5.1 CHEMISTRY OF THE ATMOSPHERE: A STUDENT-CENTERED UNDERGRADUATE LEARNING EXPERIENCE

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1. INTRODUCTION

The course, *Chemistry of the Atmosphere*, was developed as an integral component of a NSF-CCLI-A&I award (NSF DUE #9952428) that enabled the acquisition of a suite of trace gas and particle analyzers, which are used as the vehicle to engage students in authentic science as the means to scientific inquiry and conceptualization. *Chemistry of the Atmosphere* is an inherently interdisciplinary *Perspectives* course primarily serving both meteorology and chemistry majors, but available to any student having met the prerequisites. The course is appropriate for undergraduate students in their junior/senior years that have completed 36 credit hours in the Liberal Arts Core, and have taken one semester each of English composition, introductory chemistry with lab, and introductory physics with lab. The prerequisites more or less dictate that the course will attract undergraduate majors in the sciences, occupational safety and environmental health, and geography, and minors in environmental science. All students at the University are required to take a Perspectives course, and most students attempt to find a course that is relevant to their field of study. *Chemistry of the Atmosphere* was designed to create a learning environment in which meteorology and chemistry majors could interact to solve real problems. It is the only junior-senior level course in the sciences curricula specifically intended to bridge the disciplinary chasms, merge the distributed language of the chemist and atmospheric scientist, and expose students to a focused treatment of the timely and increasingly important subject of atmospheric chemistry.

Chemistry of the Atmosphere incorporates adaptations in instructional design such that the classroom/laboratory environment is modeled after science-as-practiced. Students engage in the practice of science using real-time air quality data collected *in-situ* in conjunction with upper air and surface data, satellite and radar imagery, and numerical model output (Eta and RUC) available via Unidata's IDD system, as well as NOAA's Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model, to pursue investigations in their own solution frames and debate the merits of different processes for seeking solutions (scientific discourse). The instruments acquired through the NSF award are used as tools to authenticate the activities of scientists. Students serve as apprentices engaged in the methods of data collection, problem recognition and resolution (or at least understanding), critical thinking, and algorithm testing, as a means to discovery and knowledge transfer, while developing synergistic insights and social interactions through personal and group collaborations. Since the data are not contrived in a "canned" format, but are collected in real-time, students are presented with a true sense of open investigation, where they are accountable for their activities and the rhetorical aspects of scientific knowledge construction, all of which can lead to both qualitative and quantitative advances in the transfer of knowledge.

2. STRUCTURE

Students in *Chemistry of the Atmosphere* are fully involved as practitioners, with fledgling chemists, meteorologists, industrial technicians (OSEH), geographers, and environmental science minors working together in small groups and collaborating between groups, as depicted in the cartoon in Fig. 1. The maximum course enrollment of 24 students allows for the formation of 4-6 groups depending on the mix of disciplines - each group would ideally consist of students mainly from meteorology and chemistry, with an occasional mix of geography, physics, and occupational safety and environmental health majors. The instructor serves as lecturer – there is a didactic component to the course that focuses on fundamental understanding and knowledge transfer, and as group facilitator and personal mentor.

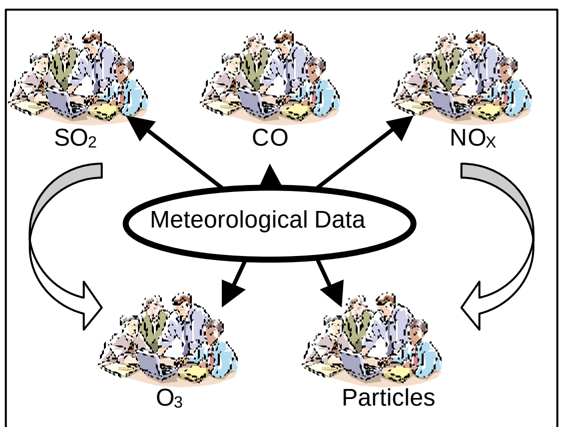

Fig. 1. Schematic of classroom environment: Each group is responsible for a principal measurement; all groups for the disposition and dissemination of meteorological data; and group-to-group interactions for correlations between trace gases and particles.

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Each group of students is responsible for the routine calibration, measurement, data collection, and quality assurance and analysis of data gathered by one of the principal instruments employed in this course. These instruments include an array of trace gas analyzers for the measurement of CO, SO_2, $NO/NO_2/NO_X$, and O_3, a 3-wavelength nephelometer for measuring total and backscattering coefficients, personal environmental monitors for $PM_{2.5}$ impaction sampling, and laser-diode scattering nephelometers for portable PM monitoring. All groups are mutually responsible for the collection and archiving of relevant meteorological data, analysis and visualization of data using GARP, NMAP, or recently released MetApps software. By archiving trace gas, particle, and meteorological data from one semester to the next, not only can scientific objectives be met, such as the study of seasonal and annual trends and variations, but students are exposed to the products and resources developed by former students. The outcome is that the benchmark for quality performance is continually being raised as students quickly assimilate what had already been done, learn what is considered acceptable, and aspire to a higher level of achievement and intellectual curiosity.

