Incorporating a Literature-Based Learning Approach into a Lab Course to Increase Student Understanding

Beth A. Parent, Gili Marbach-Ad, Karen V. Swanson and Ann C. Smith

College of Chemical and Life Sciences, University of Maryland, College Park, MD 20742

Email: parent@umd.edu

Abstract: Scientific literature was used to give a research oriented context to our immunology lab course. Immunology lab, a senior level course (60 students/year) was formerly taught in a traditional mode, with exercises aimed at learning lab protocols. To engage students in understanding we connected the protocols to their use as reported in research articles, employing an interrupted case study method called Literature Based Learning (LBL). Our goals were to give a research context to learning basic protocols, engage students in reading scientific literature, and increase students' understanding of how standard techniques are employed to address a research question. An end of semester experimental design project using mock research scenarios culminated the research oriented learning. Pre-course surveys revealed that nearly 25% of students had never been asked in the course setting to read a primary research article. Post-course surveys revealed that 94% of students thought that after the course they knew more about research and over half of the students agreed that the literature-based assignments had raised their confidence in their ability to understand scientific articles. We found that the LBL approach was an effective mechanism to engage our students in research oriented learning. While easy to implement, it had a dramatic outcome.

Key words: Literature-based learning, biology laboratory, group work, experimental design project, undergraduate course.

INTRODUCTION

When baking a cake for a party there is generally little concern over why eggs are added as long as the cake is delicious at the dinner party. Similarly students who are asked to generate a prescribed outcome from completing a protocol generally don't much care why they are doing each step as long as they get the "right" answer. Students begin to believe that science is about the answer and not about the process. When aiming only for the end result students are less likely to be engaged and as such miss the opportunity for understanding of both the scientific process and underlying scientific concepts (Schamel and Ayres, 1992).

The goals of the National Research Council's *National Science Education Standards* (1996) are for students to gain a long-term understanding of science concepts, an insight into the nature of science, and an appreciation of the skills that are necessary for scientific research. Laboratory courses are an ideal environment to meet these aims. Unfortunately, the way many labs are structured works against these goals. As Bransford, Brown, and Cocking (2000) state, there are important differences between tasks and projects that encourage hands-on doing and those that encourage doing with understanding. In traditional "cookbook" labs, many if not all of the questions and decisions that are a part of the scientific inquiry process are provided for students (Bybee, 2002).

The National Research Council's BIO2010 report (2003) states that lab courses should allow students to think independently, introduce them to authentic scientific questions and incorporate cooperative learning. The report recommends that project-based laboratories with discovery components replace traditional scripted "cookbook" laboratories to develop the capacity of students to tackle increasingly challenging projects with greater independence. These changes should increase student interest and participation and improve student written and oral presentation of scientific information. A review by Lawson (1992) indicated that changes in lab design towards investigative labs increases students' reasoning skills, concept understanding and, overall how much students "like" lab.

A specific skill that is often overlooked in the national discussions of teaching the process of science is the use of scientific literature. As an undeniably important source of information for scientists, the research literature should be a critical training ground for young science professionals. Not only does teaching students to work with the scientific literature model the activities of scientists, but having students read, interpret, analyze, and report on the research literature provides opportunities to develop skills of critical and analytical thinking and written and/or oral communication (Mulnix, 2003). Even when aware of the literature, students often find scientific papers difficult to understand and digest. In part this is because the style of scientific papers is very different from that of most other reading, including textbooks (Porter, 2005).

With this in mind, we set out to modify our existing immunology lab course to increase student understanding of standard immunological techniques using a "Literature-Based Learning" (LBL) approach. To actively involve all students in the LBL approach we used the "Interrupted Case Study Method" (Herreid, 2005) in which information is given to the students in a series of steps ("progressive disclosure" of information) allowing students to think about and discuss each step before receiving information that reveals the authors' thought process. For example Herreid (2005) suggests that a research article could be used as an interrupted case study: students receive and read the introduction section; from this alone they propose methods to address the research question. Then, students receive and read the remainder of the research article and discuss how their proposed research approach compared with that described by the authors.

This course re-design was part of the Host Pathogen Interactions Teaching group project to introduce research-oriented learning into our microbiology courses. In this paper, we will report on our teaching approach and the assessment of student engagement, and understanding of methodologies in context of immunological techniques and research design.

