Report on the NEACT Conference: "The Chemistry Lab and Its Future"

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The teaching laboratory in the 1980's is beset with challenge. New computer and audiovisual technologies challenge the laboratory on its home ground. In an increasingly litigious society, teaching labs for all but potential scientists are sometimes viewed as an unnecessary risk. Laboratories are expensive and therefore a natural target in this cost-conscious era. Finally, educational scholars have been unable to identify specific positive benefits for laboratory students.

Yet, there remains a conviction among chemistry faculty at all levels that laboratories are important, do have benefits, and "turn on" potential science students. While the facts of science can be presented in a lecture, only in the lab can one learn science as process.

A conference at Worcester Polytechnic Institute on March 7, 1987 brought general distinguished experts together to discuss "The Chemistry Lab and Its Future". This conference, sponsored jointly by the New England Association of Chemistry Teachers and by WPI, was attended by 190 teachers from all over New England.

The first session, entitled "A Place of the Laboratory in Chemical Education", had two speakers, **Leonard K. Nash** and **Audrey Champagne.**

Nash spoke of his personal experiences in the Harvard student labs in the 1930's. Students in those days spent approximately three times as many hours in the laboratory as present day BS students in chemistry at Harvard. Nevertheless, Nash's own recollection was that he had enjoyed lab a great deal and that it contributed to his decision to become a chemist, and he felt that this was true of most of the chemists of his generation.

Nash felt that the lab problem had much more to do with how they were taught than with intrinsic limitations. For example, he condemns fill-in-the-blank report forms, solely needed because teaching assistants have to look after too many students. Faculty staffing is also a problem. At some universities, professors who can, do research, those who can't, teach lectures; those who can do neither, run laboratories. In general, labs are not being given a fair chance.

Furthermore, the research that is being done on labs by scholars in education looks for concrete outcomes and tends to ignore the subtle but important changes in attitude that may result from taking labs. The integrated laboratory sequence at Cal Tech demonstrates the possibility of a truly successful lab, if one is willing to commit the time, money, and resources.

Nash felt that postponing lab made sense for many students. Puzzle labs or project-type labs provided much more opportunity for creativity and therefore were likely to more successful. The point of lab is that in the end one is disciplined by Nature. If one does not follow the procedure exactly, the results will turn out either to be uninterpretable or much poorer than otherwise. Mother Nature tends to be a much harder judge than most college faculty, and therefore well-run labs are a cram course in reality.

Nash conceded that his belief in labs was based more on faith than on experimental evidence, but felt that a "chemistry teacher without a lab was like a Jewish mother without chicken soup!"

Champagne argued that laboratory failed for many students because it was not enough like real science. There is very little discovery component in most large student labs. While faculty believe intuitively that labs work, this is exceedingly hard to demonstrate in a controlled experiment. In laboratory we tend to overload the student with information, so that the student rarely focusses exactly on the elements of the experiment that matter. Therefore, complicated apparatus may be more of a hinderance than a benefit.

The foremost goal of laboratory as seen by Champagne is to provide a chance for the student to learn about the doing of real science. This larger goal can be broken into some smaller goals such as, first, experimental design and execution (this includes variable control, selection and use of apparatus and instruments, observation, measurement, and data management), second, scientific thinking skills (data analysis, making inferences) and, third, a direct objective knowledge of the natural world.

Most educational researchers try to measure changes in conceptual understanding in laboratory students. This is particularly difficult because previous knowledge dominates the student's choice of hypothesis. Citing in some detail an experiment in which students dropped objects of different density, Champagne showed that students proposed a wide variety of alternative hypotheses, many of which were not obvious. It is therefore important to "get the student's theory on the table as an alternative." Then these student theories can be tested by additional experiments. In this model of laboratory education, the teacher's job is to help students come to an explanation that is consistent with the data, not to impose the explanation from on high.

Champagne recognizes that this may not be practical in many colleges, simply because labs are too big, too crowded, and too much is done in too short a time. Nevertheless, the goals are still worth striving for.

The second session was devoted to liability law and its effect on laboratory teaching. This talk was given by **Howard Ende** who is General Counsel of Princeton University and Princeton Plasma Physics Laboratory. Ende pointed out that a major part of his present work is concerned with institutional compliance with regulations. In the old days lawyers were rarely expected on to be involved in the nuts and bolts of instruction.