3. THE PROCESS

An example of a typical student experience may proceed as follows. The group responsible for the NO_X measurements observes increased NO and NO_2 during a morning rush hour, and displays Fig. 2 as evidence. A discussion ensues centered on the chemical reaction necessary for the formation of NO. The chemists in the group suggest that the reaction is likely to be the oxidation of NO_2, given by:

$$NO_2 + h\nu \xrightarrow{O_2} NO + O_3$$

Realizing that further evidence could be found in the time series of O_3, the NO_X group consults the O_3 group to determine if a correlation with O_3 is observed, and the O_3 group produces Fig. 3.

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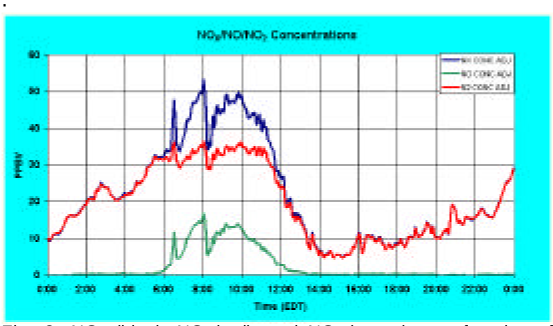

Fig. 2. NO_X (blue), NO (red), and NO_2 (green) as a function of time.

Interactions with the SO_2, CO, and particle groups proceed in a similar manner. The measurements strongly suggest a correlation between NO_X and O_3. Toward further scientific knowledge construction, the two groups submit a back trajectory analysis using the HYSPLIT model, which is shown in Fig. 4.

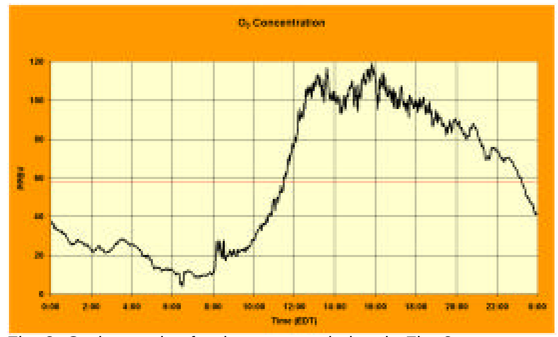
Fig. 3. O_3 time series for the same period as in Fig. 2.

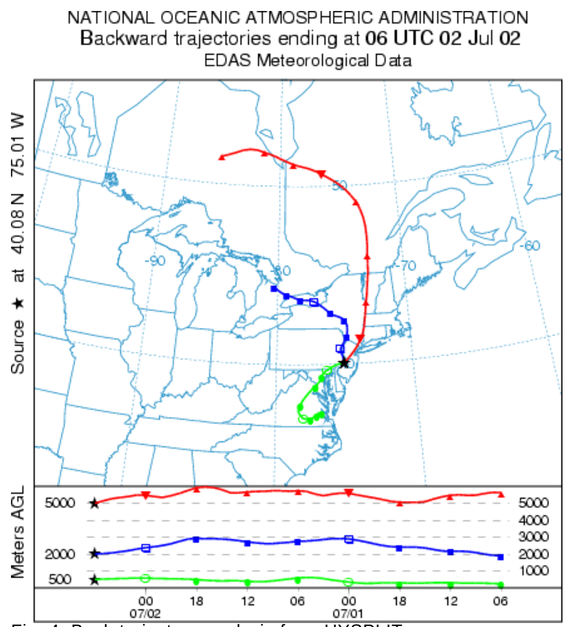

Fig. 4. Back trajectory analysis from HYSPLIT.

From Fig. 4 it becomes apparent that the low-level trajectory is a re-circulation event confined to the region. The groups surmise that O_3 is locally produced with no strong transport aloft. Additional upper air data confirms that winds aloft are light. Students archive their data along with a summary of the case study.

While this simple example is meant only to illustrate the process, all aspects of student-centered learning, including discovery, hypothesis testing, collaboration, development of synergistic insights, authentication, conceptualization, problem-solving, and critical thinking are embedded in this exercise.

