3.5 BRINGING AUTHENTIC SCIENCE PRACTICE TO THE UNDERGRADUATE CLASSROOM

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1. INTRODUCTION AND MOTIVATION

The understanding of the process of science and the evolutionary nature of its results are important educational objectives for an atmospheric science curriculum. This knowledge helps graduates interpret and critically evaluate new scientific findings, and enables effective communication with fellow scientists and members of the general public. These objectives can be accomplished through research experiences that help the student understand the development of new knowledge in atmospheric science.

Most undergraduate science curricula do not include research opportunities as standard coursework. These opportunities are understandably limited to summer internships or extracurricular work with a cooperating professor, due to time constraints in the school year. Many times these opportunities are not available until the junior or senior year. In these situations, students learn the skills necessary to perform research through interaction with the cooperating researcher (Weaver et al. 2008). This arrangement excludes many students who do not have the opportunity to participate due to various circumstances such as lack of time or knowledge of opportunities (Russell 2006).

For this reason, The *Center for Authentic Science Practice in Education* (CASPiE) was initiated at Purdue University as a part of the general chemistry curriculum. The CASPiE model gives students the opportunity to create and execute a portion of a research project under the guidance of a cooperating professor, as part of the standard curriculum. The CASPiE model gives every student the opportunity to experience authentic research. The inclusion of CASPiE in an early (freshman-level, typically) general chemistry course allows students to develop interpretation skills early in their careers, ensuring graduates who have a mature understanding of science practices and products.

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2. EXPERIMENT DESIGN

In order to bring research opportunities to all atmospheric science majors at Purdue University, the CASPiE model has been adapted to fit the unique needs of atmospheric science research, as part of a sophomore-level laboratory. The CASPiE model was chosen because of its proven success as a part of the chemistry department at Purdue University (Weaver et al. 2008). Undergraduate research opportunities have been shown to increase students' confidence, understanding and awareness, as well as increase the expectations of obtaining a Ph.D. (Russell et al. 2007). The sophomore level has been chosen to give students an early exposure to the process of science, and to benefit from the retention outcomes of research experiences.

In the adapted model, students complete two research modules created by professors (hereafter referred to as *module authors*) in the atmospheric science department. Each module is based on the author's research area, and has three primary parts. First, the students are taught basic atmospheric science skills that are necessary to motivate and understand the research problem. Second, the students are guided through a research project with procedures and goals outlined by the module author. In this portion of the module, student results are new to the field of atmospheric science, and will be used by the author in a larger research project to develop publishable results. In the third part, the students are given the opportunity to explore their own questions or hypotheses. The results from this portion may also be used by the module author, or may be used as an exploratory study for future research. At the conclusion of the module, the class members prepare a presentation to communicate their findings with the faculty and graduate students of the department.

The students who complete this course have a better understanding of the process of scientific research and the development of new scientific knowledge. They also have had the opportunity to practice communicating scientific results with each other and with professionals. In addition, they learn basic atmospheric science skills and the details of two areas of current research in the atmospheric science field.

3. IMPLEMENTATION

The new research-based laboratory has been integrated into the undergraduate curriculum as a one-credit sophomore-level course that meets once per week. The development stage started in the spring of 2009, and the first version of the course was taught in the fall of 2009. The full project timeline is shown in Figure 1.

	2009 and 2010									
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	…	Dec
Module Development										
Module Pilot Testing										
Module Revision										
Module Implementation in new course										
Evaluation: Data Collection								Pre		Post
Evaluation: Data Analysis	(2010 only)									

Figure 1: Timeline for module development, implementation and evaluation.

3.1 Development

The goal of the CASPiE model is to use inquiry-based teaching methods. Inquiry-based laboratories allow the student to make decisions concerning the procedures and analysis of projects, rather than simply following predetermined steps or directions. The involvement in educational decisions gives students a better understanding of material and helps increase student motivation (Weaver et al. 2008).

In the atmospheric science CASPiE modules, the first several classes are similar to the style of traditional atmospheric labs and focus on learning specific skills. By the end of each module, however, the learning experience becomes completely student-facilitated through the design and execution of the final research product.

