Biology Learning

Investigative Case Study Approach for Biology Learning

Margaret A. Waterman
Southeast Missouri State University
Department of Biology
Cape Girardeau, MO 63701

Abstract: This paper gives background on the investigative case study approach for biology, a variant of problem-based learning (PBL). Like many variants of PBL, this is a method of learning and teaching that gives students opportunities to direct their own learning as they explore the science underlying realistically complex situations. Students work collaboratively to identify issues and frame questions of interest to them, then to identify and manage additional information in answer to their questions. In investigative case-based learning, however, students develop questions that lend themselves to scientific investigation, they develop reasonable investigative approaches relevant to their questions, gather data and information to provide support for their conclusions, and work to persuade others of their findings. In this paper the terms “case study approach” and “case-based learning” are used interchangeably.

Keywords: biology education, case study approach, investigative case-based learning, PBL, teaching strategies

Introduction

Over the last decade there has been a growing realization that, somehow, science teaching and learning must become more effective. Study after study show that students are not able to use the science they have learned to address “real-world” problems (e.g., White, 1988). Worse, a recent NSF report “Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering and Technology” (SME&T) notes that while “America’s basic research in science, mathematics and engineering is world-class ... most of its population is virtually illiterate in science” (NSF, 1996. p. iii). While recognizing that many innovations and improvements have been taking place at the undergraduate level, the report notes that these are not yet widespread.

This NSF report recommends that “SME&T faculty: …

C. Build into every course inquiry [i.e., involving the student in asking questions and finding answers (p. 53)], the processes of science, a knowledge of what SME&T practitioners do, and the excitement of cutting edge research.

D. Devise and use pedagogy that develops skills for communications, teamwork, critical thinking and lifelong learning in each student...

F. Start with the student’s experience ... and relate the subject matter to things the student already knows. (pp. 65-66, NSF, 1996).

In this paper, we suggest that investigative case-based learning, an approach that encourages student-initiated science investigations as an outgrowth of case analysis, is one way to bring these elements into biology education. For a more complete presentation of the approach, several cases, examples, and scenarios of student learning, see Waterman and Stanley, 1998.

What is Case-Based Learning?

The use of cases is as old as storytelling itself. It is instruction by the use of narratives - stories - about individuals facing decisions or dilemmas. Learners are encouraged to engage with the characters and circumstances; to investigate so as to understand the facts, values, contexts, and decisions in the story; and to connect the meaning of the story to their own lives.

Models of case learning build on this general approach and formalize it in different ways to suit the subject matter and learning goals (Boerhrer and Linsky, 1990). Cases are most commonly used to teach decision-making skills to professionals. A well known model for this goal is the Harvard Business School case method (Christensen and Hansen, 1987) in which students receive extensive case histories that they individually analyze before attending a instructor-led, large class discussion. In the business school model, cases are often a culminating activity coming last in the instructional sequence.

A radically different case study model is called problem-based learning or PBL (Barrows and Tamblyn, 1980), which originated for learning medical biology and is being used at increasing numbers of US medical schools.
The goal of the original PBL model is learning of science subject matter, more so than development of medical decision-making skills. PBL strategies are now being used in many other settings in which science is learned, and the original medical model has many variations. Because the investigative case study approach builds on the original medical model, we present that model next. The version of medical PBL described here is the way the original model has been implemented at Harvard Medical School (Wilkerson and Feletti, 1989, Tosteson, et al., 1994).

The Original PBL Model of Case Study

The investigative case study approach to be discussed later in this paper is a variant of the original medical PBL model described by Barrows and Tamblyn (1980) and uses much of its basic framework. In the original PBL model, a group of students works together to read, analyze and understand a case which is a story about patients, their social contexts, and medical practitioners. In the original PBL model the case comes first in the instructional sequence, before or concurrently with lectures and labs. This placement is important because the case is being used to help students structure their learning of a new topic area.

An essential feature of the original PBL approach is that cases are analyzed by small groups of students working collaboratively. Students usually meet two to three times to work on any given case. Students read part of the case out loud, then discuss the elements presented thus far in the case. They draw upon what they already know, list their outstanding questions, and develop a learning agenda -- a set of issues they agree to pursue individually before their next meeting. In case discussion, then, students are actively engaged and working together to brainstorm issues, communicate what they know, and develop their plans for learning. In the original PBL model, the instructor plays a more facilitative role during case discussion, instead of a didactic or directive role.

