THE IMPORTANCE OF LABORATORY EDUCATION IN LIFE SCIENCES
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Carl Sagan has said, "Science is a way of thinking much more than it is a body of knowledge." Science is exploring, searching for and answering questions, solving problems, understanding principles and processes together with their causes and consequences. If science is more than facts, information, knowledge and truth, the student experience with science should result in more than that also.

Science is a dynamic, exciting search for the understanding of patterns, regularities and principles. In no other place does this happen better than in the biology laboratory. In no other place can it be more indelibly impressed on the minds of fledgling scientists than in an introductory course in Life Sciences. I have been extremely concerned in my former role as Director of Life Sciences with the number of students who come to Illinois as transfer students who have had no laboratory experience in a biology course.

Recently the National Commission on Excellence in Education has generated a renewed interest in education, particularly in relation to scientific literacy. This then is an opportune moment for us as teachers of biology to examine our introductory college level biology courses and to look at our curricula and ask if our courses in introductory biology, or any level of biology, reflect science as a process as it can be studied in the laboratory. It is so essential to introduce the student to living systems, to teach them to ask how and why, which can only be done when they are looking at living material.

I would like to share with you an experience I had in my early years as a professor at the University of Illinois. Having been assigned to help develop a new course in introductory biology, I went to the laboratories to take an inventory of existing equipment which I will share with you in its entirety. The inventory consisted of one rusty ring stand, twelve finger bowls, two Bunsen burners, and 100 gallons of formaldehyde. As we developed this new course which was a wedding of an old general zoology and botany course, the laboratory was the first thing developed. To me it was the most important element in that course. This is a course that runs for an entire year, 5 semester hours each semester. One-half of the entire credit or grade is attributed to the laboratory. It is not 4 hours on lecture and one hour on lab, but half of the entire grade depends on the student's performance in the laboratory.

I made a pledge then that the laboratories would, and did indeed, become a living experience. Our students would know that biology did not come out of a pickle barrel filled with formaldehyde. We worked with living plants, we worked with living animals, we brought in marine specimens; we invited the students to take them out, dissect them, look at them, watch them and have a hands-on experience with living material.

We tried to make our laboratories dynamic, constantly adding new laboratory material and new equipment. I realize that this requires a commitment from your administration which it is not always easy to come by. But, it is important for you who have gathered here today as biology teachers to perfect your craft, to go back and convince your administration that you need money for laboratory equipment. The cost of our laboratory course at Illinois is roughly $40 per student, this includes personnel, TAs, hourly help, supplies and equipment. There is a total annual budget
in excess of $27,000 for Introductory Biology 110 and 111. It is a majors course required of all undergraduates in Life Sciences. We feel gratified in knowing that all of our students go away understanding that biology is a living science.

College faculty involved in teaching biology in a laboratory setting share many common challenges—the need to develop interesting, reliable laboratory activities; to identify reliable suppliers of biological material, to maintain and manage living laboratory organisms—and this often does stretch tight operating budgets. We have a role to train assistants for laboratory teaching and to develop relevant laboratory materials. Commercially available laboratory manuals are usually based on traditional and often unreliable procedures and materials. Many published articles in biological education are more philosophical than practical. Recognizing these commonly shared concerns a group of biologists met at the University of Calgary in June, 1979 and founded an organization of laboratory biology teachers called The Association for Biology Laboratory Education or A.B.L.E. A.B.L.E.'s primary purpose is to facilitate communication between teachers actively involved with laboratory instruction in the various areas of biology. With approximately 40 charter members, A.B.L.E. has now grown to over 500 members from the United States and Canada. During its five years of existence, A.B.L.E. has tried to improve biology laboratory education mainly by identifying successful laboratory exercises that have grown out of our workshop conferences where participants have an opportunity to get hands-on experience with new kinds of laboratories. I will be talking more about A.B.L.E. in my session at 3:00 p.m.

The point I want to make here is that there is a large group of biologists out there who are making an effort to develop good laboratory material. We have developed through A.B.L.E. an extensive bibliography of 250 annotated volumes in a biology library of laboratory manuals. Throughout the five years, we have made an effort to identify papers from the research literature that can be modified into teaching laboratories. We have found that there are many current experimental procedures that adapt themselves well to an introductory laboratory education. If we can encourage more of our colleagues to specifically identify some of their research as having potential for a laboratory exercise, we would all benefit a great deal.

