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TRENDS in CONDUCTING PHYSICS LABORATORY WORK

What do we teach when we teach physics? What do we hope to accomplish when we send students to a laboratory? What is a sound program for laboratory activities? Dr. Boekelheide offers his alternative to the traditional concept and conduct of laboratory work.

It is my assumption that with little significant change many of the remarks in this article can be descriptive of development in teaching of life science courses and other physical science courses, but my words are based on observations in physics over the past years. In the review of physics teaching that has involved all the responsive and responsible practitioners in the U.S. no facet of the teaching activity has been scrutinized more thoroughly than the laboratory. Any review immediately points up that the traditional three to six hours per week of laboratory time was embarrassingly inefficient and ineffective and nonproductive from the point of view of the student, and encumbering and expensive from the point of view of the institution. Reports suggest that this concern is shared over much of the world.

The Traditional Laboratory

Put simply, the traditional elementary laboratory activity of the student was (and is) commonly a cook-bookish number seeking in an artificial experimental setup. While the laboratory arrangements were (and are) generally basic, they were stereotyped and the students functioned not at all imaginatively, participated very little manually, and interrupted the security and composure of the physics department scarcely at all. The principal benefactor was the first-year graduate assistant who was in charge, and who, of necessity, could not avoid some thinking about the setup. Except for a few, students "served time", filled in blanks and escaped from physics thought. It is this type of laboratory, stylized for simplification, that was found wanting, and was condemned. Of course few schools would ever admit that they were that way; nonetheless the same schools have vigorous programs for change.

Problems Met

Starting with the overwhelming influx of mature, inquiring returning W.W. II veterans, and the obviously much larger numbers already bulging the walls of the elementary schools, the science educator was forced to plan physical plants and shelves of equipment for this deluge. He, in conscience, questioned the fiscal prudence of duplicating many times the traditional laboratory setup with its commonly indifferent student experience without thoughtfully probing for better

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answers. The nation which had need for only a core of top flight scientists found itself in a maelstrom of scientific undertakings. Political fortunes divided the world and American science acumen was thrust into prominence with Hope and Freedom pinned to its leadership. Government and industry undertook research and development schedules in undreamed of proportions. Wages of the scientifically trained soared even beyond the cost-of-living spiral. The science educator recognized that the contribution of an institution could be multiplied by at least two ways through revamping the elementary laboratory: first, apt recruits to science might respond through positive motivation; and second, a fresh mode of operation in laboratory could give a taste of creative thinking and objective report writing. The preparatory schools, which had had a history of classic, stilted training with a few exceptions, began to adopt any or all of dynamic modernized programs and activities that shamed some colleges into review of their science. Some of these high school stimuli enumerated are 1) the mathematics program of the school Mathematics Study Group, 2.) the same for the Physical Science Study Committee, Chemical Bond Approach, Biological Science Study Group, 3) annual local and national Science Fairs, 4) newsmagazines and newspaper articles, 5.) television programs purposefully educational or not, 6.) summer enrichment programs as conducted by the National Science Foundation for high school science teachers and high school students, etc. Sensing the imminent growth in science education, the industries dependent on American education studied the problem and began to present to the science educator a wide range of new laboratory equipment, and even alternate to the routine laboratory experience, activities such as movies, film strips, class demonstration equipment, reoriented manuals, teaching machines, etc.

Examples of Answers

The responses of the many colleges to the impact of the new demands made of their laboratories, to the sundry diversifying laboratory equipment, and to the hosts of ideas pertaining thereto could not be easily enumerated. Suffice it to describe several.

In 1959-1960, in a sharp break from their tradition, Prof. Margaret Wagonner of Stanford University covered a central laboratory with representative equipment and gave few general assignments, perhaps something like "Design an experiment and report it, on the measurement of 'g' to 1%," or "Design an experiment and report it, on something significant to you on the properties of springs," etc. What a surprise to those students who had already borrowed the laboratory notes from an earlier student!

Starting in 1961-1962 many colleges used the comprehensive beautiful Harvey White movies in lieu of the ordinary laboratory. Most have modified to intersperse these wonderful movies with actual manipulative experiences in a laboratory.

Many institutions, so intent on post-graduate prestige that they can't be bothered, have done little more than assimilate contemporary concepts into the laboratory activity, and still require blank-filling, cook-bookish number-s e e k i n g. They are inclined to excuse this because of the truly vast numbers of students they must handle. Often however, there is a vivacious, knowledgeable professor in charge who makes it his teaching contribution to vitalize the laboratory, and he personally attends the students, jostling them with questions and attention until the net effect is excellent, even though stylized.

A few colleges (financially pressed ones?) conclude that laboratory is not worth the investment in time or equipment and dismiss this area of physics learning with a few demonstration lectures. Many colleges have chosen demonstration lectures to replace certain of the difficult experiments. New projection techniques enhance the worth of this scheme.

Finally a few words on the revolutionary program now in effect for elementary science students at the University of California at Berkeley. Aware of the high cost of traditional equipment, and the need for each student's manual involvement in the experiments, and sensitive to the very high quality of their selected students, Prof. Alan Portis has designed an entire 3-semester course with only five basic laboratory tools — the oscilloscope, a low frequency square wave generator, an R.F. wave generator, a power supply, and a multimeter. All laboratory experience deemed essential is synthesized to these instruments. There is mixed reception to this idea, even in Berkeley. While this scheme represents a part of the trend, I repeat that their students are highly selected. The lecture course is also significantly different from that given in most U. S. colleges.

Recommendation

Finally, I'd like to describe my recommendation to replace the traditional laboratory. I would usually try to confine all the activity to the one 3-hour laboratory period per week, with neither special student anticipation, nor take home write up. Next, and of some importance, I would try to prepare throwaway sheets and directions

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for each day's activity which would have variety and freshness in the organization of the day's time. This would be to avoid as much as possible automatic and unthinking responses. Further, I would usually aim that the student participation would produce experimental data which could be organized in graphs. This graph, then, would become the focal point for analysis. In all instances of data taking, I would point out that data are incomplete, and with little meaning, unless there are ranges of error offered with the data. Finally, I believe each of the following kinds of student participation should be emphasized in some one laboratory session or another during each school term:

(1) design of experimental set-up, — an experience of "asking questions of nature" followed in a latter session, perhaps by a trial run.

(2) actual manipulation of experimental elements and tools, with a requirement that the setup operate;

(3) dealing with error analysis;

(4) preparation of a thoughtful, concise report on experimental results; (5) involvement in at least one sufficiently complicated experiment (whether it succeeds or not) to teach the delights and frustrations of experimenting (6) care and ruthless honesty with handling experimental data that don't yield the "right answer," along with those that do; (7) create an atmosphere of questioning, encouraging and rewarding questions from students.

Summary

It is possibly true that any physical plant and any experimental gear can produce excited and exciting students. Aren't our leading scientists such products? More important than these physical facilities is the attitude of inquiry that goes on in the laboratory. It is the guess of this writer that the really invaluable reward from the present fuss and feathers about the laboratory is that more professors are thinking than ever before.