The PBL cases as originally used serve as realistic contexts that define a problem space and help students organize their learning of a body of known information. As students identify what they already know and need to know in order to understand the case, their learning becomes self-directed within the context of the case. Since learning occurs around a particular realistic problem, there is greater likelihood that the learned material will be better retained and more easily applied to similar situations (Brown et al., 1989, Schmidt, 1983).

Classically, the case is first presented to medical students without guiding questions or statements of objectives. They may receive instructor-developed objectives after the first meeting or two. The delay in giving instructor-made questions is intended to ensure student-centered learning. Since the questions the students are pursuing are their own, they are more highly motivated to answer them than they are instructor- or text-posed questions.

The original PBL model addresses several of the elements identified in the NSF report. Students are using collaborative teamwork, they are starting with what they already know, and they are developing skills of communication and lifelong learning. The problems they are working on are complex and, like real problems, require learners to draw upon information from several disciplines. The multidisciplinary nature of the cases provides openings and opportunities for faculty to work together across disciplines as well.

As mentioned above, PBL strategies are being used for learning science outside of medical schools. The basic elements of the model are usually retained, with variation existing in such features as the amount of instructor directedness, the expected amount of collaboration among students, the degree to which the problem is focused or open-ended, when and if instructor-set learning goals are revealed, and the timing of the case in the curriculum. PBL as practiced in some of these settings can encourage inquiry (see for example, Bergland and Klyczek, 1996).

There are many strengths to the original PBL model that are retained in the investigative case study approach. For undergraduate and graduate science learning, however, we found the original PBL model to be lacking an important feature: as generally practiced at medical schools, PBL does not encourage students to initiate and undertake scientific investigations.

A New Use of Cases: Contexts for Developing Scientific Investigations

“One of the greatest challenges in biology is to frame appropriate and productive questions that can be pursued by the technology at hand. You have probably had a great deal of experience in solving pre-posed problems, such as those found at the end of textbook chapters. However, if you were asked to go into a lab or out in a field and pose a research question, you will find that this is often difficult to do without some practice.” The BioQUEST Library IV: A Note to the Student, 1996.

The investigative case study approach promotes research-like environments for learning biology. While the problem space is still defined by the case, students are not asked only to learn new material as in medical PBL. Students are asked to pose a researchable question about the biological phenomena. They must also develop accountable approaches to investigate these phenomena and then carry them out. Finally, they present conclusions to the class that provide a reasonable answer to this question.

Cases written for investigative learning in biology are deliberately open-ended. They don't provide all the details; rather, they sketch a situation and provide a rich space for generating researchable questions. The cases do not necessarily point the learner toward a specific problem, but rather open a context with many potential problems that students can define. This is a significant departure from the way cases are constructed for most PBL variants.

The investigative case-based approach encourages problem posing, investigation and persuasion. By using PBL strategies in this way, biology instructors can better serve a significant objective of science education: to teach science so that learners have an applicable and flexible knowledge of science content, as well as skill in investigation.

Instruction with cases can be organized in many ways, from pairs looking at minicases in a large lecture, to small groups studying a case for an extended period, to brief case discussions before and after laboratory experiences. Ideally, cases, lectures, labs and other instructional approaches would be well integrated within a course. One of the most important elements of the investigative case-based approach (retained from the origins) PBL model, however, is that it include collaborative discussion of the case issues. In that way, students can identify what they already know and what they need to find out in order to understand the case and pose a problem to investigate. For additional information on collaborative learning see Bruffee (1993).

What Are Some Ways of Proceeding with Investigative Case Learning in the Classroom?

At the 1996 BioQUEST Summer Faculty Workshop a group of biology faculty worked on case-based learning, wrote cases and thought about teaching biology with cases. One product of that group was an analysis of how the case study approach fits with the open-ended, investigative 3P’s teaching philosophy of BioQUEST: Problem posing, Problem solving and Peer persuasion. You may wish to use this framework, shown in the box below, as a way to think about what you might ask students to do as they work with cases.


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<td>Managing information</td>
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<td>Defining problem further (share views/info.)</td>
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<td>Designing and conducting investigations</td>
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<td>With simulation software for</td>
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<td>Modeling</td>
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<td>Representing information</td>
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<td>With field/laboratory methods</td>
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<td>With new resources (further references, interviews, etc.)</td>
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<td>Presenting conclusions of investigations</td>
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<td>Developing scientific analyses or reports to persuade peers</td>
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<td>Conducting debate/opposite views or outcomes</td>
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<td>Producing other materials that show understanding of the conclusions.</td>
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Working Through an Example Using This Framework

In the box entitled *Fleening Louisiana*, is a short biology case. The first paragraph will be used to work through the framework shown above. In case-based learning, the first thing to do is to see what the case is about. Read it through to get a sense of the story and issues.
One surprisingly productive case-learning method is to have one student read the case out loud while the others in the group read along silently. This sounds silly perhaps, but it gets everyone “on the same page” and students say it helps them get started. Have a good dictionary and reference books available for students to look things up quickly.

