EXTENDING INQUIRY-BASED LEARNING TO INCLUDE ORIGINAL EXPERIMENTATION

Sarah Wyatt

Introduction

The German word for scientist is wissenschaftler (creator of knowledge), but finding new knowledge is not restricted to the sciences. All disciplines collect information. The object of this article is to illustrate how we, as instructors, can engage our students in collection of this information and, by doing so, enhance their education. This paper demonstrates the advantages of incorporating original research projects, no matter how small, into college coursework. For this purpose original research is defined as finding knowledge. The strategy the article endorses is to enhance education by giving students both an appreciation of how knowledge is gained and insights into its method of acquisition (Committee on Science, Engineering, and Public Policy, 1995; Paul & Elder, 2003). Included in this methodology are the additional bonuses of helping students evaluate, integrate, and synthesize information, thus allowing a higher-level synthesis of course content (Bloom, 1994).

Providing students with opportunities for data collection is one of the greatest challenges for science teachers. In science courses, teachers most often set up “experiments” that are, in actuality, demonstrations that students are to do themselves. These have very specific methods with complete instructions and an expected outcome. Of course, these demonstrations do not in any way resemble real experimentation. Students know that there is an expected outcome, and they also know that in many cases their grades depend on how closely they can achieve that outcome. This sets up a dangerous conundrum for students. Students often report that they either fudge their results to better meet the anticipated outcome or that they are...
forced to explain why their results are incongruous when they don’t have the knowledge to assess all the parameters correctly. Students find themselves not sure what to do.

During my postdoctoral research, I worked with a very bright undergraduate researcher. She had been assigned a project, seemed to have a good grasp of what she was suppose to do, and proceeded with her experiments. One day she arrived in my office with a picture of a DNA gel she had run. She proudly shoved it in my face and said, “Is that right?” Of course, being confused, I said, “Is what right? Where are the controls?” To which she answered, “I thought if I got the right answer, I’d go back and do the controls later.” This, of course, let to a discussion of what original research actually involved, that I didn’t know what the “right” answer was, and that we needed the controls to evaluate the data. Now, it was not that she didn’t know what she was doing, but instead that she really had no experience with research and experimentation although she had taken numerous laboratory courses and could spout the scientific method if asked. It was then that I realized that we, as instructors, needed to change the way we did laboratory courses.

By extending inquiry-based learning to include original experimentation, we help students gain not only the experience of setting up an experiment, but, in doing so, gain the ability to better assess experimental parameters and better evaluate data in texts, periodicals, and news reports. Of course to do so, several challenges must first be met. The first of these is to release the concept of the “right answer.” As with the student presented above, students, and teachers, have been groomed to believe there is a single correct answer and that education is about finding that answer. With original research there is no “right” answer to find; there is only data to be collected. Students must learn to think and to evaluate that data, and trust the process of so doing. They also must be willing to be wrong. Most of science revolves around falsifying hypotheses and what we can learn from that. Very little can be “proven correct”; knowledge is true only given the specific parameters at the time of testing. And, finally, both students and teachers must be flexible and fluid, both willing to rethink and redesign experiments and theories. We have used original research projects successfully in introductory biology courses where students have no prior research experience and in undergraduate social science
courses. And there is no reason why experimentation cannot be used in K–12 environments. I have also introduced this strategy in workshops for high school and middle school teachers and have heard wonderful accounts of how it has worked for them. With a little creativity, I think this technique could be used in a variety of classes, and here I present two examples of its use.

**Example 1: Introductory Plant Biology Laboratory**

In this introductory course at Ohio University, we have students perform both “activities” and experiments. Activities take the form of the demonstration-style experiments of standard laboratory courses, and the word “experiment” is reserved for original research that the students develop on their own. These experiments are not necessarily major research projects that provide publishable data, but they do address a question that the student initiates, with an experimental plan that is solely the design of the student or student group. For example, the first laboratory experiment involves how a plant responds to gravity or light. Questions that students have asked include: “How long does it take for a plant to respond to gravity?,” “Is light more powerful than gravity?,” “Do different plant species respond to gravity in the same manner and time frame?,” and the like. Students are presented with the framework (in this case how plants respond to environmental stimuli) for the experiment and asked to bring a question, hypothesis, and general idea of an experimental plan with them to the next lab period. They can set up their hypotheses based on the lecture material or readings from the text; no additional literature is required.

