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Using Case Studies to Teach Science

By Clyde Freeman Herreid

An ActionBioscience.org original article

articlehighlights

Case study teaching has gained a strong foothold in science education. Advances in the field include:

- *variations on methodology, from whole class discussion to the jigsaw approach*
- *an increase in educational resources on the topic*
- *over a thousand studies that show improved learning when case studies are used*
- *a survey that illustrates students enjoy and benefit from case studies*

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Using Case Studies to Teach Science

By Clyde Freeman Herreid

> *I will tell you something about stories; they aren't just entertainment. Don't be fooled. They are all we have, you see, all we have to fight off illness and death. You don't have anything if you don't have the stories.*
>
> *Leslie Marmon Silko, Laguna Tribe*

Great teachers are often great storytellers.

Storytelling permeates the human experience. It is found on street corners, in bars, in living rooms, and on playgrounds; it exists wherever people gather, be it around campfires or TV sets. Stories set cultural norms, provide us with heroes and demons, warn us of folly, and give us reason to hope for better days. They are with us from the day we are born until the moment when we shuffle off this mortal coil. They make us human. Not surprisingly, great teachers are often great storytellers.

A brief history of case study teaching

Storytelling as an education tool began in law and business courses.

- Storytelling as a formal educational device entered the didactic scene around a hundred years ago with case study teaching at Harvard.[1] There in the law and business schools, instructors and students analyzed realistic stories as exemplars of good and bad practice. They were stories with an educational message, which is perhaps the best definition of case studies.
- While long used in medical schools in the "grand rounds," the case study approach has also been most notably instituted as "problem-based learning" at McMaster University in Canada, spreading from there throughout the world.
- More recently, the entry of case study teaching into the undergraduate classroom can be traced primarily to two institutions. A dozen years ago,

the University of Delaware introduced problem-based learning (PBL) across their curriculum, and the University at Buffalo pioneered the use of cases on a large scale in science, math, and engineering.

Case-based teaching today

Case studies are self-contained stories.

In its original form, case-based teaching relied on cases that were largely self-contained stories written and analyzed through the discussion method in the classroom. This approach was exemplified by Professor Kingsfield in the movie and TV series, *The Paper Chase*, where, with an intensive cross-examination style, the professor badgered the poor student with persistent questions. Although there are more benign versions of this discussion method, it is still the method of choice for many law and business schools.

Nonetheless, story telling does not have to be limited to either the traditional discussion formula advocated in law and business schools or to using student groups as in PBL. Rather, there is a host of other ways to tell the "story with an educational message":[1,2]

- lecture method
- whole class discussion
- small groups
- individual case instruction
- mixed method

Acting out a story improves the lecture method.

1. Lecture method

Twenty-five years ago at the University of California, Berkeley, Richard Eakin was famous for dressing as well-known scientists (Darwin, Mendel, and Pasteur) and lecturing to wide-eyed students in the first person. It was as if these famous personages actually visited their classroom. Chemist James Conant championed the use of lecture cases in the 1940's at Harvard, giving an entire course in science centered on great discoveries. Both of these approaches are surely compelling alternatives to the straightforward preachy lecture.

Discussion includes role-playing and debates.

2. Whole class discussion method

The original case study teaching was a variant of the Socratic method. It was largely an interaction between a student and the professor, with other students listening and occasional student–student involvement. But there are many variations on the discussion method, for example, cases that unfold in the form of role playing, debates, trials, and public hearings, all within the framework of the whole class participating.[2]

Characteristics of a good discussion case. There are several key characteristics found in the best business case studies. They seem to hold true in the sciences, as well.[3] The cases tend to

Cases tend to be short and relevant to the

- Be short. One to three pages works well for most instructors, something that can be covered in a single class period. Yet some excellent cases can extend for several weeks or even over an entire semester.
- Be controversial. Care must be taken because students can be swept up with controversy and the competitive nature of the discussion rather than giving the topic careful analysis.
- Have dialogue. Although difficult to write well, dialogue makes the cases appear more real to the reader.
- Have interesting characters.

student, and they pose a dilemma.

- Be relevant to the student.
- Have a dilemma to be solved. Such decision cases force the reader to be involved in the outcome of the discussion because they cannot sit on the sidelines, they must take a position.
- Be contemporary. Although historical cases are interesting to experts, students greatly prefer topics in the news.
- Be real rather than fabricated. It is hard to get involved in a generic case, although a fantasy case, say, one involving Spiderman, does capture interest.
- Have learning objectives (Why else use them?) and have lessons that can be generalized to other situations.
  With that said, let me hurriedly add that many fine cases don't have these characteristics at all—and I have written some myself.

