Making Connections in the Undergraduate Laboratory

Integrating the Lab and the Lecture to Better Connect Our Students with Real-Life Experience

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Because of the feeling that the facts and skills that they are learning are not useful in "real" life, and because of their disjointed experience in science courses, students often see this learning as boring and meaningless and become more disenchanted with the study of science. We believe our integrated course arrangement served as a safeguard against this potential.

Conceived for the best of reasons—to let students actually do science instead of simply listening or reading about it—the undergraduate science laboratory can too easily become a source of frustration for both students and faculty. Several explanations for this come to mind, all of which tend to isolate or disconnect the laboratory from the course itself, from other courses, and from the student's experience:

▲ First, laboratories take a great deal of time, not to mention space and equipment. Budgetary considerations and the typical reward system for faculty often lead to laboratories being taught by the least-experienced, lowest-paid instructors available, usually graduate students. While there are many enthusiastic, conscientious graduate students, their inexperience and lack of training are bound to lessen the quality of the undergraduate's laboratory experience. Further, it is often difficult to find a graduate student who really wants to be a laboratory instructor, especially when higher status research assistant positions are available.

Unfortunately this can result in a "tag team" approach to laboratory instruction, with multiple laboratory instructors, who have trouble communicating with each other, with the professor, and with the students.

▲ Second, good laboratory problems are difficult to conceive and implement. Such tasks need to be challenging and inherently interesting, not just something done to fulfill a course requirement. Students should not automatically have a strategy for solving problems, but strategies for solution should be accessible to students given the information presented in other course work. When good laboratory problems are developed, they are often captured in a laboratory manual so that they can be presented

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consistently in spite of changing instructors or the passage of time. The use of laboratory manuals, however, makes it possible for inexperienced instructors or less-than-enthusiastic students to turn well-thought-out laboratory problems into fill-in-the-blank exercises—tasks which take little thought and for which students already have solution strategies. Students may be allowed to "plow through" the laboratory exercises in cookbook fashion without asking "what if" questions or applying the scientific method. Their goal may simply be to "get through" the exercise.

▲ Finally, even if the laboratory problems are good and the manual is treated as more than a cookbook, the lack of coordination between lecture and laboratory may be a problem. Once a set of laboratory exercises is assembled and codified into a laboratory manual, it does not easily change. The lecture portion of the course, on the other hand, can and does change fairly rapidly to reflect new developments in the field, the instructor's interests, and even the students' interests. The result is that the lecture and the laboratory become disconnected, and laboratory experiences without the necessary preparation in lectures may become enigmas—tasks which the student is not interested in answering or which the student is convinced cannot be answered.

For many years, our university has offered a meteorology course to satisfy general education laboratory science requirements. Environmental Science (ES) 101 was taught in the traditional format, two lectures and a separate three-hour laboratory each week, and it suffered from all of the above-mentioned problems. The second author of this paper taught ES 101 six times in three years with increasing frustration. In the spring of 1993, after several discussions about current educational thinking and practice, we decided to make two modifications to ES 101.

As a first modification, the lecture and laboratory portions of the course were combined by lengthening the two lecture periods so that each included a laboratory session. This meant that the course met twice rather than three times a week and that every class session had components of lecture, laboratory, and discussion. (Note that nontraditional students tended to like this arrangement because fewer class periods, though they were longer, lessened child care problems.)

The primary educational benefit of this arrangement was that the laboratory exercises became an integral part of the lecture. When humidity variables were discussed, for example, the students were issued sling psychrometers and they went immediately around campus measuring the wet and dry bulb temperatures. Back in the classroom, students calculated and plotted the relative humidity and dew point. This activity, and the discussion that followed it, gave the students the concrete referents they need to make sense of alien material. This modification alleviated the problem of disconnectedness which we mentioned above by making the laboratory experiences inseparable from the lectures. As one student put it in her evaluation, "It was always nice to be able to get a better picture of a lecture by doing a physical simulation or model experiment to see hands-on what was discussed."

ES 101 is a general education course offered mostly to non-science majors. Most of our students identify themselves as not "scientifically inclined," or, in fact afraid of science. They profess many stereotypical beliefs about science and scientists and have not developed (or been taught) scientific habits of mind. Our second laboratory modification, the redesign of the laboratory report, attempted to address these attitudes and thereby to make learning more meaningful.

