VOLUME XIV, NUMBER 14

INNOVATION ABSTRACTS

PUBLISHED BY THE NATIONAL INSTITUTE FOR STAFF AND ORGANIZATIONAL DEVELOPMENT (NISOD), COLLEGE OF EDUCATION, THE UNIVERSITY OF TEXAS AT AUSTIN • WITH SUPPORT FROM THE W. K. KELLOGG FOUNDATION AND THE SID W. RICHARDSON FOUNDATION

Letting Students "Discover" the Scientific Process

Unfortunately, most science is taught as though it operated in a vacuum. Entering college science students often believe that science operates in a realm apart from their world. Conventional approaches to teaching science at all levels have fostered student expectations that the study of science is beyond their intellectual capacity, that it entails extensive lists of "facts," and that it is foreign to their experience. These approaches promote preconceptions that are inaccurate and serve as major obstacles to teaching any beginning science course. Students become frustrated by the apparent gap between their experience and the scientific world, and this discourages them from becoming active participants in the scientific process.

We became dissatisfied with the traditional approach to teaching the scientific method because it actually reinforces students' errant notions of science. The traditional approach usually involves listing the major steps of the scientific method and providing students with examples of well-controlled experiments. By naming steps in the traditional way, such as "hypothesis formation," students are led to believe that this process is alien to their "normal" way of thinking. Since the scientific method is usually the first subject covered in a science course, students are introduced to a concept which they already believe is beyond their comprehension. This is a frustrating situation for science instructors who know that the scientific way of thinking is nothing more than a systematic means of gaining knowledge. This "scientific" way of thinking comes to us as naturally as walking upright, and everyone uses some form of it daily. Therefore, we have begun teaching scientific method in a way which allows students to experience the process before they put names to the steps in the process. We believe it demonstrates that there is nothing unusual or esoteric about the scientific method of problem solving.

On the first day of our Biology 101 class, students are divided into groups of three to five and are given a short description of the extensive extinction of species that occurred in the late Cretaceous Period. In this description students are told what species disappeared, which species remained, and that these extinctions occurred in a short geological time span. They are reassured that they need no prior knowledge of this event and that, in fact, it may hinder their objectivity in completing the assignment. Attached to the description is a list of 10 possible explanations for these extinctions. The groups decide which three explanations they find most compelling and describe what type of evidence they would need to either support or reject each explanation they have chosen. For example, if the group chose the explanation "Volcanic eruptions released ash into the atmosphere causing the temperature to drop," they might state that they would require evidence of (1) volcanic eruptions during this period, (2) volcanic ash influencing worldwide temperature, and (3) the effects of temperature changes on the species which perished during this period. After compiling their lists, the small groups report to the class-at-large, and more extensive lists of evidence to support or reject explanations are then developed by the entire class.

Students then receive a second sheet which contains a list of actual data which may be relevant to this extinction. The groups then categorize each piece of evidence on the list as either "not applicable," "supports," or "rejects" for each of the three explanations originally chosen. In the volcanic eruption example, groups may find that evidence from the list, such as "Geological record shows a slight gradual cooling of the earth," may support that explanation, while "Volcanic gases released with ash usually cause atmospheric warming" may cause them to reject this explanation, and "Mammals ate dinosaur eggs" is not applicable to this particular explanation. Small groups will then report conclusions to the entire class.

This activity shows students three things about the use of data to solve scientific questions:

1. The process is not foreign and, in fact, is similar to the way they may routinely solve other problems (i.e., deciding where to go to school, which car to buy).
2. Although there may be substantial data that support an explanation, it is impossible to be absolutely certain that this is indeed the "real/true" explanation. Information unavailable to the students now (and, in fact, to the scientific community in this particular case) may ultimately shatter the validity of

any explanation. This indeterminate approach to knowledge is and always has been the hallmark of good science. In other words, we may need to alter or even reject outright our most favored treatise in the face of new data.
3. The only thing you know for sure is an explanation that can be clearly rejected by the evidence.

This learning strategy demonstrates to students that they have the same ability to use data for problem solving as does a scientist. They begin to see science as a process that they already can and do use everyday. Having experienced this process, it is much easier for students to comprehend the textbook descriptions of scientific method. The description of extinctions are "scientific observations," the possible explanations for the extinctions are "hypotheses," and the process using the provided data to sequentially reject or support explanations is "theory development."

Students generally expect that scientists already have most of the answers. This was exemplified by a student who, after patiently going through this exercise, said, "So what's the *real* answer?" Once the students understand that no one really knows answers with certainty, they are better able to recognize that science is not simply an assemblage of facts but rather a process. They also see that scientific knowledge is dynamic rather than stagnant, ephemeral rather than permanent. We remind students that this process is ongoing for all subjects we will cover during the term.

We have found that this process has the added benefit of shattering students' first-day expectations of how science is learned. They enjoy the opportunity to participate in solving an unfamiliar problem with people they have just met. They soon realize that the sum of their ideas as a group is better than the best idea of any of them alone. This is reinforced by the large group activities where the small groups are sharing their ideas and sets the stage for an active, cooperative learning environment. We have found that many students who had once viewed the study of science as an exercise in the memorization of large quantities of obtuse factual material, now see science as a vital and exciting process.

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Student as Teacher

After several years of teaching lecture-type speech communications classes, it occurred to me that I was teaching communications without allowing my students to communicate. If I lectured the entire time, would my students have enough time to practice the new skills they were learning? I devised a plan to have students attend sessions more prepared and more enthusiastic.

In preparing this new teaching strategy, I needed to find a way to keep the students involved with their readings and class discussion. I asked the students to provide some background information about themselves on 3 x 5 index cards. These cards enabled me to learn more about my audience and also served as a deck of cards for randomly selecting the class lecturer—a strategy that further motivated students to read the assignment before class in order to be prepared to teach.

Each day, a card is selected, and the student so identified leads the class discussion on the assigned readings. To provide some support for the lecture, I write several questions in the margins of my book and give it to the student. The student follows my notes in the margins and poses the questions to the class; the class works as a team to understand the chapter's concepts, achieved through defining concepts and terms, and to apply them to real-life situations. This teamwork plan reduces the nervousness students often feel when asking questions in class. Also, I stand next to the student as he/she is teaching, reducing the student's tension and creating somewhat of a team-teaching situation. If the student "teacher" does not understand a concept, I am available to provide assistance.

The student's responsibility as the "teacher" includes reading and understanding the chapters, leading and maintaining class discussion, encouraging the entire class to participate, and maintaining discipline. Each student has a unique teaching style; a "boring" class discussion is a rare occurrence in my class!

This teaching strategy promotes class discussion and enthusiasm. It is a productive teaching method in communications classes and is applicable to many disciplines.

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May 1, 1992, Vol. XIV, No. 14

INNOVATION ABSTRACTS is a publication of the National Institute for Staff and Organizational Development (NISOD), Department of Educational Administration, College of Education, EDB 348, The University of Texas at Austin, Austin, Texas 78712, (512) 471-7545. Funding in part by the W. K. Kellogg Foundation and the Sid W. Richardson Foundation. Issued weekly when classes are in session during fall and spring terms. ISSN 0199-106X