METHODS

Our course re-design had three specific aims: 1. learning of standard immunological techniques/protocols, 2. understanding the theory and the use of techniques/protocols, and 3. applying the techniques/protocols to authentic research problems. Aim 1 was achieved by teaching the techniques and protocols as is typically done in a lab course. Aims 2 and 3 were achieved by placing the use of the techniques/protocols in the context of research design – either from published articles or as developed by the students.

Our design involved a two credit 400 level Immunology lab course that met for two hours twice a week (separate from the 400 level Immunology lecture course which is a co-requisite). Students were divided into three lab sections of 20 or fewer students taught by graduate teaching assistants. Course enrollment consisted of 56 upper-class students in three sections. Lab sections were each taught by one graduate teaching assistant per section, and the lab was coordinated by one lab coordinator. Assessment was achieved through a post-course survey that 52 of the 56 students completed.

Immunology lab design prior to innovation

The course focused on teaching standard immunological techniques/protocols which were implemented by the students as they were instructed (see Table 1, not bold). Prior to each lab period students were given background information on the protocol of the day. During the lab period the teaching assistant gave a brief lecture and students performed the protocols. After the lab period students were expected to write a brief lab report highlighting the method and results obtained. In addition to lab reports students were assessed by exams (two during the semester and a final exam) and a final project on immune-related diseases. Each student was assigned a disease and was expected to prepare and present a poster on the symptoms and other characteristics of the disease.

Revised course design: Overlay of Literature-Based Learning

In the revised course, learning immunology techniques/protocols was put into an authentic research context by requiring students to read and discuss relevant primary literature (Table 1 – Bold). To orient the students to reading primary literature, a primer article was assigned. This article (Parent [Appendix 1], 2010) was carefully chosen to be short, (7 pages and 5 figures) straightforward, at the level of the beginning immunology student and following a standard research article design with sections: Introduction, Materials and Methods, Results and Discussion.

Beginning in lab period six, research articles (Parent [Appendix 1], 2010) were distributed to engage students in understanding the context of immunology protocols. As with the primer article, we chose articles that had clear introduction, methods, results and discussion sections. We avoided articles from journals such as *Science* or *Nature* as these do not have these clearly defined sections. They also have very strict page limits which means much of the jargon, techniques, etc. are not explained in any detail. The articles we chose needed to be well written, with an introduction that had good background and a clear question/hypothesis and results that were understandable to undergraduate students. The articles were chosen because of their relevance to topics of immunology (the course topic) and pathogenesis (the focus of the Host Pathogen Interactions Teaching Team). We chose articles that used *E. coli* or *Streptococcus pneumoniae* as these were selected by the Host Pathogen Interactions Teaching Team as the "anchor organisms" for teaching concepts of Host Pathogen Interactions (Authors, 2007). Finally, the articles were selected for their use of the immunological methods that students would learn over the course of the semester.

Table 1: The Literature-Based Learning overlaid on a traditional laboratory

Lab 1: Organs of the Immune System
Paper 1: PRIMER Students read complete research paper—Bring all students to a comfort level in reading a research paper
Lab 2: Peripheral Blood Smear
Lab 3: Blood Cell Separation
Lab 4: Precipitation
Lab 5: Agglutination
Lab 6: Antibody Conjugation
Paper 2: Part 1: Students receive introduction of research paper, propose research question and techniques –Labs 1-6 are put into context. Part 2: One week later students receive complete paper and discuss—Their understanding is compared to the experts.
Lab 7: Immunofluorescence microscopy
Lab 8: ELISA
Exam I
Lab 9: Immunoprecipitation
Paper 3: Part 1: Students receive introduction of research paper, propose research question and techniques –Labs 7-8 are put into context. Part 2: One week later students receive complete paper and discuss—Their understanding is compared to the experts.
Lab 10: SDS-PAGE and Western blot
Paper 4: Part 1: Students receive introduction of research paper, propose research question and techniques –Labs 9-10 are put into context. Part 2: One week later students receive complete paper and discuss—Their understanding is compared to the experts.
Lab 11: Flow cytometry
Exam II
Experimental Design Project Lecture and group work: Students receive a research scenario, determine a research question and design experiments, using immunological techniques—Requires that all course learning is applied in a research context.
Lab 12: Antibody mediated cytolysis and cell count
Lab 13: Lymphocyte proliferation
Lab 14: Microbial killing by macrophages
Students carry out experiments for three lab periods
Students present all information in poster format with an oral presentation—Requires students to demonstrate understanding of techniques and present in mode of a research scientist.
Paper 5: Students read complete paper—culminating activity: Was there an increase in appreciation for information presented?
Final Exam

We found that some older papers were the best choices to give context to the more standard/classic immunologic methods taught in our course.

