

# Engaging Introductory Biology Students in Independent Research Projects Based on Critical Analysis (or a Meta-analysis) of Open Questions in the Literature

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If students are to develop science literacy they must be given multiple opportunities to critically analyze and evaluate information. In our Introductory Biology 151 and 152 labs we require students to:

- find, review and critically evaluate background literature
- design and conduct experiments
- analyze information gained and
- communicate what they find in scientific format.

This culminates in a semester-long independent project. This paper focuses on the methods I developed to teach students how to conduct a meta-analysis, i.e., how to develop a research question and how to mine data from the literature and critically analyze it.

**Keywords:** Meta-analysis, critical evaluation of literature, independent project, library-based research

## Introduction

For more than 20 years major studies have indicated the importance of involving undergraduates in research experiences early in their college careers. Among these studies are: the *Report on the National Science Foundation Disciplinary Workshops on Undergraduate Education* (1989), the National Science Education Standards (1996), *Bio2010: Transforming Undergraduate Education for Future Research Biologists* (2003) and most recently, *Vision and Change in Undergraduate Biology Education: A Call to Action*, published in 2011.

*Bio2010: Transforming Undergraduate Education for Future Research Biologists* does a good job of representing the general recommendations made in these different studies by stating: “To successfully undertake careers in research after graduation, students will need scientific knowledge, practice with experimental design, quantitative abilities, and communication skills... All students should be encouraged to pursue independent research as early as is practical in their education.” This leads us to the general question: how do these recommendations differ from those of today’s professional schools and employers? In addition, how do these differ from what our own students know they will need in their future careers?

It turns out it is fairly easy to find the answers to these questions. In my first lab sessions of the semester I ask my students “What skills and abilities will you need to use on a

regular basis in your future career (whatever it may be)?” I let the students discuss this for a few minutes and then collect ideas from them. To date I’ve asked over 3000 students this question. I have also asked the same question of more than 200 biology faculty. Bottom line: I get the same answers from both groups. With some variation, their lists all tend to include the following skills and abilities:

- Problem solving skills
- Communication skills (both written and oral)
- People skills, e.g., the ability to work well in groups
- Ability to think critically
- Organizational skills
- Ability to learn from one’s mistakes and a willingness to continue learning
- Ability to be flexible, to think on your feet
- Having a good base knowledge of the material

I find it very useful to have my students generate this list for me. Since they recognize the need for these skills I can use their own words to support specific goals of our courses, e.g., improving communication skills. This list also aligns very well with the Essential Learning Outcomes and the Principles of Excellence, published by Liberal Education and America’s Promise (LEAP) in association with the Association of American Colleges and Universities and many key businesses and professional schools. These skills also align with what professional schools and employers want.

Here is a list of the top ten things employers look for in new college graduates:

### **Top Ten Things Employers Look for in New College Graduates**

1. The ability to work well in teams – especially with people different from yourself
2. An understanding of science and technology and how these subjects are used in real-world settings
3. The ability to write and speak well
4. The ability to think clearly about complex problems
5. The ability to analyze a problem to develop workable solutions
6. An understanding of global context in which work is now done
7. The ability to be creative and innovative in solving problems
8. The ability to apply knowledge and skills to new settings
9. The ability to understand numbers and statistics
10. A strong sense of ethics and integrity

Source: <http://www.aacu.org/leap/students/employerstopten.cfm>

And if that isn't enough to impress our students here is a list from the producers of the *How-to Books for Dummies* at their dummies.com site:

### **Skills and Personal Qualities that Employers Want**

1. Effective communication
2. Computer and technical literacy
3. Problem solving/creativity
4. Interpersonal abilities
5. Teamwork skills
6. Diversity sensitivity
7. Planning and organizing
8. Leadership and management
9. Adaptability and flexibility
10. Professionalism and work ethic
11. Positive attitude and energy

Source: <http://www.dummies.com/how-to/content/skills-and-personal-qualities-that-employers-want.html>