An editorial published in The Chicago Tribune stated, "The distressing fact is that the overwhelming majority of our population lives in a state of debilitating scientific illiteracy." I think that no other place is that more evident than in those students who go through a biology course without a laboratory experience. With a sharp decline in laboratory teaching during the 1st 10 to 15 years, what have we harvested? I think we will have a generation of young biologists who have memorized textural knowledge and who can master our machine designed examinations to prove it. However, they do not know how to do an experiment and even more damaging, they have little or no interest in learning. They feel little or no compulsion to apply principles of a controlled experiment in their search for understanding. They do not appreciate their heritage from research, they have become biologists who fail to recognize their dependence on research for their own ability to effectively search into the unknown.

Just one example that might help students, and you as teachers, realize and stop and think about the importance of laboratory education and knowing how to function in a laboratory. Virtually all that is known in the modern handling of cardio-vascular disease has evolved within our lifetime. Our generation has seen the emergence of almost 90% of what is known in modern medicine, thus accounting for almost all of a modern physician's ability to diagnose and treat disease. This has all come about as
a result of laboratory research. I wonder if we can convey this message to our students. I wonder if we help them realize the importance of learning to function in the laboratory. Do we infect our students with a sense of excitement for a stimulation of new knowledge? Do we stimulate their natural curiosity about the biological complexities they encounter everyday? I am afraid the answer to these questions are a resounding NO. Have we as a profession abrogated our reliance on the laboratory as the place to learn biology, responsibility for teaching the principles of the scientific method? Haven't we succumbed to the temptation to emphasize hand-outs, reward the student for memorizing their lecture notes? What is happening in the biology laboratory? How many students get through all the basic sciences today without seeing a vigorously beating heart surrounded by inflating and deflating lungs?

I recall my first course in physiology when we dissected a dog and studied circulation. What an excitement it was to feel the strength and coordinated rhythm of ventricular pumping! How many of you have personally experienced the dynamic changes in the ventricular pumping action at the onset of fibrillation? Compare and contrast in your own mind the impact of just reading about fibrillation in a textbook with that elicited by holding the heart in your own hand at the very instant fibrillation is induced. This is a living system, we should be excited and our excitement should be transmitted to the student. They will gain that natural, overwhelming curiosity to find out why it works. Wh have, in many cases, opted for the easier way of teaching, some may argue that new ways are better, some will defend the teaching machine, the slide/tapes, the problem programmed computer. But if these are substitutes for the teaching laboratory, I cannot accept the argument. I do acknowledge with conviction that laboratory teaching is hard work; it is expensive in terms of time, effort and money; it requires total commitment from the best teachers in your department; and, it demands time away from your own research.

When I served as Director of Life Sciences, I deliberately assigned myself to teach in the introductory course in biology. I feel that our very best talent needs to be in the introductory course, teaching in those laboratories. Our students may get through basic sciences with virtually no research experience, often no laboratory at all. They are forced to depend entirely on sheer memory for all they know. It would be impossible for us to design a more intellectually, stupefying, stultifying framework in which to learn biology.

What are some of the tangible rewards for good laboratory teaching in biology? There are many but let's look at one or two examples. Eighty-five percent of all biology majors at Illinois are pre-professional, it may be higher—it may be as high as 90% in some years. It may be different at your schools, but I doubt it. Of that 85% less than 50% will get into the professional school whether it be medicine, dentistry, veterinary medicine, or allied medical sciences. As Director of Life Sciences for many years, I worried a great deal about these students and what they would do with their lives. In counseling with biology students, many times I have said to them in a group, "Not all of you are going to get into medical school." And one can see etched on their countenance the internal response to themselves, well I certainly feel sorry for the person to my right or my left, but he's certainly not talking about me. But the honest fact of the matter is less than 50% of them will be accepted into the professional school. In response to that, approximately four years ago I started a job placement service. I was told by many people that there was no job market for someone with a biology degree. I refused to accept that and after careful nurturing, searching, and casting about for potential job markets we have found that there is indeed a very viable job market for people with a biology major. We have gone to academic institutions, we have gone to industry, and we have gone to
the government at the local, state and federal levels. All of them have job descriptions and positions which indeed utilize people with a good sound degree in biological sciences. We routinely now have our graduates at Illinois interviewed by people from Abbott, Beatrice Foods, DuPont, Eli Lilly, etc. This brings me to the point I want to make about the payoff for good laboratory teaching. Every major corporation or government agency that has come to Illinois to recruit our students has said before they ever come, "We want laboratory trained individuals. Please do not put anyone on your interview list who has not been trained in the laboratory." There is a career, there are jobs, but there is no substitute for the laboratory experience. They have to know how to use the spectrophotometer, an analytical balance, an ultracentrifuge. Give them hands-on experience in the laboratory and they will find jobs! In a real sense, we are training them not only in a storage of knowledge and information but in practical techniques that they will take with them into the professional school or into the job market.

