EXPERIENCING SCIENCE, AN INTRODUCTION TO "REAL" METHODS OF SCIENCE FOR THE PRESERVICE TEACHER

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The "scientific method" presented in the middle school classroom introduces the experimental approach of science in a way that may actually bear little resemblance to the processes actually used by working scientists. Teachers equipped with an insight into the motivations, philosophy, tools, and culture of science will better convey an accurate and positive picture of science as a critically important human endeavor. The *Experiencing Science* course was designed to answer the challenge of giving the pre-service teacher and decision-maker better insight into actual processes used by scientists, in the context of each of the major disciplines.

Experiencing Science (VCU INSC 300), a 3 credit hour course, was developed by a Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) team from Virginia Commonwealth University, Mary Washington College, J. Sargeant Reynolds Community College, Longwood College and the Science Museum of Virginia. Support for development of *Experiencing Science* was provided by VCEPT and the Science Museum of Virginia's Center for Science Education. VCEPT is a National Science Foundation supported collaborative consisting of nine Virginia colleges and universities, the Mathematics and Science Center, and the Science Museum of Virginia. The Science Museum of Virginia is a state agency and an educational institution with a twenty year history of interpreting the principles of science. The Museum has a Digistar planetarium and over 200 interactive exhibits in nine galleries interpreting science concepts including: Optics, Acoustics, Force and Motion, Astronomy, Chemistry, Crystals, Telecommunications, Aerospace, and Electricity and Energy.

A team of four faculty members from three institutions has taught the course, with a representation from the physical sciences, life sciences and earth sciences. An important part of the revision of the course in the current term involves placing greater emphasis on the mathematical tools used by scientists in modeling, analyzing, and describing natural phenomena. Statistics, graphical presentation of data, and the power of math modeling are

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components of the course in the present semester.

The premise for the development of this course is that the "scientific method" as presented in the middle school classroom introduces the experimental approach of science in a way that is inaccurate at best, and may actually bear little resemblance to the real processes used by working scientists. Imagine for a moment the notion that for every individual scientist in daily work a new hypothesis leads daily to a new theory. As Bauer states in the course text, *Science and Its Ways of Knowing* [1], teachers equipped with an insight into the motivations, philosophy, tools, and culture of real working scientists will better convey an accurate and positive picture of science as a critically important human endeavor. The *Experiencing Science* course was designed to answer the challenge of giving the pre-service teacher and community decision-maker a better insight into actual processes used by scientists, in the context of the each of the major disciplines.

In the Summer 1997 and Spring 1998 the course was offered as a 200 level course with a PHY (physics) designation. It met at the Science Museum of Virginia, using its resources and interactive exhibits, with field trips and class meetings at other sites, designed to take advantage of the many research opportunities in science available near the Virginia Commonwealth University (VCU) campus. Semester projects, experimental investigations, readings from original science works, and an exam are part of the course structure. In order to present a unifying theme for a context of the three main disciplines, energy is taken as the central concept. Energy is seen in the physical sciences, (potential and kinetic; chemical and electrical, etc), the life sciences, (the cell as an energy transducer, the trophic pyramid and the food web), and in the earth sciences (weather, tides, orbits), providing a thread to unite the widely disparate science themes visited in the course of a semester.

In Spring 1999 the course is offered as INSC 300 (Interdisciplinary Science designation), open to all students, with the newly added prerequisites of one General Education course each in mathematics and science. This change was intended to give the student a more effective set of tools to see examples of science at work. The first two semesters revealed that a level of understanding in biology and physics, as well as some facility with mathematics is required to grasp the key elements of the course. This modification has served the course well, as the current Spring 1999 semester is composed of future teachers with a much stronger background in several sciences and in mathematics.

As modern science is increasingly a distributed process, communication is a critical and functional element. The essential aspects of collaboration and competition in the working science disciplines are modeled in the class and in the research projects. The all-important recognition and communication of science research, the peer-reviewed paper, becomes in this course an introduction to science as it is practiced. Students conduct research projects in teams and present their work in regularly scheduled symposiums during class time, with class participation in questions and suggestions of the other research teams. Thus, the communication of science to the immediate community and beyond is introduced in a real-world format. The portrayal of discoveries in the news media is studied and the analysis of this communication is incorporated into course activities. The benefits of collaborative efforts and the productive aspects of competition are studied in readings and experienced in course projects such as a classroom "race" to identify a new species and submit the report of its discovery in an abstract to a journal editor.

The course employs a student journal as a model of the research tool, as a lab notebook, a personal journal, and a means of communication between student and the teaching team. The journal is used for in-depth evaluation, as researcher's diary, and as an assessment tool.

The remarkable differences in approach among the different science disciplines are recognized in the course: the physical sciences and the repeated experiment, the field studies of the life scientist, and the computer model of the astrophysicist. Students investigate the distinct culture of different science disciplines -- a direct result of the nature of the subject matter, which may be data-rich (meteorology or geology) or theory-rich (cosmology).

An important part of the revision of the course in the current term involves placing greater emphasis on the mathematical tools used by scientists in modeling, analyzing, and describing natural phenomena. Statistics, graphical presentation of data, and the power of math modeling become a larger part of the course in the present semester. Students take data in experiments, (the time of falling objects from different heights, for example). They plot the data and use analysis to determine error, confidence based on scatter or variation, and eventually determine the acceleration of gravity.

Another example of mathematics applications is found in the semester-long projects. One project team is attempting to measure the acceleration of Earth's gravity (g) at several points in Central Virginia with the greatest accuracy possible, using a pendulum and a stopwatch. They will use statistical methods and error analysis to describe the degree of confidence in their result, with data taken at one location for comparison to a published value. This approach, rather than the use of modern, solid state instruments, challenges the student to be resourceful, to think critically, and to use mathematical tools to the greatest advantage. A second team is determining the size and distance of the moon by measuring apparent angular size without modern instruments. (They will, however, have access to a good photograph of a lunar eclipse for part of the data-gathering). The mathematical tools used in this project will include Euclidean geometry and error analysis. A third project will be the correlation of the "afterimage effect" of color perception in humans as a function of different colors used, with a statistical analysis of results.

Dealing with the question, "What is Science?", is an important aspect of the course. In fact, distinguishing the examples of "pseudo-science" from what is recognized as real science is a recurring theme throughout the semester. The writings of Karl Popper in the course text, *Science and Its Ways of Knowing* [1], are used as an introduction to a delineation of the scope of science. Should scientists study UFO reports, or search for extraterrestrials? A core concept is presented: a proposition which is put forward to the science community to be tested and to be proven false, is a scientific statement, while a deeply felt belief is not a part of science at all. Thus, Creationism, Scientology, and other examples of doctrine-driven cultures are distinguished from science in the course, as they are not open to objective study and testing.

The course offers practice in critical thinking techniques for gaining understanding: recalling and identifying key facts and relationships, applying and combining known information in new applications, and judgment about precision, accuracy, consistency, or effectiveness of information. Different methods of investigation are modeled: observation, classifying. communicating, measuring, predicting, hypothesizing, modeling; inferring from, interpreting, and analyzing data.

Readings from the text introduce ideas of some of the great scientists, giving a more sophisticated appreciation of science concepts, and benefitting a non-science major in a modern decision-making or teaching career. The course is intended to give future teachers a sense of the importance of science to all of modern life and human endeavor. ■

Reference

[1] J. Hatton and P. B. Plouffe (eds), *Science and Its Ways of Knowing*, Prentice Hall, Upper Saddle River, NJ, 1997.