The teacher has the duty of reasonable care in the laboratory. A breach of duty that causes injury may create liability for the teacher personally or for his or her institution. The teacher's responsibility to his or her students is larger than the parent's responsibility to his children. Some obvious duties are adequate supervision and appropriate warning of students about hazards. Furthermore, a teacher has a duty to protect against unauthorized experiments, by, for example, locking up dangerous material. The institution further has a duty to provide safe premises and equipment.

In the case of a suit, the judge will decide if the duty exists (it almost always does in a teacher–student relationship), and then a jury will decide if there has been a breach of that duty. Factors relevant to this decision include the foreseeability of the accident, the degree of harm done, the age and capacity of the student, common practice in the field, and compliance or noncompliance with statutory rules such as those put out by the Occupational Safety and Health Administration. The plaintiff must further show a direct causal relationship between the teacher's breach of duty and the injury received.

Various defenses exist. Some of them are that the student's negligence contributed to the accident or that the student took on a hazardous operation knowing full well the dangers. Teachers should be warned that juries tend to be biased in favor of compensation of injuries and tend to "rob the rich".

There are various things that teachers can and should do. They should check to see that stockroom personnel are adequately trained for the tasks undertaken. Second, it is important that bottles be labelled with appropriate warning stickers, that equipment be checked for safety, that glassware be cleaned and unchipped, that fire extinguishers be adequate, and, most important of all, that the lab never be left unsupervised. Hazardous reagents must be kept under lock and key. Experiments should be reviewed for the educational value versus the risk.

Teachers are protected against liability in two ways. The first is an indemnity, a situation in which a third party is responsible for the liability. This party might be the employer or an insurance company. Parents or students can in principle waive the right to sue, but it is unlikely that such a defense would stand up. The institution's own immunities to suit may help protect the employee. These include sovereign immunity in many state or government schools, and charitable immunity for private institutions. However, if the institution itself is immune, the teacher may be sued simply because he is the only one left exposed. Teachers should talk to their administrative officers, risk managers, or the general counsel's office of their organization. Unions and professional associations are further sources of information on liability issues. Ende felt that the final solution to the liability problem in student labs would be to set up a worker compensation arrangement for students. Under this system, students would waive the right to sue but would be compensated for their injury by insurance.

The third session of the meeting explored the uses of computers in laboratory education. Speaking were **Stanley Smith** and **Jerry Bell.**

Smith showed a complicated simulation of an experiment using computer and laser disk technology. This method avoids hazards in laboratories and allows the student to explore many possible variations in a very short time. His arguments for computer simulations were that they were much cheaper after the initial cost, much safer, and very much more time effective. He showed a clever demonstration of kinetics and a chromate–dichromate equilibrium in which the computer was used as a record keeper and the laboratory work was almost as simple as a video game.

At the University of Illinois, a system of half computer-simulated laboratories and half real laboratories has been used with great advantage in the freshman chemistry program. Rigorous statistical testing showed that this system produces more concept mastery than the classical lab alone.

Jerry Bell spoke of the potential damage to the educational system that might be done if computers completely replace labs. The question is not whether to involve computers but how to involve them in a way that makes the synergism of lab and computer useful to the student. He approved of data reduction from interpretive experiments, interfacing experiments where the computer was an automated notebook, and simulation used to teach strategy or approach to a problem as a premliminary to a real "hands-on" experience. His own computer simulation of the N-solution problem was used to demonstrate that, while the computer is efficient in teaching symbolic and simulated experience, it was not providing the same experience as real labs.

Pickering, whose topic was the management of large TA run labs, argued that the failure to consider the human dimension of lab structure was at the root of our lack of progress in laboratory teaching. Laboratories depend crucially on teaching assistants, many of whom are uncomfortable with the authority-figure roles into which they are often placed and who need help in making the transition from self images as students to self images as professionals. The use of quality circles can promote this transition and generate good ideas. Lab instruction also suffers badly from the conditions under which most lab directors are hired. Too often these people are not given ordinary faculty privileges such as leaves, rotation between courses, and time for scholarship and are judged by how much weight they lift off faculty shoulders. This is short-sighted because in the end "the quality of labs just might depend on the quality of the people running them".

Pickering then compared his own interest in the structure of labs (grading, TA motivation, flow of authority) to the usual faculty concerns about curriculum, sequence of experiments, and quality of equipment and closed by pointing out that laboratories are an area in which important new ideas can be generated by a lone teacher without enormous resources. He closed the conference with an appeal to the participants to try new ideas, to publish, and to push for change.