The Case Study Method in the STEM Classroom

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Abstract

"Active learning" where students are required to do something in the classroom rather than simply listen to a lecture has been repeatedly shown to be superior to the lecture method in advancing student learning. The use of case studies in the classroom is one of the most successful active learning methods of teaching science, technology, engineering and mathematics (STEM). How this method evolved and is currently revolutionizing teaching has major implications for metropolitan universities where many students are non-traditional and at risk.

What are Case Studies and What is Case Study Teaching?

I have asked virtually hundreds of faculty these questions and the variety of answers is staggering. The term case study is used by law and business instructors to describe real problems or situations that these professionals face; when these cases are analyzed in the classroom they are always taught by a professor holding a discussion with a class (Leenders, Erskine, and Mauffette-Leenders 2001). The term was used by Harvard chemist James Connant (1949) to describe how he lectured to students about major discoveries in science in great depth. In medical schools this is called Problem-Based Learning (PBL) and occurs when physicians take a patient problem and present it to a small group of students and have them "puzzle out" a reasonable diagnosis. Sometimes the situations are true; sometimes fiction. Sometimes the cases are closed (there is a real answer to the question) and sometimes the cases are open (there are multiple possible answers). Sometimes the cases are dozens of pages long and sometimes they may be a single paragraph. Sometimes the cases extend over several days or even over a whole semester while sometimes they last only part of a class period. The variations seem endless.

Yet, I propose there is a true essence to case study teaching that is evident in spite of all the variations. It is this: Cases are stories told with an educational message (Herreid 1997). Students learn better by understanding the material in context. Case-based instruction is designed to engage students in thinking about theoretical, applied and deeper conceptual understanding (Shulman 1992). But as I mentioned above, the story can be "told" using different classroom techniques: in discussion, lecture, or small groups. The many variations include Problem-based Cases, Interrupted Cases, Debate Cases, Public Hearing Cases, Role Playing Cases, Team-based Learning Cases, Trial

Cases, Directed Cases, and Quiz-based Cases—all with various strengths and weaknesses (Herreid 1994, 1998a).

But for clarity, let us focus on one method, the classic discussion approach. Suppose that a teacher wishes to take up the question of what are the basic properties of life—a standard lecture topic in a general biology course. Instead of reciting a boring list of criteria, the teacher can offer a case study about a recent discovery of "cells" in a meteorite from Mars. This is a fictionalized account of the historical announcement by NASA on August 7, 1996 that they had strong evidence that life existed on Mars. In the Mars case, a young scientist, Michael King, who is part of the investigative team, is doubtful that NASA should make that claim. Yet the team plans to go forward with a press conference, and Michael is thrown into a dilemma as to what to do. In the teaching of this case, I routinely ask the students first to list the specific claims that the characters are making, writing them on the board. Then in a discussion format, I ask them to provide the evidence that is cited in the case. I follow this by asking them to list the characteristics that they believe identify life. This allows us to discuss the pros and cons of each and to see if the evidence that the NASA team is mentioning really addresses these issues. Finally, I turn to the ethical questions that are involved in the case: Is it appropriate to call a press conference before peer review has occurred, etc? And lastly, I ask the question, what should Michael do when he does not agree with the team leader's decision and what might be the consequences of his actions?

Through this case, not only do students learn the basic characteristics of life, but they come to understand the difficulties in applying these criteria. And they learn a great deal more—perhaps the most important lesson—something about how the scientific process really works in the context of society. Such revelations are especially appealing to the non-traditional and at risk students populating our metropolitan universities and community colleges. Isn't it more valuable to teach students about virus biology using an AIDS case such as the tragic case of tennis star Arthur Ashe who contracted HIV by a blood transfusion rather than give an abstract lecture?

What Makes a Good Case?

The key to writing a good case depends first and foremost on instructors having clear goals as to what they want the case to do and being sure that they craft the case to meet those goals. Several hundred such cases and teaching notes identifying the case goals are published on the Web site of the National Center for Case Study Teaching in Science at http://ublib.buffalo.edu/libraries/projects/cases/case.html.

When we analyze the characteristics of what makes a good case study in the eyes of a student, several criteria come to mind. The list for science cases is similar to the one developed for business students. The best cases tend to be short (perhaps three to four pages); have controversy, dialogue, interesting characters, a dilemma to be solved; and are contemporary, real, and relevant to the student with a clear pedagogical value (Herreid 1997/1998).

What Do We Know About Case Study Teaching?

