The Future of Case Study Teaching in Science

By Clyde Freeman Herreid
University at Buffalo

Abstract: Case study teaching in undergraduate science courses began 20 years ago. Today thousands of K-16 teachers are using the method and there are major websites that post hundreds of case studies and teaching notes in all STEM disciplines, especially the biological sciences. It is a puzzle why more chemists and other physical scientists have not embraced the method, since there is strong evidence that it is superior to the traditional lecture approach. But since there are over a dozen different methods of case teaching, which variation is the best surely depends upon an instructor's goals. In this paper I pose a possible way to test the relative efficacy of different methods. Also, I examine possible ways that STEM instructors can move from the lecture mode (which arguably has the lowest learning retention) to active learning methods, especially those using cooperative learning.

The Past: A hundred years have passed since the Harvard Law and Business Schools adopted case study teaching. Their innovation was to use real-world problems and bring them into the classroom as exemplars of the complexity that the students would face upon graduation. These problems, criminal and civil, would be cast into stories: persons grappling with the complexities of the justice system or the workplace. What made the case problems interesting was not just the puzzle that had to be solved but the storyline itself—a protagonist who was going to reap success or ignoble failure depending upon his or her choices. The most successful cases were those that created empathy with the central characters, had dialogue and generality, were current and relevant to the reader, required dilemmas to be solved, and were short.

McMaster University's Medical School was to get into the case study business in education in a big way in the 1970's. Unlike the legal and business cases, which required that the case studies be taught using classroom discussion, McMaster created a different formula for teaching young physicians in training—Problem-based Learning (PBL). This technique placed the students in small groups with a faculty facilitator. They were given patient scenarios with limited information. The students had to determine what they knew about the case, what they didn't know and what to look up. The students then divided the workload and went off to search the literature. When they met later and shared their findings, they often would receive additional clinical data. They pooled their views and again went to the literature. Usually in their third class period, they would attempt to come to a conclusion about the case. Then they received another case. This small group approach has many variations and has found its way into undergraduate science classes where it is the favorite method of case instruction (Herreid et al., 2011).

Twenty years ago the University of Delaware began to use PBL across the spectrum of undergraduate education; the University at Buffalo with more eclectic choice of pedagogies started a major effort to incorporate cases in science education (Herreid, 1994). As a result of their vigorous proselytizing via seminars, workshops, and conferences, today many thousands of faculty have been trained to write and teach with case studies. Indeed, the University at Buffalo at Buffalo's National Center for Case Study Teaching in Science has roughly 2,000 visitors each day and a subscriber list of about 14,000. The site has nearly 400 case studies with teaching notes for teachers across all STEM disciplines. Intriguingly, although the website was designed initially for college instructors, a third of the case study enthusiasts are high school teachers.

There is a fascinating and perhaps disconcerting note to all of this. Drawing from our recent poll of 1634 case teachers, about 90% identify themselves as biologists (Herreid et al., 2011). Where are the physical scientists, the physicists, the geologists, the engineers, and yes, the chemists? Surely, these instructors are interested in active learning strategies---after all, the most well known study showing that active learning is far superior to the lecture method was published by a physicist Richard Hake (1998). And the POGIL method has clearly garnered a following among chemistry teachers. But the case method simply has not caught on; perhaps it is not easy to come up with story lines to teach basic physics and chemistry. Yet, this explanation seems hardly applicable to the fields of geology, meteorology, and engineering with their obvious tie-ins to environmental disasters and practical problems. Storylines abound. Think Japan. Think Katrina. Think Haiti. Think volcanoes. Think the Minnesota bridge collapse. Think snowstorms, mudslides, earthquakes, and tsunamis and…….. There must be other reasons.

The Present: This is the situation today in a nutshell. 1) Active Learning in the science classroom has gained a lot of adherents in the last couple of decades. A growing number of serious studies have been carried out and published showing the efficacy of these methods. That is of vital importance to those of us who are trained to value evidence (e.g. Yadav et al. 2007)

2) As one of the best active learning strategies, the case study method has many advocates. Besides the University at Buffalo and University of Delaware's touted websites, there is growing number of other resource centers of case material as we list at the end of the article. Yet, even if we count the tens of thousands of case teachers who have been trained in active learning methods, there are still hundreds of thousands of K-16 teachers who still rely exclusively on traditional stand and deliver methods.

3) Surprising numbers of science faculty either do not know about the data or do not care. To offset this void, many science societies such as the *Journal of Chemical Education* have established special journals or specific sections of their disciplinary publications devoted to the field of education. It is becoming harder and harder to ignore the facts.