How to begin?

Individuals approach learning with cases in very different ways. You may wish to consider having students do one or more of the following after reading a case:

• Recognize potential issues. Go back and read the case again, this time noting words or phrases that seem to be important to understanding what the case is about. If students have a hard copy, they may underline these phrases. They are looking for learning issues that they might explore further. They might jot down ideas and questions about these phrases. If students are working in a group, this approach might be done as a group discussion, with one person keeping a list of issues (maybe on the chalkboard) as they are raised.

Here’s an example of some of the kinds of issues raised in one paragraph of Fleaing Louisiana (items that are underlined):

Moses Anders hung up the phone after talking with Ella Cardinale-Jones about her troubles. She had ticks on the dog, roaches in the house and hungry mosquitoes chewing up her kids. “Now Mr. Anders, I’m used to seeing some bugs around -- this is Louisiana. But it seems no matter what I do there are more and more of them. How can I get rid of them? I don’t feel like my children are safe.” Ms. Cardinale-Jones was the 19th caller about these insects* this month, and it was only January 7th.

Moses Anders is an intern with the Louisiana Cooperative Extension Service while he finishes his BS in biology. Moses dug out the last of the old tick, flea, and roach pamphlets in the files to send a copy to Ms. Cardinale-Jones. It said that these insects shouldn’t be significant problems until late spring, it didn’t mention mosquitoes, and the pamphlet did not really answer Ms. Cardinale-Jones questions.

He talked about this situation with his internship mentor Fran Collins, an agent who has been with the Service for several years. “Yeah,” she said, “it’s been really busy this winter. In fact, it’s been this way all the time for a couple of years now.” She agreed with Moses that the pamphlet needed to be updated and that he could take on the project, once he’d given her a work plan and time line.

Moses and Judy Yee, an intern in the public health office, traded stories over lunch at one of the city’s crowded outdoor cafes. She told him that the first case of Lyme disease in the area had recently been reported, and he told her about his new project. Their talk turned to the weather as they made their way back to work.

*The author is well aware that ticks are not insects but arachnids, but because many Extension Services and even Entomology Departments include these in their pest lists along with insects and the general public thinks of them as all being “bugs” or insects, we have treated them in a similar manner. Certainly, you can point out the difference to your class if they do not do so to you before you get around to it.
• **Pose specific questions.** Another way to generate ideas and connections is to be clear about what is known so far, and then to see what questions arise.

  **What we know now:** It’s January in Louisiana. There are lots of insects, perhaps more than usual, and people with safety concerns are calling Moses Anders about this.

  Using the first paragraph again as an example, here are some questions raised by learners who have worked with this case:

  ✓ Why are there lots of insects in January? What affects the number of insects at any given time of year? Are there really more than usual? What is the usual pattern?
  ✓ Why is Ms. Cardinale-Jones concerned for the safety of her children? What diseases do ticks, roaches, and mosquitoes carry? Are there other reasons besides disease to be concerned about these insects?
  ✓ What can Ms. Cardinale-Jones do to control the insects? What advice should Moses give her? What is the biology of ticks? Roaches? Mosquitoes?
  ✓ Why are people calling Moses Anders about this? What do they think he knows or can do for them? What sorts of jobs deal with these issues?

  By generalizing on the questions raised, students can identify potential learning issues. For any one of these issues, they may generate further questions to structure their learning.

  **Potential learning issues:** Insect populations and the factors that affect them. Problems posed to humans by insects. Insect control measures. Unusual insect occurrences in winter. The job held by Moses that would lead people to call him.

  Brainstorming can lead to a long list of questions, and there is not time to pursue them all. Have groups spend time identifying a few key questions of interest. Students are usually careful to use the contextual clues provided by the course title, syllabus topics, etc., as ways to help them narrow the list of potential topics. But you never know, a student may become very interested in a good question that is only tangential to the case. If the goal is to learn to pose questions, solve problems, and argue convincingly, some instructors might decide any topic related to the case is fair game.