Articles were distributed to students in sections according to a modified interrupted case study approach (Herreid, 2005). First, the students received the introduction section: they were asked to determine the specific research question, and to choose a technique (from the techniques previously learned in lab) that would be most appropriate to address the proposed research question (Parent [Appendix 2], 2010).

In lab students would discuss their responses and then receive the complete research article. At this point the authors' research question was revealed along with the experimental design and the techniques used (Parent [Appendix 1], 2010). The interrupted case study approach was used to engage students in understanding scientific research by engaging them in the same process that was first followed by the authors. Student discussion was meant to help students learn that there may be more than one way to state a research question, and a variety of experimental approaches or techniques may be appropriate to address the question. Throughout the semester students had the opportunity to see the protocols they learned in lab used in authentic context and they were engaged in the research process. Like the authors of the research articles, the students developed research questions and chose from protocols or techniques that they had learned to address open ended research questions (cf. Table 1 and Parent [Appendix 2], 2010).

To cement student understanding of how standard techniques/protocols are applied to address research questions students completed an end of semester Experimental Design Project (EDP). Students worked in teams to address a research scenario (Parent [Appendix 3], 2010). Because of the complicated nature and potential high cost of immunology research, we chose to use mock scenarios. Students received authentic research stories, but most of the samples with which they worked were mock. For instance, bovine serum albumin (BSA) was used to simulate various proteins and B cells were used to simulate other types of cells. This way we only had to purchase a limited number of antibodies that were against common antigens (BSA, B cell receptor). This helped keep the cost of the projects within the course budget. Teams of 3-4 students were established at the start of the semester based upon student self-selection. Students were expected to discuss the problem, define a testable research question and apply any of the immunology techniques/ protocols learned over the semester. Following completion of the lab work (3 lab periods) students presented their research methods/design, results and conclusions in an oral poster presentation to their peers.

Profile of students

Students that responded to the pre- and post-course survey (52 students) were asked to provide details about their background. We respect students' sensitivity towards exposing background information; therefore we present the distribution of data that we gathered from the survey and not from their transcripts. Figure 1 shows the percentages for those who provided the information.

Gender: (47 students)
55% females
45% males

Age: (47 students)
15% between 19 to 20
72% between 21 to 25
6.5% between 26 to 30
6.5% above 30

Ethnicity: (43 students)
2% African –American
26% Asian
67% Caucasian
5% Hispanic

GPA: (40 students)
10% GPA 2.0-2.5
26% GPA 2.6-3.0
44% GPA 3.1-3.5
20% GPA 3.6-4.0

Final grade in the prerequisite General Microbiology class: (40 students)
55% A; 30% B; 15% C.

96% of the students were Biology majors

Fig. 1. Student background information

Research instruments

Pre-course survey

To assess the students' competency and comfort in reading scientific literature and their knowledge of immunological techniques prior to this class a pre-course survey was administered through WebCT (Web Course Tool). Students were asked to complete open ended questions about their:

- familiarity with immunological techniques in general and with respect to the exact techniques and protocols that would be covered during the course.
- background (year in school, gender, race, GPA etc.), their expectations for the class and their plans after graduation.

Since these questions were open-ended, similar responses were grouped into categories. This approach was validated by the lab coordinator of the course, another science faculty member and a science education expert.

Post-course survey

To receive student feedback regarding the incorporation of the Literature-Based Learning and the Experimental Design Project, a post-course survey was administered through WebCT (for the full survey cf. Parent [Appendix 4], 2010). Analysis of the open-ended questions was performed as stated for the pre-course survey. To assess students' level of competency in reading and understanding primary literature (Table 1 and Parent [Appendix 2], 2010), we assigned the reading of one last research article to students.