The development of each module begins with a proposal of a research project by a module author within his or her own expertise that has the characteristics necessary to allow it to be adapted into the CASPiE teaching model. The model requires a project that has a portion of research that can be completed and understood by students in a short amount of time, here within a 7 to 8 week time period. Also, this portion of the work should be part of a broader project that will be of publishable quality. This type of project ensures the authenticity of the research experience for the students, while also creating class results that will help further the module author's research goals. The portion performed by the students ideally allows the class to find preliminary results or to reach preliminary conclusions.

At the completion of the course, students benefit from the full process of science, including forming conclusions and sharing these with others. Likewise, module authors benefit from testing new ideas that may later be used for writing grant proposals, or they benefit from the results of large numbers of similar kinds of experiments that would take an individual researcher much longer to complete.

After the module is written, the module author makes only occasional visits to the laboratory. These visits are used to monitor progress and help guide students through the research and the development of conclusions based on their research findings. In the third section of the module, the author guides the class in developing a new research goal and experiment. The role of the author in this stage includes helping students focus ideas and ensuring the development of meaningful research projects.

3.2 Module Description

The course in the fall of 2009 consisted of 15 sessions, each three hours in duration (one per week). The students completed two modules during these fifteen weeks. The class consisted of 18 students. All students were atmospheric science majors. Most (16) students were sophomores, and 2 were juniors who chose the course as an elective. Students worked in teams of two or three people. The bulk of the laboratory was taught in a computer lab.

The first module was entitled *Influences of Projected Regional Climate Change on Precipitation*. The broad educational objectives were for students to gain an appreciation for basic regional climate change and the many scales of atmospheric phenomena and their interaction, to experience running a cloud and precipitation model, and to apply statistics for use in research at a more sophisticated level. In this module, students used the microphysical parcel model of Cooper et al. (1997) to examine differences in cloud characteristics from past and future soundings generated by a climate model. The students' goal in completing this module was to identify and recommend cities where the microphysical model indicated changes in climate, coupled with the characteristics of the local aerosol, may have a large impact on cloud characteristics and specifically, the production of precipitation by the warm rain process. Students were not expected to have any background in this area prior to completing this module.

The module consisted of eight laboratory sessions. The first three weeks were spent in skill building exercises. These exercises were necessary to ensure the students understood the science behind the research project. For example, the first laboratory allowed students to experiment with the ability of different substances to act as cloud condensation nuclei (CCN). At the end of the experiment, students were able to identify the types of aerosol particles that would act as CCN, and this would later help them interpret regional differences in CCN measurements presented in the formal literature. The second portion of the this session took place in the computer lab, where students examined CCN data collected in field studies and learned how to analyze the raw data in terms of a logarithmic scale to input later into the cloud model.

The next three weeks of the module were dedicated to performing the research project outlined by the module author. The first week required students to replicate a case already analyzed by the module author, as a check to ensure students understood the procedures necessary to conduct this type of research. The students had the experience of running the numerical model, and interpreting results similar to what they would find in their future research project. The next session was spent finishing the project described by the author. In this session, there was no instruction required, and students spent the entire three hours working in the computer laboratory on their individual cases. They ran the model and interpreted the results in the same manner as the previous week, but for many more cases, producing new and unique results. The following week, the module author helped students develop a new question and guided them in properly developing procedures for investigating their question. Students spent the remainder of the class period and time outside of class running their experiments, comparing results, and drawing conclusions.

In the seventh session, students had an opportunity to share their results with the rest of the class using a "round table" approach. At this time each individual group shared their results with the class, and the module author was available to help the students draw overall conclusions. The following week students presented their research findings to the faculty and graduate students of the department through a poster session and a fifteen-minute oral presentation. Students presenting to the graduate students and faculty is shown in Figure 2.