  The questions raised by the brainstorming can lead to different sorts of learning activities. Remember that the goal with investigative case-based learning is to develop problems of interest to students, that can be investigated using the tools of science. Below is an analysis of some of the different types of learning that might follow from some of the questions on the brainstorming list.

  • **Define problems further by sharing views and concerns:** As learners define problems and frame specific questions to investigate, it will be important for them to consult with others: most likely members of the group or other classmates. Talking about ideas and plans with others is an important step in refining problems, and can lead to different perspectives that might help shape good research problems. You might want to save some class time for this kind of activity, or students could do it on-line, or out of class. Encourage learners to continue this practice of sharing their ideas, plans and concerns with others as they gather evidence in answer to the problem and as they prepare to present conclusions. Such conversation and collaboration is a hallmark of the work of scientists.

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<tr>
<th>Learning Activity</th>
<th>Questions</th>
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<tr>
<td>Further brainstorming</td>
<td>“Why is Ms. Cardinale-Jones concerned for the safety of her children?” or “What affects the number of insects at any given time of year?” or “What sorts of jobs deal with these issues?”</td>
</tr>
<tr>
<td>Searching out basic facts</td>
<td>“What diseases do the insects carry?” or “What is the biology of ticks?” or “What advice should Moses give her?” These questions in and of themselves do not pose a scientific research problem, but learning more about these may lead to other questions that are scientific.</td>
</tr>
<tr>
<td>Decision making.</td>
<td>“What advice should Moses give her?” Students will need to understand the issues, and evaluate the consequences of the options before they can answer this question. Group discussion and negotiation of diverse viewpoints will also be involved.</td>
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<tr>
<td>Finding information, analyzing it and finding patterns.</td>
<td>“What is the usual pattern of insects in Louisiana?” and “Is it different this year?” These questions might lead students to the Internet or elsewhere to get insect sampling data for analysis.</td>
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<tr>
<td>Scientific investigations</td>
<td>“What affects the number of insects at any given time of year?” could be refined to focus on climatic variables. These could then be investigated by modeling (with Biota or EDM), by actually collecting weather and insect population data, by using data sets collected by others, or by finding published information on the topic.</td>
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We’ve Got a Question, Now What?

Once the students clearly define a problem they wish to investigate, you might consider proposing that they do any of the following:

“Research is not complete, no matter how many experiments have been conducted, no matter how many puzzles have been solved, until peers outside of a research team are persuaded of the utility of the answers. Persuasion is a social process and an essential one for you to experience in order to understand the nature of scientific theories and paradigm shifts. Communication in the science community is an active process full of controversy and debate. The productive side of science involves open criticism of the methods and conclusions made by a research group. This controversy and debate is important to the creation and acceptance of new scientific knowledge.”

(The BioQUEST Library IV: A Note to the Student, Soderberg, 1996)

- Obtain additional references/resources. No matter what type of question learners pose, it is likely they will seek and use additional resources to help them support and research a reasonable answer. Resources may include textbooks; other library materials; results of computer simulations; results of lab or field research; articles from professional journals or popular press; data sets, maps, emails, websites or other electronically based resources; pamphlets from organizations; interviews with experts; information from museum exhibits, etc. Encourage students to be creative in seeking information.

  Suppose, for example, the students chose to study the question: What affects the number of ticks or mosquitoes in Louisiana at any given time of year? They could consult entomology books to learn the basic biology of the chosen insect, or they could locate tick or mosquito sites on the World Wide Web. Such sites might include annual data on mosquito prevalence collected by the CDC, or it might include a scientist describing his/her research on global warming and insect populations. They could search the professional literature for likely articles. They might contact a Lyme disease support group to see how to find information on tick prevalence. They could see if the cooperative extension service had contacts with scientists who regularly sample insect populations or who work on insect control. A different sort of resource students could seek might be computer simulation software that could potentially be used for modeling studies.

- Design and conduct scientific investigations. These might use appropriate laboratory or field methods or perhaps computers with relevant software modules, spreadsheets, graphics, etc. One important mode in which scientists operate is the synthesis of pieces of existing information into a new theoretical framework (work which may be accompanied by modeling, as was done by Watson and Crick). Students might locate datasets, conduct interviews, and gather ideas from their reading and library research. What makes this kind of work scientific is the use of these bits of information to form a new, justifiable and testable point of view.