Open versus closed cases. There are other considerations to think about, and one is the open or closed nature of the case.[4] Most cases used by business schools are open: There are several plausible solutions; reasonable people can differ. The student must sift through the facts, evaluate them, and weigh the possible options and consequences of the decision s/he must suggest. For instance, the question "Should the United States sign the Kyoto treaty?" clearly has people on different sides. This type of case is set at the high end of Bloom's taxonomy of knowledge (see "learn more links" at the end of this article), where synthesis, analysis, and evaluation have a high priority.

Cases may or may not have a right or wrong answer.

At the other end of the scale are cases that may be considered closed. These cases do have right and wrong answers. Cases of this type put a premium on facts, principles, and definitions. They focus on the lower end of Bloom's taxonomy of knowledge. Many medical school cases are like this, whereby the patient has a particular complaint, the correct diagnosis is essential, and woe (not to mention malpractice suits) be to the student or physician who gets it wrong.

3. Small groups

PBL is only one form of case instruction, albeit one of the very best. In its original incarnation at McMaster University's medical school, about a dozen students along with a faculty facilitator puzzled out patient problems. For each case they would follow the same sequence: The first day, they would be given some details about a patient's symptoms. They would separate out the things they knew and those they didn't. The students would then seek information from texts or the Internet to assist in their deliberations. When they gathered together for the next class, they would pool their information and again determine what was or was not known. At this time they might receive additional information, perhaps some clinical test results or a new complication. Once again they would reanalyze the situation and seek more information. As a rule, after a couple of cycles of this, they would finalize their diagnosis and receive their next case. The PBL approach has been praised for producing students with increased analytical skills and talents for teamwork and independent learning.

Cases sharpen student analytical skills and teamwork.

The use of the original PBL has come under criticism because of the heavy investment of faculty time.[5] As a result, PBL has become so modified that it can hardly be recognized. One sees the phrase used for large classes and small, with facilitators and without.[6] The only unifying features may be that these cases begin with problems to be solved and not all of the information is given at once.

Students can be given cases in stages.

The interrupted case. A favorite method of many science faculty is a variation of PBL, called the interrupted case.[7] Like PBL it uses progressive disclosure of information rather than giving away the entire story line at the outset. The approach differs from PBL only in that in the interrupted method the case is accomplished in a single class period. The power of both variations is that receiving information piecemeal mimics the way that scientists actually have to analyze problems. And the method provides obvious structure to the discussion, an important point for those students who do not appreciate a freewheeling conversation.

Students can be asked to arrive at a consensus.

The jigsaw approach. This approach is a robust way to use cases and small groups.[8] First, student groups are given different pieces of information and asked to come to a consensus about a problem. Each group may represent a different stakeholder. Take a case of overfishing near the Galápagos Islands. When the government of Ecuador clamped down on this illegal activity, bands of fishermen took over the Charles Darwin Research Station and held the scientists hostage. An instructor running this case might set up different groups to represent the scientists, fishermen, tourists, shop owners, and politicians. Second, after the groups establish their initial position, the teacher sets up new groups, each with one representative from the former groups, and they are responsible for hammering out a compromise policy.

4. Individual case instruction

Cases can be studied in a tutorial setting or by individual assignment. One of the most interesting approaches is to use a *dialogue case*.[9] Here the instructor gives a student the task of writing a short play about a controversial subject, say, the use of stem cells for research. The student is asked to write a verbal exchange that might take place on this topic between intelligent, informed people on opposite sides of the question. S/He must write at least 20 comments and responses for each protagonist. The comments must be substantial rather than frivolous or superficial, such as, “You’re a jerk!” At the end of the paper the student must write her/his own opinion along with a reference section. Not surprisingly, students often change sides after completing such assignments—not a bad result.

A student may analyze both sides of an issue.

5. Mixed methods

There are many hybrid approaches. Commonly, instructors start cases working with small groups and finish off by running general discussions with the whole class.

One of the most frequently used methods, the *direct case method*, does not fit neatly into one or another category. This technique is a favorite of teachers of anatomy and physiology courses, where the coverage of material is of paramount concern.[10,11] In this approach, the case is often one or two paragraphs that outline a patient’s symptoms, say, high blood pressure. This is followed by a series of questions. The students receive the case and questions at the beginning of the unit dealing with the cardiovascular system. They work individually over the next several days to find the answers to the questions, consulting any authority. Meanwhile, the instructor gives a series of traditional lectures on the subject. At the end of the unit, one class period is set aside to deal with the questions; the instructor collects the student papers and then runs a discussion of the topic, keeping track of the students and their responses. The cycle is repeated with each unit starting off with a case and questions, a series of lectures, and then papers turned in with a discussion.