I use these lists to make the following points with my students:

1. You will notice none of these lists are tied to specific majors. They apply to all majors.
2. If this is true, what does all this have to do with being successful in biology (or any other career)? Bottom line: To be good in biology (or in anything else for that matter), you need a good understanding of the facts and techniques. But more importantly, you need to be able to add to that knowledge base on your own and use the knowledge you have to work out solutions to problems that don't appear in textbooks. Oh—and of course having these abilities isn't enough—you need to effectively communicate what you know what you have found, etc.
3. In other words, you need knowledge of facts, but you also need practice in all of these skills and abilities. Doing independent research is one good way of doing all of these things. And as an added benefit you can do this all in an area of interest for your future career.

As noted above, there is no question that our students know the skills and abilities they will need in the future. The questions then become:

- Are we helping our students build these skills and abilities in our intro courses?
- What role(s) can the lab play in this?

In Introductory Biology 152 (the second semester of a two-semester course for biology majors), all students are required to do an independent project on either (a) mentored experimental research or (b) a meta-analysis of an open question using data mined from existing literature. The independent project accounts for half of their lab grade in the course or about 1 of the 5 credits (with lecture being 3 credits). The focus of this paper is on the methods I have developed to teach students how to conduct a meta-analysis, i.e., how to develop a research question and how to mine data from the literature and critically analyze it. The mentored experimental research option has been described in a previous publication; see Heitz and Giffen (2010).

## Student Outline

### What types of lab activities did I develop?

I have developed a lab manual, *Experiencing Biology from Proposal to Presentation*, designed to guide students through the process. During the first three labs of the semester, students focus on Chapters 1 and 2. Chapter 1 addresses the questions:

1. How do we develop a research question? (Week 1)
2. How do we critically analyze scientific literature? (Week 2)

Chapter 2 focuses on Using the Library for Scientific Research and is conducted in association with the biology librarians during Week 3. The remaining chapters include information on proposal preparation, final paper preparation and conducting oral presentations. This paper focuses on the Chapter 1 activities.

### Week 1: How do we develop a research question?

As noted in the introduction, we begin the first lab by asking students about the skills and abilities they will need in their future careers. During introductions we also ask them about their independent project research interests. Our lab instructors then use this information to reorganize the students into groups with common research interests. Once students are in their new groups we start the lab with a large-group brainstorming session about developing and presenting a research question.

- What characteristics will a good research question have? Where do research questions come from? (approximately 10 min)

We stress that library research—a meta-analysis—is done to discover what we know and equally important, what we don't know. It is this area (what we don't know) that leads to new avenues of research. Key points to look for from your class in this discussion:

- A good research question should center on an area of research that is ongoing and as yet unsettled.
- The question should be well-studied in the literature so that there are many sources to draw from.
- Different aspects of research should contribute to the same general question (at least two aspects for two-author IPs and three for three-author IPs). A couple of examples: 1) Is a new class of cancer drugs effective at combating cancers? One “treatment” here could be effect of drug regimen X, while the other “treatment” could be the effect of drug regimen Y. 2) Effects of water-borne pollutants on aquatic plants: field studies (“treatment” 1) vs. lab studies (“treatment” 2).

Following the group discussion, give student groups about 20 minutes to perform some initial on-line searches for information in their topic areas of interest. Google Scholar is a good tool to use here. Students should not be too narrowly tied to one idea because they may have to redesign or edit their questions depending on the type and amount of relevant literature that they can find. This is why we ask them to come up with more than one possible research question.

We take some time to go around the room and have groups share their ideas. Make it interactive so that those that are having trouble might receive suggestions, e.g., as they share, indicate that they can ask the class for suggestions on how to narrow, broaden, modify their question.

Finally, have each group answer the following questions for their two research questions of interest:

1. What is your larger research question?
2. What is your rationale or reason for investigating this question?
3. What evidence will you look for in the literature, i.e., what smaller questions will you need to answer to investigate this question? (Develop a prioritized list of these associated questions.)