In spite of its extensive use in law and business schools (Williams 1992), case method in these arenas does not appear to have been seriously assessed. In contrast, the use of PBL in medical schools has prompted close scrutiny. More recently, case study instruction has received increasing attention as it has penetrated undergraduate college and K-12 classrooms. Here are case study findings we can report:

- A meta-analysis of over twelve hundred studies comparing the performance of students educated using cooperative learning strategies (including case studies) versus those taught by the lecture method showed that cooperative learning promoted greater learning and greater retention in verbal, mathematical, and physical skills. Students enjoyed the experience more, had better attitudes toward the subject, developed better social skills, became more articulate, and became more tolerant of differing viewpoints than with the lecture style (Johnson and Johnson 1989, 1993).

- Hoag, Lillie, and Hoppe (2005) and Lundeberg (1999) reported students believe that content is easier to remember and apply when using case studies, and they experience more enjoyment when using case studies in class.

- An important meta-analysis examining forty-three research studies on problem-based learning in medical schools revealed a significant improvement in the clinical application of knowledge and higher order thinking (Dochy et al. 2003). There were no significant differences in knowledge on standardized tests. However, when the assessment task was open-ended (e.g., recall, short answer, simulation, oral, essay) and/or when the assessment task measured critical thinking rather than basic knowledge, students in the PBL group showed higher gains in performance compared to the traditional group. Essentially, the higher the level of knowledge and thinking required on the assessment task, the more likely that case study teaching will produce greater gains in student understanding. Similarly, Bergland and others (2006) reported that tests that require students to engage in higher order thinking, such as interpreting data from simulations and cases, generally produce higher performance among students than do traditional multiple choice course exams.

- Since small groups and active learning methods are generally used to teach cases, it is important to note that the literature (involving thousands of students) is especially rich in indicating that these approaches are demonstrably more effective than the lecture method in achieving learning and increasing motivation and positive attitudes toward STEM subjects (Hake 1998; Udovic et al. 2002). Importantly, "the positive effects of small-group learning were significantly greater for members of underrepresented populations (African Americans and Latinas/os)" (Springer, Stanne, and Donovan 1999, 40).

Pitfalls in the Implementation of Case Study Teaching

Generally, faculty do not know what cases are, do not know how to teach with them, and do not know how to write them. These basic problems must be addressed even if we accept the virtues of the case approach. Fortunately, faculty are increasingly becoming aware of the method as the literature grows, as workshops are hosted, and as word of mouth spreads. As they become knowledgeable, many teachers ask, "Why are we using a technique (the lecture) that is demonstrably inferior?" They wonder if the lecture method of instruction is at fault when 40 percent of their students receive "Fs" or "Ds" or withdraw. They are ready for a change.

The introduction of alternative methods of teaching meets with serious obstacles from the individual teacher, the students, and in some cases colleagues and administrators (Herreid, 1998b). Teachers are afraid of the risk of failure, the increased time (after all, they have their tried and true lecture notes), and they don't know how to do it; the students—especially if they have been successful with the lecture method—will ask why they must endure being a guinea pig as a professor tries out an experimental method at their expense; and colleagues and administrators—they may have their input, particularly when a young untenured assistant professor is coming up for tenure. Many lessons can be learned from the chaotic experience that occurred at Duke University when they introduced their version of case teaching in the chemistry department without an adequate preparation of either faculty or students (Herreid 2004).

Dissemination Efforts for the Case Study Method of Teaching

The United States has three major centers for the development of case study teaching. It is valuable to consider how these centers, these models, developed and how their successes have made an impact on teaching. The first two models originated in graduate schools and it is only recently that the case paradigm has penetrated in an important way into the K-16 classrooms.

The Harvard model and the discussion-based learning model. The century-long history of case study teaching in law and business schools gives us an exemplar of how the discussion case approach has spread throughout the world. It is hard not to argue that a large reason for its success is because "Harvard does it, so it must be good." Since its inception, faculty and students have left "The Citadel" and carried the "Word" like disciples into the academic wilderness. Indeed, I first heard of the method from a professor of law from Cornell who had received his law degree at Harvard.

Another reason for its success in both law and business is that a collection of cases rapidly began to accumulate to share with fellow colleagues. Within a dozen years after discussion cases were introduced into a course at the Harvard Business School, Melvin Copeland published his book of cases, *Marketing Problems*, in 1920. In December of that same year, his Dean, Wallace Donham, spent $5,000 to set up a

collection of cases in a systematic way, proposing that Copeland should focus on course problems for Industrial Management. Copeland, together with young business school graduates, began searching for material on behalf of Donham's organization, the Bureau of Business Research. Success followed rapidly and full-time staff were added to search and write cases. Dean Donham then actively began to stimulate the interest of his faculty in the use of cases. He held luncheon conferences where using cases were discussed (Leenders, Erskine, and Mauffette-Leenders 2001).

Another driving force was that students showed a strong preference for the case method. Within four years a high proportion of Harvard courses were converted from lecture to discussion. Within twenty years Dean Donham solicited two million dollars for the development of cases with the result that today approximately two thousand cases in the Harvard School are available for purchase. Comparable numbers of cases are available at two other major case business centers. Additionally, the Harvard law school and the Kennedy School for Public Policy have large numbers of cases for sale as well.