Students may be asked to find solutions to questions about a case.

Strengths and weaknesses of the different methods

A reviewer of this article pointed out that stories are different from problems: "One engages the student in a human context and a narrative learning style; the other is oriented towards skill development (in problem analysis, problem solving, perhaps persuasion)." I don't think the distinction is this clear. Many narrative cases have a strong component of skill development, as in medical cases[8] or lab-based cases or, indeed, as in many business cases where accounts need to be analyzed.

Teachers should have a clear goal of what is to be accomplished.

What is true is that the instructor should have a clear view of what s/he wishes to accomplish with the case, then design it to do the job.[12] Lecture cases are still lectures and have the same limitations as any other lecture; they may be more fascinating as stories, but the listener is passive. There is evidence that, regardless of the expertise of the lecturer, student performance does not differ on exams.[13]

Discussion cases with the whole class have limitations as well: Students are often reluctant to speak out, and a few individuals may dominate the discussion. Also, in large classes only a few individuals can contribute. And often science faculty have had limited experience leading good discussions.

Small group cases are the most popular.

Small group cases appear to be the easiest cases to teach for faculty used to the lecture method; they do not demand the questioning and listening skills that many of us have not acquired. Instead, a case may be given to small groups to analyze. Then a team representative can report on the group's deliberations. Faculty are then in an ideal position to comment. Students are more apt to participate in small groups of, say, five people, and if they don't prepare, this is immediately evident.

A meta-analysis of over 1200 studies in which researchers compared the performance of students educated using cooperative learning strategies (including case studies) versus those taught by the lecture method shows the following:

Studies show that using case studies improves student performance.

- Cooperative learning promotes greater learning and greater retention in verbal, mathematical, and physical skills.
- Students enjoy the experience more, have better attitudes toward the subject, develop better social skills, become more articulate, and become more tolerant of differing viewpoints than with the lecture style.[14,15]

Barriers to the case method

There are three major barriers college professors face when they shift to a new method of teaching: themselves, the students, and other faculty and administrators.[16] And if we consider the K–12 classroom, we should add the parents as a potential barrier. Novelty is worrisome and risky.

1. Faculty barriers

Some faculty worry about content, time, and control.

The faculty barriers are fairly obvious: It takes time to convert your course; there are always a thousand other things to do, like research. (Not surprisingly, the instructors that attend teaching workshops mostly come from teaching institutions.) Then there is the question of content coverage: The case approach often does not permit instructors to cover as much material as is possible with lectures—never mind that most students forget the information the moment the final is over. Control is an issue with some instructors, who worry about relinquishing the floor to students—who knows what they will say? And instructors may not know how to run a discussion; indeed, they may never have seen a discussion in a science classroom. What do you do when no one talks? Finally, some of us just don't want to give up center stage. Others may not feel their teaching is as effective. What happens to teaching evaluations, and how do you know if students are truly learning?

2. Student barriers

Some students oppose change in the way they are taught.

Students have their issues, too. They like the familiar. They have grown up with the lecture method and know how to cope with it, even if they aren't doing sterling work. If you suddenly throw them into uncharted waters, they don't know what will happen even if you tell them that the results will be better. This can be especially threatening to the preprofessional health students and honors students who do rather well with the lecture method. (Most faculty have clearly survived quite well, too, and have their own experiences to fall back on when trying to justify not changing.)

3. Colleague and administrative barriers

Our colleagues and administrators may stand in the way. They may not give a fig about what you do in the classroom, but if trouble starts brewing, they are sure to have an opinion and get into the act. If you wish to read a cautionary tale, check into the chaotic events at Duke University a couple of years ago when they tried to introduce cases into their introductory chemistry class.[17]

4. Parent barriers

Finally, parents can act as a barrier if they believe that a new method of instruction puts their child at a disadvantage, especially if it involves a controversial topic such as evolution or sex education.

Impact of the case teaching method

Numerous studies confirm students do well with case studies.

In spite of the long history of case-based instruction in business and law, there has been little effort to evaluate the method. However, PBL has been intensively studied, and the results of 43 carefully conducted studies have been summarized in a meta-analysis.[18] *The results clearly indicate that PBL has a major positive impact on students' skill development, and that their knowledge retention is improved compared with retention of standard lectures.*

Through workshops and conferences, thousands of faculty have now been trained in using cases, and many have transformed their classrooms. In a recent unpublished review commissioned by the National Center for Case Study Teaching in Science, 152 faculty members were surveyed after attending either a five-day summer workshop or a two-day conference. Even though these instructors were predisposed toward the method, the results are of interest:

A survey showed that students like case studies and learn more with them.

