informed opinion on the causes, likelihood, and consequences of human-caused global climate change.

B) Example instructional activities that address these SLO's
   a. Weather Journal exercise—daily/weekly monitoring of weather, demonstration of principles learned in class; application to personal lives.
   b. Weekly lab exercises—demonstrating key atmospheric processes/systems, application of quantitative skills, addressing topics such as climate variability and change, paleoclimate (proxies for demonstrating climate change over time). Students who systematically achieve low scores on these weekly problem-solving assignments are identified for additional interventions as needed by the instructor and TA s.
   c. Self tests on D2L—these are done as formative assessments so that students can determine for themselves how they are doing in the class;
   d. Mid term and final exams which are partly multiple choice, and partly designed to have students demonstrate mastery of concepts via short answer, interpretations of figures.
   e.

C) Metrics or evidence that students are achieving these goals
   a. Weekly lab scores and assistance for students with low scores;
   b. Weather journals; graded for completeness, scored against a rubric;
   c. Test scores
   d. In class questions / answers designed to provide formative assessment of the degree to which (most) students have achieved mastery.

D) Lessons Learned
   a. Adding the in-class problem-solving exercises has increased the workload by about ~ 200%
   b. Increasing class size from 40 to 80 to 100 presents challenges additional challenges. We have been able to assign a TA to help with grading and supervising the problem-solving sessions for the class when we had ~60 students; this term we added 1/3 of a TA assignment to help with the overload of students that now approaches 100. We are considering changing the class delivery to include a formal lab section, but this presents additional challenges in scheduling our teaching labs. We will need to have additional TA support for this class if we continue to have enrollments approaching 100, and if we are to continue using the current problem-solving approach (which we believe is pedagogically superior to having another hour of straight lecture).
   c. Even though this is a junior level science course, many students are grossly underprepared in their math skills. In the future we will add a course pre-requisite for students to have completed at least the pre-Calculus proficiency in Math. This will help maintain the quality of instruction that requires application of simple formulae, graphs, and mathematical models

### 4. Geography 425: Geographic Thought (William Wyckoff)

Geographic Thought is the "capstone" course for our geography majors. It provides a reflective overview of the principles and methods used in geographic practice (that have been introduced throughout the Geography Curriculum). Enrollment in this class has traditionally been in the range of 20-28 students. It is an interactive class that requires critical reading of the literature, follow-on contributions to class discussions, an in-depth analytical essay, and three essay exams.

A) Student Learning Outcomes include:
   a. Describing the major intellectual traditions of Western geography from Greek times to the present.
   b. Appreciating the particular contributions of Western, Islamic, and Chinese geographical traditions in the historical evolution of geographical thought
   c. Identifying the connections between the era of European exploration, global colonial expansion, and the development of modern geography as a European discipline
   d. Tracing the specific connections between German, British, and French geographic traditions with the evolution of American geographical tradition.

e. Understanding the timing and significance of the profession of geography in the United States between 1875 and 1925
f. Tracing the evolution of American geography between 1925 and the present
g. Learning about new topical, thematic, and technological developments driving American geography today
h. Describing and explaining through an independent research project (including a class presentation and written term paper) the evolution of one specific subfield in the discipline of geography since 1990.

B) Example instructional activities that address these SLO's
a. Extensive readings assigned each week provided background on the evolution of the field: both historical and modern examples…
b. Students engaged in daily in-class discussions of readings
c. Students completed an exercise that described and compared major professional journals in the discipline
d. Students attended a research workshop at Renne Library to identify appropriate research materials in the field
e. Students developed research topics on different modern subfields of Geography
f. Students each made formal oral presentations and written term papers summarizing their subfields

C) Metrics or evidence that students are achieving these goals
a. All students were expected to contribute to class discussions and participation was utilized to assign grades
b. All students completed 3 all-essay exams (including a comprehensive final) that evaluated them on their mastery of the material
c. All students were graded on an assignment that evaluated several major geography journals
d. All students were graded on the style and content of their oral and written term projects
e. Course grades indicated overall performance: 7 A/A-; 15 B+/B/B-; 5 C+/C/C-

D) Lessons Learned
a. Students also completed an exit assessment for the entire program. They were asked about their top geographical skills in the program and what they felt was most lacking. These results have been passed on to the Geography Curriculum Coordinator.
b. This survey will be repeated in future years to evaluate the larger Program and its evolution.
c. No basic course format changes are anticipated. Future plans include: a) incorporating new readings as appropriate and to develop new research topics

for the term project that reflect the changing nature of the field; b)  devoting more time to open-ended discussions in class on course readings in the future; and c) asking all Geography faculty to briefly (15-20 minutes) visit the class and share thoughts on their research and what they see as career opportunities in the field.