The discussion based case study model has spawned several summary books and the model has made its way into other disciplines including fields such as teacher training and clinical psychology. Harvard received a grant from The Pew Charitable Trusts to disseminate the method across disciplines, which led to individual faculty promoting the method, including the development of a Web site at the University of Minnesota specializing in environmental and agricultural cases. The U.S. Department of Education Fund for the Improvement of Post-Secondary Education played an important role in dissemination; they funded William Welty and Rita Silverman from Pace University for many years to run case discussion workshops for all disciplines. Welty and Silverman had a particularly important impact on teacher training, as they produced a book of cases devoted to the subject.

McMaster University and the problem-based learning model. In the late 1960s, the Canadian McMaster University Faculty of Health Sciences established a new medical school with a novel curricular approach (Barrows 1996). Disappointed with the traditional lecture method, they wished to produce graduates that were lifelong learners, practitioners who worked well in teams, related well to their patients, and were excellent problem solvers who knew how to do literature searches. Thus, they created the model that we know as Problem-Based Learning (PBL) and graduated their first class in 1972. At nearly the same time, the College of Human Medicine at Michigan State developed a PBL track and other newly established medical schools in the Netherlands (Maastricht) and Australia (Newcastle) introduced the method. Additional schools with well-established curricula undertook the more daunting work of overhauling their programs. Leaders in this reform were the University of Hawaii, Harvard University, the University of Sherbrooke (Canada), and the University of New Mexico. Today, dozens of medical schools use some variation of PBL. Health professions such as nursing, occupational therapy, and physical therapy have caught the PBL fever and have produced a plethora of hybrid models of PBL.

What were the driving forces involved in this movement? First, there was a basic disenchantment with the prevalent lecture method in the health-related professions. Second was the enthusiasm of the first tutor/instructors of the method and the word of mouth spreading of the basic strategy. Third was the willingness of McMaster and especially the University of New Mexico to eagerly lobby for the method by setting up visiting opportunities for teams of faculty from other institutions to see the method in operation. Fourth, articles began to be written about the strengths and weaknesses of PBL along with questions of assessment. Indeed, PBL is arguably the best examined pedagogical approach in education today. Fifth, the dissemination of the approach got a great boost in the United States with the 1984 publication of *The Report on the Panel in the General Professional Education of the Physician and College Preparation for Medicine* sponsored by the American Association of American Medical Colleges. The publication touted promoting independent learning and problem-solving and reducing lecture hours (Barrows 1996).

PBL moved into the undergraduate sphere in a serious way in the early 1990s when faculty at the University of Delaware heard about the method and contracted with the University of New Mexico to assist them in setting up PBL courses at their institution (Allen, Duch, and Groh 1996). This led to Delaware receiving national grants from agencies such as NSF, The Pew Charitable Trusts, and the U.S. Department of Education. As part of their proselytizing for the method they held national workshops and traveled extensively to other institutions as emissaries giving workshops. This has led to a network of hundreds of faculty who are using PBL, and the University of Delaware has established a Web-based clearinghouse for PBL cases. More recently, another major player in the undergraduate PBL movement is Samford University, which has received funding from The Pew Charitable Trusts to encourage PBL use across disciplines. Several summary books have been published on the method in the undergraduate classroom such as Wilkerson and Gijselaers' *Bringing Problem-Based Learning to Higher Education: Theory and Practice* (1996).

The National Center for Case Study Teaching in Science at the University at Buffalo. The use of cases to teach science at the University at Buffalo was an outgrowth of a curriculum reform in the 1980s (Herreid 1995). As part of that renovation, the university faculty devised new science requirements for all students. Although two of the science courses were traditional, two were not. One of them, Scientific Inquiry, was devised to tell stories about how scientists actually went about their work; in a sense, this was a response to Harvard chemist James Conant's lament, after the Second World War when he served as President Franklin Roosevelt's science advisor, that the public does not understand how science is actually done. This course focused on contemporary science problems (such as genetic engineering) and dealt with the science, social, and political issues involved. The method of instruction was to be discussion-based, a method of instruction that few science teachers were schooled to use. The second course, Great Discoveries in Science, was story-telling focused around key moments in the history of science—clearly, a lecture version of case study teaching.

Buffalo was successful in receiving an award from the Fund for the Improvement for Post Secondary Education (FIPSE), administered by the U.S. Department of Education, to train faculty in the teaching of these courses. There was no precedent on how these courses were to be taught, and since they were to be for non-science majors, there was no built-in faculty constituency arguing that certain material had to be covered. Over the next three summers the University at Buffalo held workshops and discussions with faculty who were designated as instructors in these courses. Outside experts in different styles of instruction were imported, among them William Welty from the Business School at Pace University, a frequent workshop leader on the use of case studies. Even after the grant ended, the University at Buffalo continued to hold summer regional workshops for faculty on different strategies for instruction in science.