The "Connections" portion of the report was an attempt to get the students to realize that what scientists do, and what science is about, have connections to many parts of life, not simply to the laboratory. Students were asked to reflect about and identify ways in which laboratory, lecture, and text material were connected.

The laboratory report was central to the students' learning. For each laboratory experience, students were required to write a laboratory report "from scratch" which included the traditional, "scientific method" sections of Purpose, Hypothesis, Materials, Procedure, Results, and Conclusions. Additionally, the lab report included a section called Connections, in which students were asked to comment on the connections they saw between the course work, the laboratory exercises, and their own previous experience.

Information to be included in all but the last section could be completed during class and in conjunction with the group. This type of report and the responsibility it entailed took some getting used to. Student comments indicated that they felt somewhat at a loss given this amount of freedom. They felt, at first, that they needed the structure offered by traditional lab books that required them only to fill in blanks. That way, they said, they would know what to write because they would know "what you wanted." One of the purposes of this type of reporting was to encourage the students to think about their thinking and the process skills they were using, so that they could develop scientific habits. As one student said, "I not only learned about meteorology, but scientific and logical thinking in general."

Although students were free to work on all aspects of the report together, they were encouraged to personalize the Connections section. This portion of the report was an attempt to get the students to realize that what scientists do, and what science is about, have connections to many parts of life, not simply to the laboratory. Students were asked to reflect about and identify ways in which laboratory, lecture, and text material were connected; questions they might still have about the topic; and about ways in which the laboratory related to personal experience, other courses, and "life." In many ways, Connections was the most interesting aspect of the lab reports. Many of the students had not had this type of experience before and found it very difficult, though rewarding. In fact some of the students' comments reflected this novelty. "Although sometimes difficult to write due to lack of a guide, these self-written experimental summaries were quite helpful in the learning process."

The traditional arrangement of separate laboratory and lecture sections often becomes the model for the type of learning that occurs. Unfortunately, this arrangement may allow the lecture and the laboratory to become not only separate but disjointed. The resultant lack of connectedness in the student's experience may encourage the use of the rote memorization of definitions and sets of disconnected facts.

Because of the feeling that the facts and skills that they are learning are not useful in "real" life, and because of their disjointed experience in science courses, students often see this learning as boring and meaningless and become more disenchanted with the study of science. We believe our integrated course arrangement served as a safeguard against this potential for "disjointedness" and served as an alternative model for students' learning by embedding facts and skills in meaningful problem solving experiences. This integrated type of learning allows concepts to be more accessible for use since they are learned in context and therefore are connected to complex, interwoven mental maps. (Caine and Caine, 1991).

Connections are made among concepts within the course and also with other life experiences. According to one student, "Information gained through this [class] is valuable in that it helps one to make connections with real life situations." As long as we can make such connections with simple items, more people will have an interest in environmental science.

The two modifications to the laboratory also facilitated the use of a four stage learning cycle model in planning individual class sessions. Originally developed by Robert Karplus, the model is widely accepted as vehicle for concept development (Karplus, 1980). Student interest was engaged through lecture, discussion, and other class activities; students then explored concepts through the laboratory activity; students and the professor explained concepts orally through interaction with their laboratory group and in class discussion and in written form through their laboratory reports; finally students expanded their understanding of concepts through follow up class discussion and the Connections portion of the laboratory report.

The two modifications explained here, the integration of the lecture with the laboratory and the changed form of the laboratory report, arose in response to instructor frustration. Was it relieved? To a large extent, yes. By combining the lecture and laboratory, the instructor had much better interaction with the students. (He even learned all their names!) The students asked many more questions than those in traditional-format classes, and not least, the students evidenced considerably more independent thought than previous students. Although not perfect in its implementation, the redesigned course lowered the "frustration level" of the instructor.

Did our modifications serve the students? In an evaluation form distributed at the end of the class along with the university's standard course evaluation, we asked students to rate the class in comparison with other laboratory science courses they had taken using a five-point scale with the choices: much better, better, the same, worse, and much worse. Sixty three percent rated it better or much better than other courses, 37 percent rated it the same as other laboratory science courses, and zero percent rated it as worse or much worse than other courses.

This is not meant to be a scientific survey and inferences made from the data are therefore limited. Our conclusion, however, is that students responded favorably to our modifications. For this group of students, at least, the course was a meaningful learning experience. As one of them put it, "Science done the right way is both rewarding and fun." We suggest that other professors may want to implement similar modifications in their laboratory science courses. ❑

References

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