At this point we pull the lab together again and ask the following question: **“Does anyone really do this type of research?”** To answer this question, we have the students watch a Bill Moyers exposé entitled “Chemical Fallout” (<http://www.jsonline.com/watchdog/34405049.html>). While watching the video the students are asked to answer the following questions:

1. What were the reporters doing (what was the question they were addressing)?
2. Why were they doing this?
3. How did they do it (i.e., what methods did they use)?
4. What challenges did they face?
5. How does what the reporters did relate to what you will do in developing your independent research project question and ultimately your research paper?

Following the video, we have a large-group discussion covering the questions above. In this video, the reporters were doing a meta-analysis of the effects of Bisphenol A (found in most food containers) on human health. Note that what the reporters do

in this video parallels very closely what the students are being asked to do as they conduct a meta-analysis, including the frustrations that may arise. For example, the reporters thought their initial study was complete until they gave it to their supervisor for review, who tossed it back to them saying that they needed more. “More” here meant more real data, i.e., (1) additional and more-specific papers documenting BPA studies; and (2) more importantly, it meant tabulated data (in Excel™) that allowed them to identify and target specific areas of concern or question in groups of studies. Their report would have been nothing without the data: they would not have been alerted to issues or correlations in the studies and without data, their study would have been largely (or solely) opinion.

## Week 2: How do we critically analyze scientific literature?

For many years after developing the independent research option focusing on library research and meta-analysis-research, I searched for a good example to provide students. In 2007, I read a newspaper article about a study that examined the effect of cocoa vs. tea on blood pressure in humans. The research article itself is well written. It is relatively short, and details the thought process and methodology behind the selection of papers for inclusion in the study. It also includes Excel™ spreadsheets indicating the types of data the authors gleaned from the papers chosen. This article by Taubert et al. (2007) proved to be invaluable and became the basis for the second part of our lab activity.

The premise of the lab is the following: A number of both popular science and peer-reviewed journals have reported that the polyphenols and flavanols in foods like chocolate and tea may reduce blood pressure. For this exercise, assume you are interested in the effects of polyphenols or flavanols in tea and chocolate on blood pressure in humans. For your library research project you plan to do a meta-analysis of data available in the scientific literature to answer the question “What effects do chocolate and tea intake have on human blood pressure?”

The lab begins with a fairly large pre-lab assignment designed to show students how to select articles based on the types of data they contain and how to organize the information from the research articles they choose using Excel. The pre-lab assignment follows: (You can find the articles we provide our students at: <http://tinyurl.com/ABLE2012HEITZ>).

### Week 2: PRE-LAB QUESTIONS AND ASSIGNMENTS

1. Go to the course web site to read either the chocolate or tea research articles. After reading the assigned articles (see below), complete the associated Excel spreadsheet and Exercise 1. **Note: This may take you two to three hours.**

#### If your last name begins with A to L:

- a) Examine the partially completed Excel™ spreadsheet containing information gleaned from articles about **TEA** and its effects on blood pressure.
- b) Determine the types of data (or metrics) that you will need to collect from additional TEA articles (posted on the course web site) to determine if tea has an effect on blood pressure.
- c) Skim the 4 TEA articles posted to determine which two contain the types of data needed.
- d) Complete the Excel™ spreadsheet and Exercise 1 using information you gather from a more-careful review of these two articles. You can find electronic versions of the spreadsheet and of Exercise 1 on the course web site.

#### If your last name begins with M to Z:

- a) Examine the partially completed Excel™ spreadsheet containing information gleaned from articles about **CHOCOLATE** and its effects on blood pressure.
- b) Determine the types of data (or metrics) that you will need to collect from additional CHOCOLATE articles (posted on the course web site) to determine if chocolate has an effect on blood pressure.
- c) Skim the four CHOCOLATE articles posted to determine which two contain the types of data needed.
- d) Complete the Excel™ spreadsheet and Exercise 1 using information you gather from a more careful review of these two articles. You can find electronic versions of the spreadsheet and of Exercise 1 on the course web site.