RESULTS

The pre-course survey was given to the class in the beginning of the course. Fifty-two students responded to the pre-course survey. Fifty-one students responded to the pre-course question "What are your expectations from this course?" The majority of the students (26) that responded to this question indicated that they expected to learn more about immunology in general. Fourteen students indicated that they wanted to learn about procedures and hands-on techniques that are used in labs. Nine students referred to their expectation to be prepared for medical school, research lab, or other career choice. Six students referred to the applicability of the laboratory to everyday life. Three students reported that they expected the lab to apply to or reinforce concepts learned in the Immunology lecture course. Three students mentioned their expectation to learn about current research/articles and understand them. Three students wished they would pass the course with a good/decent grade. Only one student brought up the expectation that the course would be interesting.

Fifty students answered the pre-course question “What are your future plans?” The majority (43 students) reported that they intend to pursue an advanced degree (medical school, graduate school, dental school, physician assistant program, veterinary school, pharmacy school, optometry school and law school). The others (7 students) responded that they intend to obtain jobs that do not require further education (military, government, high school teacher and pharmaceutical sales).

As mentioned in the methods section, the post-course survey included twenty-five questions (Parent [Appendix 4], 2010). The questions targeted the evaluation of the three major innovative initiatives in this lab: reading research papers, implementing the Experimental Design Project (EDP), and working in groups.

Reading Research Papers

The main goal of the primer paper (research article 1) assignment was to share with the students how scientific work is presented to other scientists through a formal research paper. Therefore, in the post course survey we asked students to reflect how much they learned about how scientific work is formally presented (Question 11, Parent [Appendix 4], 2010). Fifty-eight of the students (30) reported that by completing the paper 1 assignment they learned more about how science is presented. Interestingly, most of these students (17) reported that they already understood how scientific work is presented prior to the course, but the assignment helped to increase their understanding. From the 42% of the students (22) that reported that they did not feel that the assignment increased their learning on this topic, thirteen students reported that they already understood how scientific work is presented prior to the course instruction.

The primary rationale for assigning research articles 2-4 was to expose to students the process scientists use to formulate a research question (Parent [Appendix 4], 2010, Question 12) and to select appropriate techniques/protocols to address a given research question (Parent [Appendix 4], 2010, Question 13). The majority of the students (81%) reported that they learned more about how to formulate a research question from the assignments for papers 2, 3 and 4 (Question 12). Most of these students reported that they had some understanding (33%) or that they understood (31%) how to formulate a research question prior to the course, but gained more understanding from the assignments. Only 19% of the students did not report any increase in learning on this topic. The response pattern for question 13 was similar to that of question 12. Most of the students (88%) reported that they learned more about how to choose appropriate research techniques from the assignments for papers 2, 3 and 4.

Overall, students were very positive regarding the use of the papers during the course. In response to the question *“*Five research papers were used in this course. What did you like about the research papers and the way that they were used?” (Question 4), the majority of the students (92%) responded with positive comments. Students reported that reading the papers gave them an understanding of the research process and how research is presented and refined their ability to read research papers (“I appreciated how the research paper assignments taught me how to be able to pick up a scientific paper without being overwhelmed… I liked that the assignments for each paper were primarily the same each time. The repetition of assignments for the papers really helped me to practice on how to read and analyze these papers”).

Students also commented that the papers allowed them to see how techniques learned in the lab are applied (“…It was nice to see how the exact assays we performed in class were applied in actual scientific studies,” “…It really helped me reinforce the knowledge of immunology techniques that we learned over the course of the semester”). Other students mentioned that the papers were interesting and made them think (“…It also made us critical thinkers in regards to other possible techniques that could have been done”). The four negative comments indicated that these students found that the reading was not challenging and did not extend their learning.

Implementing Experimental Design Project (EDP)

All students responding to the survey submitted a positive comment regarding the completion of the EDP. Table 2 shows categories of students’ responses to the question “What did you like about the Experimental Design Project (EDP)?” (Question 15). Students reported that they liked that the EDP allowed them to be creative and work independently on their own project. One student stated,

“I liked the idea of being left to figure out the research question on my own. This broke away the repetitive four year lab process where I would normally be given protocols and forced to carry them out. When you know what the end result is supposed to be, you feel less concerned about answering your question and the goal basically becomes ‘getting through the lab’. However, the research project forced me to use some creativity to try and figure out what I need to do. I mean our group almost figures out how to design our experiment by ourselves…”

Students also liked that the EDP required them to work in groups ("… I liked the fact that we actually carried out the experiment in a group like labs in the work place").