4) Lecturing is still the favored method of teaching. Yet, it is arguably the most ineffective way of teaching someone (Dale, 1969; Lord, 2007). Many faculty still favor the method not only because they have their courses already prepared and don't want the extra work, it is because they survived the didactic method quite well themselves. That may be the essence of the problem. It is a Darwinian process. The survivors control the system.

I am surprised that more of us don't have guilty consciences. Many introductory science teachers in large university courses have had the distasteful experience of failing, or giving D's to over 40% of the students (Hatch et al., 2005). This hardly seems like success. It is easy to fault the students, blaming their lack of preparedness, laziness, or immaturity. And be done with it. But could the method of instruction be part of the problem?

5) The lecture method can be faulted for driving away many excellent students from the sciences. Sheila Tobias in her ground-braking books (1990, 1992) thinks so. She argues that the method is particularly hostile to those students who are not already committed science majors.

The Future: So with this as background, what do I see as the future? Here are some questions that I would like to see answered in the next ten years:

1) **How can we convince faculty that the active learning strategies are superior to the traditional stand and deliver approach?** It is true that more and more faculty are moving toward active learning, but the speed of conversion is glacial. Is there anything we can do to hurry the process along? The journal *Science's* recent push toward publishing articles on education is one noble effort. But there are hundreds of thousands of science teachers left untouched by the "revolution."

2) **What makes one type of active learning better than another?** If we restrict this to case studies, what makes one case better than another? We can write boring or exciting cases. What exactly makes the difference? We have anecdotal evidence that some of the same characteristics that make great law and business cases also make great science cases [dialogue, controversy, relevance to the student, dilemmas to be solved, etc. (Herreid, 2006)], but a serious study needs to be done on the issue.

3) **What makes one strategy of case study teaching better than others?** If "Case studies are stories with an educational method' (Herreid, 2006), then there are many ways to tell the story. I have identified a dozen different case methods (Herreid, 1994; 1998; 205; 2006); for example, PBL, debate, public hearings, and whole class discussion. It is likely that the method of choice should depend upon the topic at hand. For instance, a debate method is

especially effective where controversy such as the medical use of marijuana is considered.

4) **What makes one case teacher better than another?** Effective teaching techniques are the subject of an endless stream of "How to books" (e.g. Svinicki and McKeachie, 2011), but here I am focused narrowly on case studies. Can we identify great case teaching, and can we coach it? In our website at the National Center for Case Study Teaching, each of our cases is accompanied by extensive teaching notes written by the person who wrote the case. But is that the best way to do it? We need studies where we compare the same case being taught by different teachers. We have one such a comparison; large differences were found in learning success and student attitudes between a dozen college teachers using the same cases at different schools (Lundeberg et al. 2011). But we really don't know why these differences occurred, because each institution has its unique culture along with variations in teacher effectiveness and student readiness and competence. How do we get a handle on this?

An experimental proposal: To wind up this article let me pose a possible way to attack one of the above questions: Let's compare the effectiveness of the different methods of case teaching. We have a model that will help. Many years ago, Dale (1969) created what has been called the cone of learning. It appears in Figure 1 where several different teaching methods are compared in regard to the degree of learning retained after a period of time. The lecture method is shown as the poorest method whereas learning done in cooperative groups produces the greatest retention. Thomas Lord (2007) took it as a challenge to test this model and found it surprising accurate: several classes of students were taught how to put a puzzle together using different teaching strategies and the results were practically indistinguishable from Dale's original proposal.

