Are lab courses a waste of time?

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"Why do you people spend so much time and energy teaching lab courses?" That's a question I hear from hard-pressed administrators these days. Labs are very expensive, they are not popular with the students, and they are time-consuming for the faculty.

Everyone grants the need for labs in training future scientists, but the vast majority of students in most lab courses consist of premeds, engineers, and other casual visitors to the world of science. A substantial number of administrators believe that were it not for "archaic" professional-school requirements, we could save both money and hassle by reducing the number of lab courses for these people. The problems is compounded by the fact that most faculty members in the sciences are not clear about what teaching labs can do, or ought to do, for these students, and the lab is often asked to do jobs for which it is unsuited, while its real strengths are ignored.

First among these misconceptions is the idea that somehow labs "illustrate" lecture courses. Alas, almost all the most important ideas (molecular structure in chemistry, evolution in biology) are difficult to illustrate in a simple one-afternoon exercise. Most scientific theory is based on a large number of very complicated supporting experiments. For the topics that can be illustrated, surely lecture demonstrations or audio-visual aids could be used.

Second, labs do not exist to teach "finger skills." Science is not some complicated form of gymnastics. Even if it were, it is important to remember that most of our students are headed for engineering or medicine, and very few of the techniques will be directly usable. Granted, every premed should learn how to use a microscope, but the importance of manipulative skills is usually oversold by defenders of labs. Also, to a large extent, the finer skills taught in large lab courses are obsolete.

At a time when few biologists do dissections and few chemists do titrations, these skills are worth teaching only as tools to be mastered for basic scientific inquiry, not as ends in themselves.

A good lab course is an exercise in *doing* science. As such it differs totally in mission from a good lecture course where the object is learning *about* science. In the same way that one can gain vastly greater insight into music by learning to play an instrument. One can experience the doing of science only by going into the lab and trying one's hand at measurement.

Good lab teaching is essentially Socratic. It is the posing of carefully defined questions to be asked of nature. The questions have been answered before, but that does not interfere with the style of the inquiry-- it is a mere timesaving convenience to use known methods to answer the questions rather than having to invent them.

In a well-designed lab course the intellectual process is that of real scientific research. After the student sees how difficult it is to obtain totally unambiguous data, the result will be healthy skepticism about purported "facts" that have not been confirmed and reconfirmed.

Were this achieved by lab courses, I think even the most captious questioner would see that they fit naturally into the larger goals of a classical liberal-arts education. However, lab courses in most institutions fall far short of these possibilities. Since they are unable to "illustrate the lecture" and the teaching of finger skills is not central to the liberal-arts tradition, they end up doing nothing well.

Why, then, don't labs live up to their potential? First, it is not easy to teach a lab course. Any reasonable well-prepared professor can do a tolerable, if not exciting, job in a lecture course. Large lab courses require a compulsive attention to detail that is rare. Also, since in most institutions the actual lab teaching is done by graduate teaching assistants, running the course is a problem of organization and management where results have to be achieved through other people's work.

Faculty members are rarely comfortable with, and basically unprepared for, the role of manager. Management means motivating graduate teaching assistants, a difficult problem in most institutions, where there are few rewards for good performance, and where it is traditional not to dismiss T.A.'s for poor performance. It means also that a continuous process of training must be developed because the turnover of teaching assistants is high. These problems are only beginning to be faced and solved by colleges and universities.

Too few lab courses offer any sort of confrontation with the unknown. The student is expected to produce a verification of something that he already knows, and so ends up trained to ask what a result is supposed to be, not what it in fact is. The element of creative suprise is almost completely missing. The results of an experiment should be ambiguous enough so that a student is compelled to think through the bearing of his results on the possible conclusions.

In this context, teaching of generally useful, but rarely taught, statistical techniques fits quite naturally into the struggle to decide whether measurements reflect "real" agreement or disagreement with expected values.

The role of the textbook (or teacher) in a good lab course is like that of a guide in a foreign country. The book should point out what to look (and look out) for, not what the traveler is to see. The difference is subtle but immensely important. It is easy to fall into the trap of saying, "In the next cage is the such and such beastie, and isn't he an interesting animal?" instead of saying, "Here is a beastie. What sort is he? What does he do if we tweak his tail?" The general drift of lab textbooks has been toward the more concrete experiments. That makes the course easier to manage from the professor's point of view, but the lack of creative ambiguity reduces the lab to a "cookbook" exercise.

The grading of lab courses contributes to the problem. Students weight their effort according to the perceived rewards. In the same way that the income-tax system does not exist simply to collect money, but also to provide incentives for various sorts of economic activities, so grading is not simply an evaluation process; it is a way of providing incentives for various sorts of intellectual behavior.

As with the tax system, the incentives provided may have quite unintended side effects. That has happened in lab courses and can be seen in the ways in which observational skills and scientific insight are traditionally graded.

It is often said that observation is the root of all scientific inquiry and that the need to learn this skill is a major justification for laboratory courses. That is a glittering generality; the truth is far more complicated.

Learning that copper sulfate is blue is not a useful goal, since such information is only to use to a person working in the chemical sciences and, in any case, is readily available. Similarly, learning the innards of a frog is more a test of memory than of observational prowess. However, for the premedical student, the habit of "noticing" the apparently inconsequential is an essential mental acquisition because medical diagnoses often turn on small and apparently insignificant details. The task is to teach observational *skills* not just observable *facts*.

Skills will grow only if rewarded, and the grading systems of most lab courses tend to give observation low priority. Often the practice is to exhort the student to "keep a good notebook," which will be graded by a teaching assistant in some vague, subjectvie, and idiosyncratic way; or alternatively, to reward the memorization of isolated facts.

Why not have an "open-notebook quiz," in which the student is expected to retrieve observations from his notebook? At one stroke this eliminates the need to memorize, and directly rewards the careful observer.

If our goal is to teach scientific insight, we should provide a direct incentive for its development. The traditional method of basing grading on lab reports ends up rewarding volume and frills. Instead, perhaps the reports should be reduced from their present dimensions to the equivalent of the homework so often assigned in lecture courses in the sciences. That we could base grades on some sort of standard that separates the scientists from the cooks. One possibility is an open-book written exam with questions of the sort, "If you used dark beer instead of light beer on step three, how would the results be different?"

By offering a genuine, unvarnished scientific experience, a lab course can make a student into a better observer, a more careful and precise thinker, and a more deliberate problem solver. And that is what a college education is all about.

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