The laboratory activities that precede the experiment can serve as a framework to guide a student’s experimental plan, as is the case with the second experiment for this class: factors that affect enzyme activity. But the design is up to the individual student. The teaching assistants and instructors answer questions, provide materials, and give some general comments, but developing the plan is left to the student. Most of the experiments are easily performed in a single lab period of two hours or carry over from one lab period to the next. After the experiments are completed, students are asked to
evaluate their experiments (Browne & Keeley, 2004). They are pro-
vided questions such as “Did your experiment answer the question
you asked?,” “Are your conclusions valid or could there be another
conclusion one could draw?,” and “What are the major faults of
your experiment?” One of the most interactive and exciting parts of
this strategy involves students verbally sharing their experiments.
Each student or student group is allowed a brief time to share his or
her experiment and the results. This allows everyone to benefit
from the array of experiments performed and provides an opportu-
nity for student critique of methodologies based on the above ques-
tions. These critiques can then be incorporated into the laboratory
report and provide additional advice for future experiments. Finally,
each student is expected to write up the experiment using the stan-
dard scientific format of introduction, materials and methods,
results, and discussion (Perelman, Paradis, & Barrett, 1998). (Lab
reports are done independently even if the experiment was a group
effort. This allows for each student to discuss and critique the
experiment.)

Example 2: Undergraduate Social Science Courses

These experiments involved natural observation for the most part
and were performed by a sophomore-level communications class.
The class was a relatively large lecture course with no laboratory.
Students were asked to select a topic from the lecture topics to
explore experimentally and then given some general ideas about
how to collect data. One group of students selected personal space
as their topic and set about observing people interacting across cam-
pus. Each student in the group was assigned a particular aspect of
personal space for which to collect data. These aspects included stu-
dents interacting with other students, students interacting in dating
situations, students interacting with faculty, and so forth. Then the
students came back together and discussed and evaluated their data
and strategies for collecting it. Another group assessed communica-
tion strategies, comparing e-mail versus posted signs versus per-
sonal invitation. Many of these students were in a club that had an
upcoming event that they used as a format for their evaluation.
Others selected student/student and student/teacher interactions and seating arrangements in large lecture halls. These students crept into the back of lecture halls and collected data. Granted, these experiments may not have been scientifically valid, but that only added to the discussion. Student groups worked outside of class to complete their experiments, and, once completed, shared results during a lecture period, and turned in formal papers.

Assessment

Assessment has varied in all of these classes, but one thing remained constant. Assessment was focused on the process, not the results—the evaluation of the data collected and the collection methods, not the data itself; what the students learned from the experience, not the final answer. Parameters like adequate controls were taken into account, but more important, whether the student recognized a lack in the controls or how he/she evaluated the data based on the controls was taken into account.

Faculty and Student Perspectives

All faculty that I have worked with have been thrilled at the results. They report that students are more engaged in the lecture, and that the experiments increase the depth of interactions with the course materials. Students ask more questions and are more willing to interact. I have even had students ask me about unusual plants they see on campus and tell me about experiments they are doing at home with their house plants. They are getting better grades and have better long-term retention of the material than students in previous terms. The other faculty have been so pleased with the results that several of them have initiated similar strategies in their courses. Incorporating true experimentation in coursework has also increased interest in performing formalized undergraduate research projects. Our department is seeing more undergraduates starting research projects earlier in their careers and staying with them longer. The brief foray into experimentation in the introductory classes seems to
have demystified the process for the students and made them more willing to take the next step.

Students also appreciate the experience. One non-science major in the introductory biology course said, “These gave me a better appreciation for science and how it fits into my life. How to evaluate the stuff I read.” A plant biology major reported, “This was great! The best part of lab. To ask my own questions and figure out the answer. Definitely, not what we usually do.” One undecided undergraduate said, “At first it was hard, I really didn’t like it. I didn’t know what to do, but now I realize how important it was, how much I got out of it.” One student wrote a letter to the chair of my department. In it he states, “this was a real-life research experience. . . . The students behaved as quasi-autonomous researchers. . . . The benefits . . . vastly exceed those of any course that I have taken in my 9-years of taking college courses.”

I must, however, admit that for the graduate teaching assistants these laboratory set ups can be more difficult. Although I usually have TAs requesting my assignments, one TA did mention that “it would be a lot easier if you just did things like everyone else.”

Conclusions

Asking students to perform original research improves their critical thinking not only about their own work, but also about results of research in general. Research experience helps to increase students’ awareness of how data can be used to justify a given point of view and makes them much more savvy about data presented in newspapers and Websites. They ask questions to be able to evaluate the data or the method of data collection instead of accepting conclusions at face value. Students become much more interactive with the learning process.

References