4. ASSESSMENT

Several levels of assessment are incorporated into this course. Students are required to maintain a log-journal that includes a self-assessment of their understanding of the scientific process, as well as an assessment of their role as practitioners. In addition, students working in small groups are required to develop a joint-reflection paper as an outgrowth of their log-journals and interactive discourse, incorporating their attitudes toward contextualization of scientific inquiry, expectations of what scientists do, differences in insights of the scientific study, and the benefits of authentication and cooperation. The joint-reflection paper is submitted in written form and presented orally as a culminating activity. Finally, in a more classic manner, students are tested and their lab work evaluated to assess cognitive achievement.

Expected outcomes and classroom assessment techniques used to evaluate student learning are based on the methods outlined in the NISE[1] *Field-Tested Learning Assessment Guide for science, math, engineering, and technology instructors (FLAG)*. Upon completion of this course, a student should have gained the following skills and attitudes as evidenced, through assessment, by the successful achievement of a set of student learning outcomes:

Knowledge Skills

- *Demonstrate basic knowledge of facts, concepts, and theories used in atmospheric chemistry*
- *Demonstrate an understanding of the bases used in hypothesis testing.*
- *Demonstrate the ability to synthesize and integrate information and ideas*
- *Develop skill in using tools and technology central to atmospheric chemistry*
- *Learn to evaluate methods and tools germane to atmospheric chemistry*

Analytical Skills

- *Analyze and interpret experimental data effectively*
- *Organize information into meaningful categories*
- *Recognize interrelationships between the problems and issues*
- *Recognize the interrelationships between theory, observation, and interpretation*
- *Apply principles and generalizations to new problems and situations*

Communication Skills

- *Communicate in writing, speaking, and presenting effectively*
- *Bridge and articulate the distributed language of atmospheric chemistry*
- *Use facts and graphs to support results and conclusions*
- *Develop presentation-quality portfolios*

Research Skills

- *Use computer-based and other resources effectively*
- *Demonstrate ability to formulate effective questions*

Attitude Skills

- *Indicate perceptions about interdisciplinary nature of atmospheric chemistry*
- *Indicate level of confidence*
- *Indicate expectations (met or unmet) of working in collaborative groups*

4.1 Classroom Assessment Techniques (CATs)

The *FLAG* Classroom Assessment Techniques (Angelo and Cross, 1993) incorporated into this course design have been employed by many SMET instructors to guide and assess student learning, and are consistent with criteria employed by various accrediting bodies. Key assessment elements adopted in this course design are *ConceptTests, Conceptual Diagnostic Tests, Performance Assessments, Reports, Attitude Surveys, and Portfolios*. ConceptTests are used to gauge subject mastery in real-time, and can be used immediately to modify an approach to learning. Concept Diagnostic Tests are especially important in identifying misconceptions related to environmental statistical analysis. Performance Assessments are accomplished by means of exams, assignments, and quizzes, and are used to quantify a student's ability to apply conceptual and procedural knowledge, solve problems, and reveal the success of various approaches to learning. In conjunction with the performance assessment, students submit weekly reports summarizing what they had learned and what remains unclear. Students are expected to submit assignments as portfolios, in formats that are fit for professional presentations, which clearly demonstrate their mastery, comprehension, application, and synthesis of a given set of concepts. Finally, students are given an entrance and exit assessment tool that will focus on the assessment of knowledge, skills, and attitudes.

4.2 Evaluation of Student Performance

Student performance are evaluated on the basis of quizzes, assignments, and exams. These evaluation tools will be designed to assess student mastery of key concepts (ConceptTests), misconceptions (Conceptual Diagnostic Tests), and the ability to solve problems and apply conceptual and procedural knowledge skills (Performance Assessment). *Class participation is expected*.

[1] NISE is the National Institute for Science Education.

Assignments are completed as if students were presenting their results and conclusions to a professional group interested in outcomes for decision-making. The real-time ConceptTests, in-class diagnostic tests, and attitude surveys are included as a measure of student learning, but are not part of the student performance evaluation.

5. CONCLUSION

Chemistry of the Atmosphere has been taught once as an experimental course and once as a special topics course while the course proposal threaded its way through the university approval process. The course will be taught for the first time in Spring 2003 as an approved course. Students in chemistry and meteorology will have the choice of using this course either as an elective for chemistry majors in the environmental chemistry option, as an elective for meteorology majors, or as a Perspectives course for any major that has fulfilled the prerequisites. The first two course offerings were successful, except that the enrollments coming from chemistry were disappointingly low, resulting in less than optimal distribution of students in the two disciplines. This problem has been remedied by developing the course as a *Perspectives* course, a category required by all university students, so that chemistry majors can now opt to fulfill their Perspectives requirement by enrolling in this course. The course also benefits students pursuing B.S. in Secondary Education in the Earth Sciences and in Chemistry.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

Angelo, T.A., and *Cross, K.P.*, Classroom assessment techniques: A handbook for college teachers. Jossey-Bass Publishers, San Francisco. 1993.