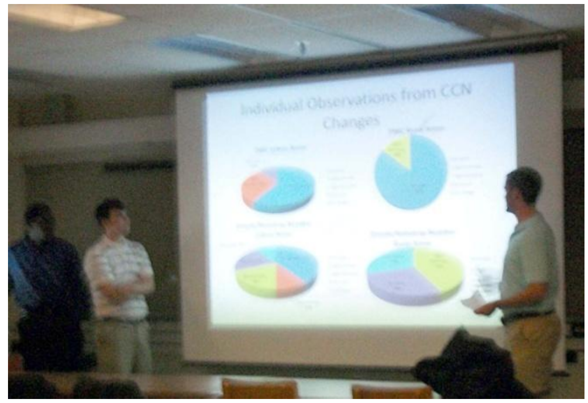

Figure 2: Students presenting results from the first module to graduate students and faculty.

The second module was called *Supercell Thunderstorms: Occurrence, hazard, and upscaling effects*, and consisted of seven weekly sessions, and followed the same general format as the first module. The first three weeks were used for skill development, the following three weeks involved data analysis, assimilating results and producing conclusions, and a final session was used for the presentation of results to faculty and graduate students in the department.

The second module focused on two topics related to supercell thunderstorms. In the first portion of the module, the students investigated the relation between severe weather damage, supercell thunderstorm occurrence, and geographical location across the United States. The second half studied any possible large-scale effects of supercell thunderstorms upon their environment. In this module, the skill building exercises focused on understanding the development and characteristics of supercells. Skill building laboratories covered traditional synoptic map analysis and supercell identification using Doppler radar with modern radar software. After students finished the module author's research project, they were again given one week to investigate their own hypotheses, and spent the following week compiling results and preparing presentations for the final lab session.

3.3 GRADING

The addition of authentic research projects to the classroom laboratory complicated the grading process. The first portion of the class, the skill building laboratories, was graded based on the correctness of the student's work. However, the weekly results of the research portions of the laboratory were unique for each group of students and could not be evaluated using traditional approaches, such as an answer key. For these laboratories, students were asked to complete formal lab reports. The rubric used for grading these reports was based on five categories: Introduction, Data and Procedures, Theoretical Support, Results, and Conclusions. Each section asked students to thoroughly discuss and explain their activities and conclusions. For example, in the conclusion section, students were graded on their ability to draw conclusions that were consistent with the data analysis and on their ability to summarize findings within the context of their experiment. This description based each laboratory grade on the results of individual research projects, rather than predetermined answers.

Research groups were expected to work together to perform activities and discuss results, but individuals were responsible for formal laboratory reports. This design ensured the understanding of the experiment by each student independently of his or her partner or group.

3.4 MODULE RESULTS

The module results are necessarily preliminary. As noted earlier, the students are expected to perform a small portion of an overall larger research project. This portion is in the exploratory or early stages of the project.

However, by the end of each module, the students are able to begin to see trends and recognize notable outliers in the results. For the modules used in this course, two different types of outcomes were reached by the students. The first module culminated in the recommendation of areas which appeared to be promising for future research. For the second module, students concluded their work by recommending better strategies and methods for continuing the project.

4. FUTURE WORK: EVALUATION OF THE SUCCESS OF THE LAB

The first offering of the class was completed in the fall of 2009, and future work will focus on evaluation of the educational outcomes of the class. This process began with the collection of data from participants of the Fall 2009 lab, and a control group, the 2008 sophomores enrolled in the atmospheric science major. Both classes were given the same survey to assess their understanding of science and its practice, with an additional survey given to the 2009 sophomores to acquire more data on the influence of the new laboratory course. The survey questions focused on how the class felt about scientific research, ranging from opinions related to personal experience with research, to confidence in partaking in research in the future. In addition to these surveys, four students agreed to pre- and post-course interviews, which will give in-depth information about their experience in the new course and its effectiveness.

The goal of this course is to prepare students to interpret scientific data, understand the process of science and to improve their communication skills. Through these surveys and interviews, the goals of the course will be evaluated. A longitudinal study will be used to evaluate the final goal of student retention within the atmospheric science major at Purdue University. Pending the degree of success, this model of student learning will then be expanded to other universities offering atmospheric science programs.

5. ACKNOWLEDGEMENTS

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