2. Complete Parts 1 and 2 of Exercise 1 on pages 10 and 11 of the lab manual. Bring both digital and **print copies of these to lab**. Be prepared to hand these in as you enter your lab.

The goal of this assignment is two-fold:

1. To help students learn how to skim articles for key pieces of information. For example, what key metrics are contained in the Excel™ spreadsheet data provided? Which of the four articles posted contain these key metrics?
2. To help students understand how organizing the data in an Excel™ spreadsheet can allow them to more easily sort, subset, compare and analyze the existing data.

In the lab itself, students first work in tea- or chocolate-only groups to compare their Excel™ spreadsheets and come to consensus on their analysis of the data. Next they work in combined chocolate-and-tea groups to do a cross analysis (meta-analysis). Questions they are asked while doing this include the following:

*How should we analyze the data we collect?*

- Are there certain issues, facts or ideas that all the articles agree with? What are these?
- Are there any areas of disagreement among the articles? Are there differences in methodology, etc., that might lead to the disagreement? For instance, did all the studies use similar subjects or similar doses?
- What types of evidence are presented to support each of the argument(s)?
- What additional evidence, etc. is needed to determine which, if any, of the results or arguments is more valid?

When the students examine the data in the Excel™ spreadsheets it becomes clear quickly that tea has no significant effect on blood pressure. As they examine the methods, they soon discover that this is true regardless of the type of tea or dosage. However, examination of the Excel™ spreadsheet for chocolate articles indicates that 4 out of 5 studies show a significant decrease in blood pressure. This leads the students to examine what is different about the one study that found no difference. They quickly discover a difference in dosage that may account for this.

We next ask the students how they would analyze/graph the data for chocolate vs. tea to present these in a paper. This allows them to see that they need to rework the data not simply report it.

We follow this with a general discussion of “**How would you convert what you just did into a final IP paper?**” This is a good segue to: “Voilà! Look at this actual paper (Taubert et al. 2007) written by medical doctors that does exactly what we just did.” We project the paper digitally and let students know we will post this later on the web. We emphasize that the authors based their conclusions on the same evidence, logic, and general forms of analysis as the students just used. Students are then assigned to read the paper before the next week’s lab.

## Materials

All materials for conducting the lab activities described can be found online at the URLs noted in the text of this article or in the appendices associated with this article.

## Notes for the Instructor

### What should instructors know before trying the student labs described in this article?

A number of instructors' notes are included in describing the student activity above. In addition more-complete instructor notes are included in the appendices on-line.

Does using these labs make it absolutely clear to all of our students what a meta-analysis is? Do they make the connection between what we did in lab and what they will be doing for their independent project proposals and final papers? Some students get the idea right away. For others, it takes going through a review process and one or more one-on-one discussions. As a result, while I can't say that this lab has solved all of these problems, I can say that it has helped considerably to have a solid example.

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## **Appendix A**

IP Lab Manual - Experiencing Biology from Proposal to Presentation (Complete lab manual).

## **Appendix B**

Chapter 1 Instructor Notes Background (Chocolate and Tea articles, partial Excel™ spreadsheets and other information for Chapter 1: Chocolate and Tea activities).

All of these materials are available at <http://tinyurl.com/ABLE2012HEITZ>

## About the Author

Jean Heitz is a Distinguished Faculty Associate in Zoology at the University of Wisconsin-Madison and has worked with a two-semester Introductory Biology sequence for majors since 1978. Her key roles have been in development of active learning activities for discussion sections and open-ended investigations for laboratory sections. Jean has also taught a graduate course in “Teaching College Biology” and is the author of *Practicing Biology: A workbook to accompany Biology by Campbell and Reece*, 9th Edition and *Practicing Biology: A workbook to accompany Biological Science by Freeman*, 2nd edition (Benjamin Cummings, 2010).

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