  For our example, the students might decide to use insect trapping methods to assess insect population size and dynamics over a several month period. (They might even propose it as a multiyear project, to be carried on by future students.) Or they might decide to use software like BioQUEST’s Biota or Environmental Decision Making to investigate and model the effect on insect populations of changing climactic variables. Their instructor might have laboratory experiences coordinated with this case, so that, for example, students learn concepts of population dynamics using models and simulations. Then the students could tailor these skills to their specific question.

How to End? (Peer Persuasion)

  When learners are ready to present their own conclusions, consider asking them to do one or more of the following:

- Develop scientific analyses and reports to persuade others of the ideas. Any of the formats that scientists use to describe their work might be appropriate here. These might include: a report written in the format of an appropriate journal, a poster such as might be presented at a professional meeting, an article about the work for the popular press, or a report such as scientists in an organization might write to administrators. Such reports or posters would provide an evidence-backed position on the question.

  For our example, students studying insect patterns might include data tables, photographs of insect-laden traps at various times of the year, or relevant printouts from the simulation programs in their reports.

- Produce materials that support understanding of the conclusions you are making. The possibilities for these materials are vast: posters, poetry, plays, videos, booklets, pamphlets, consulting reports (if you are role playing), artwork, designs for new technology, scientific publications, newspaper stories, a new case study, etc.

  For Fleaing Louisiana, learners might produce a new pamphlet that includes the information about yearly fluctuation in insect populations, a scientifically based public talk of the kind extension agents offer, or
a set of insect control guidelines. Any of these could be used to incorporate findings from student scientific investigations of the questions.

• **Initiate debate on views or outcomes.** This could be several things. It could be that a poster session is set up, with a discussion (led by a commentator?) on the views and outcomes presented. Or, it could be an actual debate. For “Flealing Louisiana,” a debate on global warming might be something teams of students might choose to prepare. Or it could be a format that brings in perspectives in addition to the scientific. For example, in the case of global warming it could be a heated exchange of letters to the editor in a newspaper (such as happened in my town this year) or a fictional email exchange between opponents and proponents of global warming. The perspective of an anti-global warming member of Congress could be represented for other students to respond to, as a persuasive exercise.

**Conclusion**

While no one method or educational approach is a panacea for science education, investigative case-based learning offers promise as one more tool in the biology instructor’s toolbox. The investigative case study approach addresses several of the elements identified in the NSF report. Students work collaboratively. They begin their learning with questions stemming from or based on what they already know. As they work in teams and as they present their findings they develop communication skills and the information management skills needed for lifelong learning. Most importantly, students develop and use skills of scientific inquiry as they develop, conduct and present their own investigations.

Interest in case-based approaches is rapidly growing in biology education: our Internet searches have turned up numerous examples of people using narratives to structure student learning. Few of these are designed to be truly investigative, but many would lend themselves to that pedagogy. See, for example the project called “Hello Dolly” and several items in the *Handbook of Engaged Learning Projects* (Fermi National Lab, online, Fraccaro, W. et al., online and Peretz, S., online). Resources for connecting with others using cases are listed in the box to the right.

**Some Starting References on Cases and Problem-Based Learning**

In addition to those in the Literature Cited:


Connecting via Internet to others using cases and PBL:

• See also the Fermi Lab references in Literature Cited.

• The University of Delaware is using cases and other forms of problems for an institution-wide reform of science learning and teaching. [http://www.udel.edu/pbl/]

• Clyde Herreid has been working with faculty at the University of Buffalo on case-based science learning for several years. This is a well-organized web site, with links to many other projects and faculty working with cases in several disciplines. [http://ublib.buffalo.edu/libraries/projects/cases/case.html]

• At the University of Oregon a group has been developing “workshop” biology for the past few years and uses some case material, especially for the “issues” activities. [http://biology.uoregon.edu/Biology_WWW/Workshop_Biol/Activities/format.html]

• At Niagara University, a project on cases for human anatomy and physiology is underway. They have a few cases on line, and some highly structured questions that accompany them. [http://www.niagara.edu/~bcliff/]

• The BioQUEST Curriculum Consortium has been working on the problem of connecting cases to open-ended student investigations. A multipart case “Kingdom’s Entangled: Molecules, Malaria, and Maize” is designed to help students and faculty raise researchable questions. The case is supported by the BioQUEST library of investigative software. For the complete case, see also Waterman and Stanley, 1998. [http://bioquest.org]

• Mark Bergland has developed Case It (also part of BioQUEST Library), a DNA electrophoresis simulation with cases to be solved. [http://www.uwrf.edu/~mb02/welcome.html]

**Literature Cited**


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