- 97 percent reported that students who were taught with cases learned new ways to think about an issue.
- 95 percent reported that students took a more active part in the learning process; 92 percent reported that students were more engaged in classes.
- 84 percent reported that students in classes using case studies were glad case studies were being used.
- 59 percent said students were more likely to do independent research outside the classroom to improve their understanding of the material (only 5 percent said they were less likely to do independent research).
- 68 percent said students demonstrated, in some way, that they learned more in classes using case studies (only 2 percent said they learned less).

Evaluation of the strengths of the different case methods is in its infancy, and we must wait for data to accumulate. But it appears that the case study method has developed an important following, for example:

Resources on case studies are growing.

- Several journals routinely publish articles with cases or assessing the method. The Journal of College Science Teaching has a regular column dealing with the case teaching method, and it publishes an annual issue devoted solely to case studies.
- The websites of the University of Delaware (https://chico.nss.udel.edu/Pbl/) and the University at Buffalo (http://ublib.buffalo.edu/libraries/projects/cases/case.html) have several hundred cases with teaching notes available for teachers. They are regularly downloaded by university and college faculty and by K–12 teachers who are cutting and pasting these cases into lessons for their students. The traffic on the website of the National Center for Case Study Teaching in Science is impressive: there are several million hits in the course of a year and about a thousand visitors a day.

Case study teaching has gained a strong foothold in science education. Perhaps it is not for everybody, but it is here to stay. It is the stories that hook us. A well-told story will be remembered and with it the educational message.

About the author: Clyde Freeman Herreid, Ph.D., is a distinguished teaching professor at the University at Buffalo, State University of New York. He has published over 100 articles in the fields of physiology, ecology, and education. He is the American Society of Physiology's Claude Bernard lecturer of the year 2000 and director of the National Center for Case Study Teaching in Science. He writes a regular column on case study teaching in the *Journal of College Science Teaching*. Herreid received degrees in biology from Colorado College, Johns Hopkins University, and Pennsylvania State University. He has taught at the University of Alaska, Duke University, and the University of Nairobi. http://www.udel.edu/ce/pbl2002/speaker_herreid.html

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Other case study articles

» Tapping into the Pulse of the History of Science with Case Studies
http://www.actionbioscience.org/education/allchin.html

» Issue-Based Teaching in Science Education
http://www.actionbioscience.org/education/lewis.html

» Case Studies Across a Science Curriculum
http://ublib.buffalo.edu/libraries/projects/cases/curriculum.html

» Problems: A Key Factor in PBL
http://www.udel.edu/pbl/cte/spr96-phys.html

» Problem-Based Learning, Especially in the Context of Large Classes
http://www.chemeng.mcmaster.ca/pbl/pbl.htm

Bloom's Taxonomy

The article "Learning Domains or Bloom's taxonomy" summarizes three domains of learning activities.
http://www.nwlink.com/~donclark/hrd/bloom.html

Read a Book

» *Teaching High School Science Through Inquiry*, by Douglas Llewellyn, provides case studies, tips, and tools to harness the power of students' curiosity and improve achievement in science. (Corwin Press, 2004)

» *The Power of Problem-Based Learning: A Practical "How To" for Teaching Undergraduate Courses in Any Discipline*, edited by Barbara J. Duch, et al., is a guide for using problem-based learning in undergraduate courses. It discusses how the process uses real-world problems to motivate students. (Stylus Publishing, 2001)

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BioQUEST
This LifeLines OnLine Project supports faculty in developing case-based teaching materials dealing with real-world problems. About 50 cases are online.
http://www.bioquest.org/lifelines/

Lancaster University
This site has 17 environmental biology cases that are descriptive without teaching notes.
http://www.es.lancs.ac.uk/casestud/index.htm

McGraw-Hill case studies
» Short bioethics and law scenarios with questions written by Ronnee Yashon, author of three texts using this same approach. http://www.mhhe.com/biosci/genbio/olc_linkedcontent/bioethics_cases
» Ecology and environment case studies focusing on regions of the U.S.
http://www.mhhe.com/biosci/pae/environmentalscience/casestudies/

National Center for Case Study Teaching in Science
Hosted by the University at Buffalo, State University of New York, the site has several hundred cases and teaching notes in all areas of science and engineering. In addition there are articles, conference announcements, workshops, case teachers' addresses, and links to other case sites.
http://ublib.buffalo.edu/libraries/projects/cases/case.html

University of Delaware Institute for Transforming Undergraduate Education
Within this website are cases and articles, conference announcements, and resources in various fields focusing on problem-based learning.
http://www.udel.edu/inst/

Samford University Center for Problem-Based Learning
Information on PBL and on Samford's project to implement the method across the curriculum.
http://www.samford.edu/pbl/

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