# The Minds-On Approach: Student Creativity and Personal Involvement in the Undergraduate Science Laboratory

*"Minds-on" lab activities challenge students to develop questions based on their observations and to refine them into testable predictions.*

*Douglas Schamel and Matthew P. Ayres*

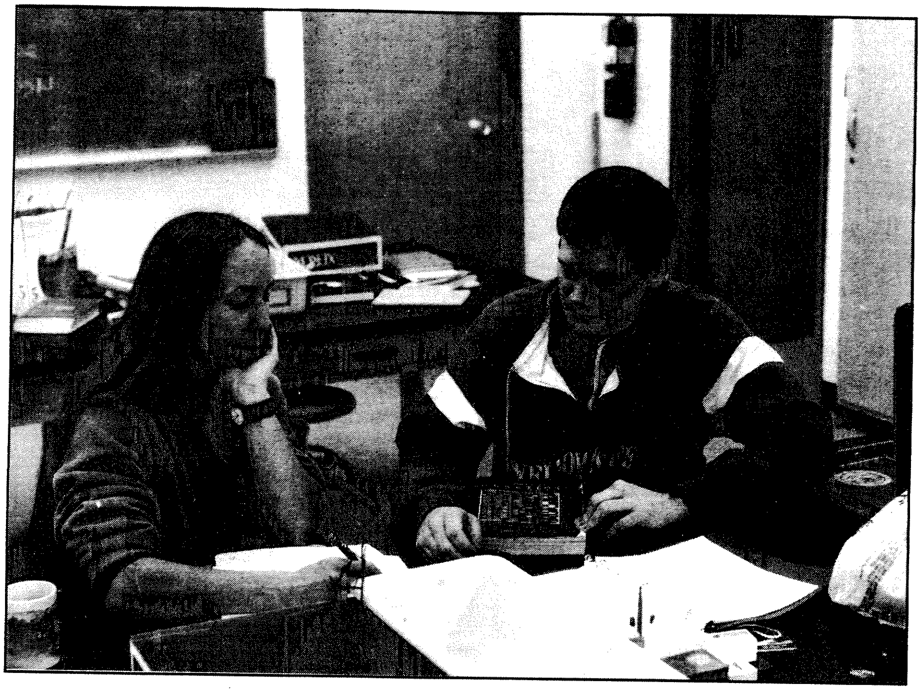
Students may learn more if we teach them less.

Most of us learn best by doing. This is certainly true in science laboratories. But not all doing-laboratory exercises are equal. The typical hands-on approach allows students to actively pursue an experiment by following a set of directions devised by a trained scientist. The student may be busy with his hands, but where is his mind? Could it be in neutral? We like to think of our laboratories as "minds-on" exercises.

This "doing" concept springs from science in its purest form. Instead of a predetermined exercise with a foregone conclusion, we provide students with an opportunity to make their own observations, and challenge them to develop their own questions based on those observations. Their tentative answers are refined into a hypothesis. From the hypothesis, they generate specific predictions that can be tested. They must design and conduct this test, then critically evaluate their predictions and the underlying hypothesis in light of obtained results. Students make observations and pursue questions in small teams (2-5 students per team). Thus, there may be a diversity of questions examined during any one laboratory session. We find the title "minds-on" approach appropriate, because our students must be mentally engaged from start to finish. There is no opportunity for minds to be in neutral.

Our first exercise is deliberately open-ended. We ask students to go outside and observe nature, focus on some interesting question, and pursue that question scientifically. In prepara-

***Douglas Schamel is an instructor of biology in the department of biology and wildlife and Matthew Ayres is a research associate at the Institute of Arctic Biology, both at the University of Alaska Fairbanks, Fairbanks, AK 99775.***



*Students planning their individual experiments at the University of Alaska.*

tion for this exercise, students are required to read the section of the laboratory manual that explains the scientific method and outlines a variety of questions, simple experiments, and interpretations of data. This approach immerses students more quickly into the excitement of science than the science process activities suggested by Rhyne and Golden (1986).

Without doubt, the biggest problem encountered by students is "what should I investigate?" Although it would be relatively easy for us to assign specific questions, we try to avoid that. The laboratory materials include some general observations that need closer examination to formulate a question. Many students find these helpful, while others are still stymied. In some cases, we find it necessary to accompany students into the field to discuss observations with them. In other cases, students have wonderfully complex questions that require an electron microscope and three years of research time to answer. We help simplify these questions.