Another payoff for good laboratory teaching is found in the potential of bringing undergraduate students into your own individual research laboratory as an assistant. If you can generate in them the excitement and interest in biological systems through their experiences in basic biology laboratories, they will be filled with the excitement of laboratory experimentation. This can be extended into your own personal research. Collin Pittendrigh, the world authority on circadian rhythms, during his years as a professor at Princeton University had many post-doctorals working in his laboratory. But all of the research on circadian rhythms and eclosion was done with undergraduate students who had been excited about biology and who came to work on individual projects in Pittendrigh's laboratory. I recall the first time I visited his laboratory at Princeton his taking me into a room with 4 or 5 cots and all kinds of experiments on the laboratory benches. These students who were working on eclosion were sleeping in the laboratory, living, eating and breathing the excitement that was going on in a research laboratory. Many of them published joint papers with Pittendrigh. Each one of you, can you imagine the potential of developing a program in your own laboratory? Each student is a potential pair of hands with not only a desire but an excitement to work in your area of research. A year ago I was at Brigham Young university in the laboratories of an old post-doctoral student of mine, Dr. Gary Booth. He is an outstanding toxicologist and has been working on the sediments on river bottoms in the major waterways in the United States. He has at least 15 or 20 undergraduate students standing in line by his office door every year begging to go to work for him because they have been excited about their introductory course. They are excited about the biology laboratory. He has a tremendous manpower and can assign each one of those students a portion of a research project and generate a tremendous amount of work. I know you carry heavy teaching loads and there are administrative responsibilities, committees and duties at a university that take you away from that you most dearly love—research in biology. These students can become a powerful asset in your own individual programs. You really cheat yourself if you don't utilize that potential. They are eager, they are anxious to be involved and, I suspect I shouldn't dwell on this very much, you don't need to pay them anything. You can have them sign up for research credit; they can work in your laboratory and for their efforts go away with 3, 4, 5 hours credit and they are ecstatic because they have had an opportunity to work in a research experience.

These are just two of the many bi-products, if you will, or rewards for good laboratory teaching. The more general rewards are obvious. The students who do well in the laboratory will be accepted in the professional schools. They are the ones who will be successful in their careers.
I am no longer director of the School of Life Sciences. I am currently Director of the Division of Rehabilitation Education at the University of Illinois, and so the last part of my talk I would like to impress on you the responsibility I feel that each one of you have to get students who have disabilities involved in science. For the past nine years, I have been involved in the National Science Foundation in developing programs around the concept that there should be more individuals with disabilities enter the field of science. For a long time, there has been a stigma that one should not go into laboratory or expect to do bench science if indeed they have a disability. It is important for you as teachers and I make a plea, an earnest plea, that you encourage students with disabilities to become involved in biological science. Teach them science, let them know that they can function. I will never forget Joe Lilienthal at Johns Hopkins, my physiology professor. When I returned to graduate school, after breaking my neck some 34 years ago, calling me into his office and sitting squarely in front of me and putting his nose in my face, saying, "Larsen, I am sorry you broke your neck, but if you're going to take my class, you're going to do everything everyone else does in the lab and I don't give a damn about your wheelchair." Well, I don't know whether he was trying to make me mad or whether that's how he really felt, but he was successful. He angered me to the point where my internal gut reaction was I'll show you, S.O.B. I went into the physiology laboratory that afternoon and saw the typical laboratory bench normally found in a dog lab. Tables high enough for "Kilroy" to peek over, I could have worked under the table more conveniently in a wheelchair. That night I returned to the laboratory with one of my friends and a saw. I took a laboratory table and cut 18" off every leg of one of the benches. The next day Lilienthal came into the lab. We had our dog at lap level and were carrying out an experiment in our group. He walked over and saw that his table had been cut down to my size and said, "What in the hell is going on?" Now I had a turn to look him straight in the eye and say, "You take care of the course and I'll take care of the student responsibilities." There was an embarrassing moment of silence, he walked out of the lab and never said another word. I believe in expediency, there is always a saw and hammer in my laboratory and whatever needs modified will be modified. It is important, as you work with people that have disabilities, that you encourage them to adapt themselves to the maximum. When they have reached maximum adaptation of self, then you modify the environment as necessary to meet their needs. You have to be careful in pressing them to independence. I recall one day as a graduate student needing a bottle of sulphuric acid which was located on the fifth shelf. I pulled the arm out of the chair, reached as high as I could and pulled the bottle to the edge of the shelf. As a five pound bottle of sulphuric acid plummeted toward the earth, I could hear someone behind me inhaling and as I caught the bottle in the cradle of my right arm he said, "My God, Joe!" If you need anything, just ask me. I'll get it for you." You will find that if you will be willing to make reasonable modifications that will not detract from that laboratory setting for anyone else, you will generate an excitement in many young minds who have been previously denied.