Working in Groups

Students were asked to describe the one thing that they found most rewarding about working in a group for the Experimental Design Project (Question 17). Students reported that the group work allowed them to share ideas (16 students), learn more from others (11 students) and share responsibilities (10 students). One student wrote, "The people in the group complemented one another's strengths and weaknesses. It seemed like, while one person might be good at coming up with the methods, another would be good at interpreting results... I felt like I learned from other people". Students also mentioned that the group made the work more fun, allowed them to make friends and learn how to think (8 students).

Overall most of the students thought that after the course they knew more about research than before the course (94%). Eighty-one percent reported that the course met their expectations and 12% reported that the course exceeded their expectations. Ninety-six percent of the students indicated that they would recommend this course to their friends. Students found the course interesting and challenging. They enjoyed learning immunological techniques and found that the design of the course gave them an exposure to and appreciation for the research setting.

Table 2: Frequency of students' responses to the question about the use of the Experimental Design Project (EDP) in the course.

15. What did you like about the Experimental Design Project (EDP)? (Categories)	No. of responses*
The EDP allowed an opportunity for me to design my own project/be creative/work independently.	27
The EDP allowed me to apply what I learned in lab this semester.	18
The EDP was like a true research experience (an authentic learning opportunity).	14
The EDP required me to think/understand.	8
The EDP allowed me to work with my peers.	8

* The sum of a single column can exceed 100% because there are students whose responses fell into more than one category.

DISCUSSION AND IMPLICATIONS

The teaching standards set forth by the National Research Council (1996), the AAAS (1993), and BIO2010 (2003) call for the science curriculum to emphasize research processes such as understanding, reasoning, and problem solving. Students need to acquire skills that are necessary for scientific research and understand how scientists work (Handlesman, 2004). However, the sense of discovery felt by scientists involved in generating new information is unfortunately rarely communicated to undergraduates. Instead, instructors often feel compelled to teach their students an ever growing body of facts. As a consequence, many undergraduates have little sense of how scientific knowledge is generated, how research projects progress over time, or how scientists think about and actually do research (Pukkila, 2004).

The Host Pathogen Interactions teaching group (website will be given after review process) is concerned with meeting the goals of the NRC, AAAS and BIO2010 and creating experiences for research oriented learning. The Literature Based Learning model was designed to engage students in learning basic immunology techniques in the context of current literature of Host Pathogen Interactions, specifically targeting *E. coli* and *Streptococcus pneumoniae* (Author, 2007). In the model reported here students learn and apply basic immunology techniques/protocols in the context of authentic research. Students completed readings relevant to protocols and later through the Experimental Design Project students worked co-operatively to apply these protocols to authentic research problems.

The majority of the students responded with positive comments regarding the research papers, and all students submitted positive comments regarding the completion of the EDP. Students liked the exposure to the scientific literature which made them think, showed them how techniques are applied and helped them understand how science information is presented. Students mainly reported that they liked the independence of working on a project of their own design. They appreciated the opportunity to apply techniques that they had learned in a manner that was designed to mimic the authentic research setting. Most of the students also reported that the research papers and the course assignments were useful in preparing them for the Experimental Design Project. Students liked and seemed to benefit from the group work where they had the opportunity to share ideas, work in a collaborative and collegial setting on a project that was their shared responsibility.

The Literature-Based Learning approach could be overlaid upon any technique-oriented lab course. The most significant increase in time required for implementation comes from the time needed to select appropriate readings and develop the scenarios for the Experimental Design Project which are to be based on published research studies and must utilize the techniques learned in the course. Our impression of the revised course is that it is dramatically improved. The students are more engaged and enthusiastic about their work. From student reactions and the level of knowledge expressed by students during poster sessions it is clear that student understanding of scientific research and immunological methods are increased from the level in the previous course design. Using the interrupted case study method to parse out the reading of primary literature in connection with learning standard protocols provided the basis of a research-oriented approach to lab science instruction. This Literature-Based Learning approach was first implemented in spring 2005 and continues to be used with similar success.

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