In the early 1990s the University at Buffalo received an NSF grant to train faculty in how to write and teach with case studies in science. These workshops were to be national in scope and five days in duration. A novel feature of them was that faculty would develop cases and teach them to a group of students that were hired to be critics. Not only did the faculty gain facility with case teaching, but also large numbers of students were exposed to the method.

By this time I was an enthusiast for the method and wrote a summary article for the *Journal of College Science Teaching*, "Case Studies in Science: A Novel Method of Teaching," which was published in 1994. This led to the establishment of a regular column in the journal on case studies. Also, we created a Web site for case studies, a place where faculty could publish their cases and teaching notes (essentially lesson plans). These would be available free. It seemed clear that unlike Harvard, which had a large clientele for case studies, we could not charge for this service as our audience was limited; few faculty knew about using case studies in science.

Two years later we obtained a grant from The Pew Charitable Trusts which allowed us to continue our workshops, develop a national presence by establishing The National Center for Case Study Teaching in Science, host an annual two-day conference, and with the co-operation of the *Journal of College Science Teaching*, edit and publish an annual issue of the journal devoted entirely to case studies. This work has expanded under our current NSF grant for the dissemination of case study teaching, which allows us to also provide satellite workshops at other institutions, especially those serving student groups traditionally underrepresented in science. Finally, in collaboration with Mary Lundeberg of Michigan State University, a Co-PI on our grant, we have seriously begun to address the question of assessment of the case method vis a vis the lecture method.

The results of these activities are several: (1) well over a thousand teachers have been trained in the use of case study teaching in the sciences; (2) a large number of cases have now been published, not only in the *Journal of College Science Teaching*, but also in other venues including other science education journals and in books; (3) over 250 cases and teaching notes have been published on the National Center for Case Study in Science Web site, which are accessible free of charge. About two thousand teachers

visit this site each day, half of whom are high school faculty who download the cases for use in their classrooms. The availability of such cases is especially important to faculty with heavy teaching loads who may not have time to write their own cases. (4) In two assessment surveys of 277 university and college faculty who tried out the case method after a training workshop, 97% reported students taught with cases learned new ways to think about an issue; 95% reported students took a more active part in the learning process; 93% reported students were more engaged in classes; 84% reported students in classes using case studies were glad case studies were being used; 89% reported students in the classes using case studies demonstrated stronger critical thinking skills, 83% were able to make connections across multiple content areas; 90% developed a deeper understanding of concepts; and 91% were better able to view an issue from multiple perspectives (Herreid forthcoming).

Lessons Learned About Dissemination

There are some basic similarities among the three successful case center models:

- Prior to the adoption of the case method, there was a basic dissatisfaction with the lecture pedagogy; large numbers of students were not performing at acceptable levels. Faculty were receptive to alternative ways to instruct.

- Students exposed to the new case methodology recognized its value to their education because it related to their life goals and careers—the cases were relevant to the real world, not abstract problems.

- Cases were made available to new instructors who wished to try out the case method. They either used cases written by others, or they were trained to write the cases themselves. Large repositories of cases were rapidly established and made available either for purchase or for free. Major Web sites, journal publications, and books were developed by the Centers.

- Faculty were trained in how to teach with cases primarily by attending workshops and conferences held by the Centers along with teaching videos, CDs, and DVDs.

- The flexibility of the teaching method was important especially as envisioned in the Buffalo model. Teachers could see that the method could be used within their disciplines. Cases could be readily molded to meet their specific styles and needs. Indeed, the fact that "the case method" is hard to define is a plus. Defining it simply as "a story with an educational message" meant that faculty who felt they could not successfully use the Harvard discussion or PBL models were free to invent alternative ways to tell the story.

- Money played a significant role in case development and dissemination. Whether it was spent accumulating a number of initial cases and continuing to build large databases as with Harvard or in running training workshops and conferences or publishing special case study issues of journals and books as with Buffalo, money

was vital to success. The National Science Foundation, the U.S. Department of Education, and The Pew Charitable Trusts, along with university support, were essential along the way.

- Finally, unbridled enthusiasm by early users of the method meant that word of mouth traveled far and wide.

The case study method has had a long history but most of it has been in the sphere of graduate education. In the last fifteen years it has entered the K-16 classrooms. Its success comes from the fact that the story line approach puts learning in context. The lecture method seems singularly inappropriate for most students, who do not memorize abstract facts well, especially when the facts appear to have no relevance to the real world. Most students are not going to go into science. Our first obligation should be to not turn them off to science, however, and the lecture method does just that (Tobias 1990). It seems time that we recognize that there are better ways for students to learn.

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