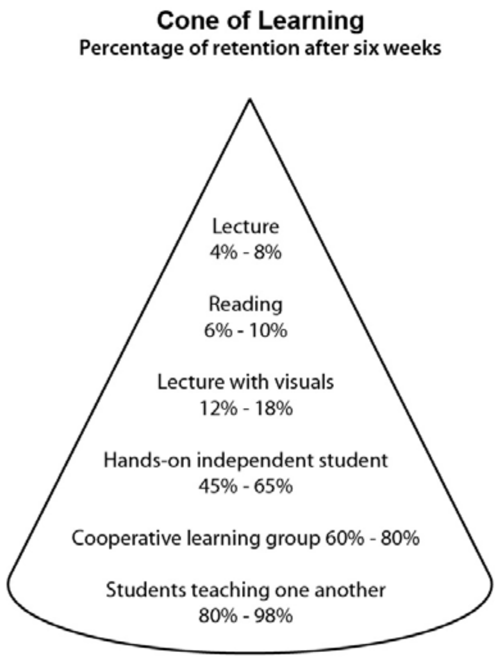

Figure 1 from Lord, 2007

We can use this model's scaffolding and insert five major ways that case studies have been used. (Herreid, 2006). See Figure 2. ***1) Lecture Method.*** Chemist James Conant from Harvard employed this technique in the 1940's when he taught students about the great discoveries in science. ***2) Clicker Case Method.*** This approach depends upon the recent advent of personal response systems ("clickers"). Here a story is told using PowerPoint slides and interactive questions are interspersed to encourage participation, which would otherwise be impossible in a large classroom. ***3) Classroom Discussion.*** This is the classical method instituted in the Harvard Law and Business Schools; it is still favored by these groups today and some STEM instructors, although it demands considerable interrogatory skills. ***4) Individual Case Instruction.*** Cases can be given to individuals to puzzle out one or more solutions, usually with an assist from the literature. Typically, the student will turn in a lengthy report, dissertation, or thesis as a product. ***5) Small Group Cases.*** In this approach, teams of students work cooperatively to deliberate and unravel the case mystery. PBL is the most formal and famous of these methods. Moreover, it is the method of choice by the case teachers who have taken our recent poll (Herreid et al. 2011).

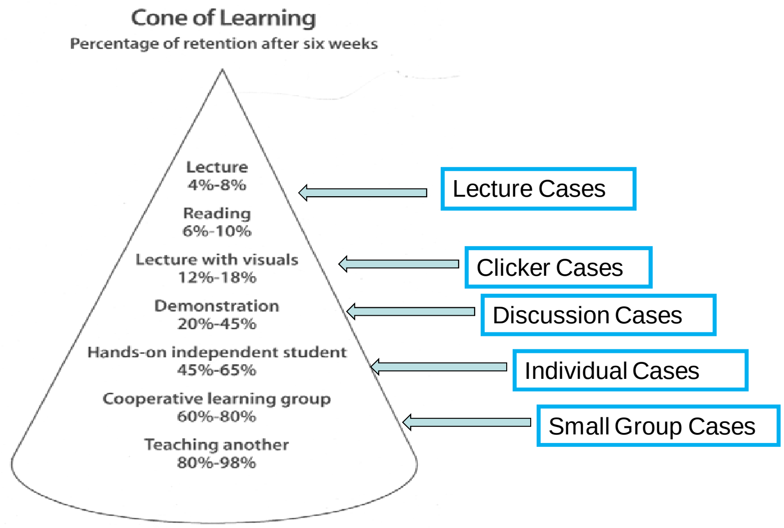

Figure 2.

Now with this scheme, can we design a way to compare the effectiveness of the various techniques? Certainly, we can compare the effectiveness of clicker cases with the lecture method in general biology classes (Lundeberg et al. 2011; Wolter et al. 2011). And if the results of this experiment are any indication, the case method will win out, but the relative effectiveness will strongly depend upon the institution's clientele and faculty, and the case topic that is used. This one-to-one comparative testing method will surely continue to be used; but for the most part, it will be teachers trying to show that their method is better than the lecture method. What I am advocating is that we compare different active learning methods themselves.

Here is one way to go about it without setting up *mano-a-mano* testing:
Let's use the cone of learning as the scaffolding. Let's see if my placement of the various techniques of case teaching is in any way accurate. For example, let's compare the lecture method of case study presentation with the model. If it is correct, then the lecture case will lead to about a 5% retention at the end of 6 weeks. (After all, even though delivering a lecture in the form of a story is perhaps more interesting than a normal lecture, it is still a lecture.) We ought to be able to easily test this.

The other case approaches can be attacked the same way: We aren't going to test them against each other, but against the model. This means that we should simply present a case in one of its forms and then after a time compare its learning effectiveness against the predicted value of retention. This means that anyone who is a case teacher can run an experiment, but there will be a lot of variables that will be potentially come into play. Among them would be these:

1) The topic chosen
2) The faculty and his/her personal style.
3) The students and their personal characteristics and background (the institution's culture)
4) The number and quality of other encounters that the students have with the material besides this single case. (i.e. some topics require more than one class period)
5) How much study that students put into preparing for the exam beyond their exposure to the case. (Good students are apt to put in much more time than their less serious students)

Now, with these variables in the mix, can we design an experiment to test the model and get comparative data on the different case methods? This is a pretty challenge for the future. It should be doable.

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Resources

National Center for Case Study Teaching in Science, University at Buffalo
http://sciencecases.lib.buffalo.edu/

PBL Clearinghouse, University of Delaware
https://primus.nss.udel.edu/Pbl/

CASES Online, Emory University
http://www.cse.emory.edu/cases/

Case It! University of Wisconsin – River Falls
http://caseit.uwrf.edu/

Enduring Legacies Native Cases, The Evergreen State College
http://www.evergreen.edu/tribal/cases/