Probably the most difficult decision to allow me back into graduate school had nothing to do with the wheelchair or my functioning in the laboratory, it had to do with who was going to to give up a parking place. There were only 11 spots and they were reserved for deans and administrators, and nobody wanted to give up their parking place. I encourage you to make whatever modifications are necessary to allow people who have physical disabilities to come into your laboratory. You will have a great, rewarding experience. I recall not long ago of having two dwarf people in class who could not function at a normal laboratory bench. They had difficulty climbing up on high stools and were very uncomfortable. During that week, I had the unpleasant opportunity to visit my local dentist for a little grinding and polishing, and as he
tipped me back in that luxurious lounge and pumped sweet music into my ear while he proceeded to destroy my mouth I noticed him going up and down on a hydraulic stool. When he had finished his torture, I inquired as to where he obtained that. He said from a dental supply house. I just press the button; it takes me up or down. I called the dental company immediately and told them I'd like to try, on a demonstration basis, two of those hydraulic stools. They brought them out, I explained what I wanted to try. The two "small people" used them with delight and efficiency. The dental supply company was gracious enough to leave them with me when they understood what the purpose was, at no charge. It's amazing what you can get done if you just give people an opportunity. Those two students did a tremendous job in the course. Both received As and for the first time they had been able to approach a microscope on a laboratory bench at their level.

We'll, I've exceeded my time. It's been good to be with you; I have enjoyed sharing with you my enthusiasm for laboratory teaching and I hope that as you go through your conference today and tomorrow addressing your theme of "Biology and Experimental Science" you will remember that biology is an experimental science and could not be so if it were not for the laboratory. Therefore, do not cheat your students at that most crucial point in their educational pathway of the laboratory experience in introductory biology. There they will truly realize that biology is indeed a laboratory experience and an experimental experience where they can gain hands-on excitement of life's processes.

**USING HUMAN SUBJECTS IN THE LABORATORY**

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In a biology course for non-majors, or an introductory biology class, it is easy to "cook-book" the laboratory portion of the course. It is equally easy to use only dead specimens and thus have a course in necrology rather than biology. The following exercises can be used to involve students in collecting data about themselves. Details of procedure can be obtained from a wide variety of laboratory manuals. The listing is not intended to be all inclusive.

**Eye Dominance:**

**Procedure:** Cut a 2.5 cm diameter hole in a large sheet of cardboard. Using both eyes, sight a distant object through the 2.5 cm hole while holding the cardboard at arm's length. Hold the cardboard with both hands and move it gradually toward the face, keeping the distant object sighted. Determine which eye is used. Repeat several times. Do you always use the same eye to keep the object in sight? Is your dominant eye on the same side as your dominant hand? The dominant food-chewing side of the mouth? Make a record of eye, hand, and side of mouth dominance for your laboratory group. Does a consistent pattern emerge?

**Depth Perception:**

**Procedure:** Prop a large sheet of white cardboard (60 cm x 90 cm) about 5 meters in front of the class, and several feet from the front of the room. The top of the cardboard should be about 10 cm above eye level of the students.

**Trial 1:** Hold a strip of black paper 1 cm wide and 30 cm long, 10 cm behind the large white cardboard, with 5 cm showing above the card. Students are now to judge the distance...