Many students enjoy the freedom to explore something of personal interest. In fact, students often say that they "have wondered about that for years and were glad to have a chance to investigate it." Some of the more interesting questions pursued included: 1) Is timing of leaf-color change affected by soil temperature? By leaf position on the tree? 2) Is there a difference in seed production between roses in the sun versus roses in the shade? 3) Do beavers show a species and/or a diameter preference when harvesting trees? 4) Can red squirrel cone harvesting behaviors be altered by hiding/augmenting their cut cones?

*Students participate in what practicing scientists usually regard as the most challenging and rewarding aspect of "doing science—" questioning and designing experiments.*

Students complete this exercise and share findings during the first part of the second week. In the second part of that week's laboratory, we introduce students to a more narrowly focused problem. We provide them an opportunity to observe osmosis in plant and animal cells under a variety of conditions. Equipped with this background (and the simultaneously acquired knowledge of basic techniques), students are asked to design an experiment investigating the selectively permeable nature of plasma membranes.

Experimental design begins in the laboratory and continues as a homework assignment; groups arrive at the next meeting with a written outline of their proposed experiment. We agree with Stewart (1989) that students need ample time to transform basic procedural techniques into their own experimental design. Students are asked to place orders for supplies at least one day before arriving in lab.

Obviously, the role of the teacher is quite different in this scheme. We become facilitators and consultants. We steer students away from overly complex experimental designs. We help trouble shoot their plans by asking "what if?" (What if you obtain the following results? How would you interpret such results? Are other interpretations possible? If so, how can you amend your design to eliminate those interpretations?) In comparison to the rote exercises that they replace, the laboratory activities are far less predictable. No two laboratory sections will ever be exactly the same. We find this a refreshing and stimulating change.

Table 1. Problems in "traditional labs" and solutions to those problems.

*1) Students seem detached from and disinterested in the laboratory experiment.*
*2) Students arrive at the laboratory session unprepared. They do not understand the goal of the experiment or how the outlined methods will achieve that goal.*
Solutions using "Minds-On" approach
Since the experiment is conceived and designed by the students, they are naturally interested in discovering an answer to their question. Because they have a vested interest in the experiment, they carefully think through the procedures (that they devised). The question "what are we supposed to do at this step?" is no longer valid; they are following their own design. If students arrive unprepared, they must design the experiment in lab, while their classmates are performing experiments and recording results. This usually means working beyond lab time or producing a clearly inferior product.

*3) Laboratories are aimed at the average student. Slower students are overwhelmed; more advanced students are not challenged.*
Solution using "Minds-On" approach:
By allowing students to design their own experiments, we also allow them to choose a comfortable level of challenge. Slower students may want a fairly simple experiment. Advanced students may perform several experiments or a more sophisticated experiment. Students can (and should) be challenged by their experiments, but the level of challenge may vary with individual differences. In all cases, students are learning how to do science. And they are growing. Only their starting points are different. An important feature of this arrangement is that slower students are involved and challenged at a level where they can achieve success. The positive feedback inspires them to continue striving and to accept new challenges.

*4) In large laboratory sections, aggressive students receive the most attention, while other students who need assistance are left to languish.*
Solution using "Minds-On" approach:
An interesting by-product of our organizational structure is that students rely heavily upon peers in their working group. In some cases, students are able to answer virtually all their own questions. Students discover that they can work effectively as a team to overcome problems (Johnson et al. 1984). This knowledge increases their confidence and ability to tackle future difficulties creatively. This frees time for the instructor to work more closely with groups that need assistance.

*5) Students overlook mistakes or are ashamed to admit to having made a mistake.*
Solution using "Minds-On" approach:
We maintain that mistakes are a natural product of scientific activity. They are mis-steps while walking on new paths. Mistakes are far more likely to be discovered by students who care where the path leads. It is pleasing to us that our students can identify their mistakes and correct them, without a feeling of failure.

*6) Students gain little practice in critical thinking.*
Solution using "Minds-On" approach:
The grand finale for the laboratory exercise is the sharing of information. Groups give oral presentations outlining all major aspects of their investigation, from initial observations through conclusions. We encourage groups to critique their own study and to suggest follow-up studies. We also encourage fellow students to ask questions about the study. This sharing of ideas in healthy discussion is an integral component of scientific endeavor. Students also get a chance to discover basic patterns and themes that emerge from the assortment of studies devised by classmates. In some cases, the same question is approached in very different (but equally valid) ways by different groups. In other cases, follow-up studies proposed by one group were actually conducted by another group. Because the students are discussing their own projects, the presentations tend to be coherent and lively. Fellow students seem truly interested in the work of others. As a follow-up exercise, we frequently ask students to turn in an abstract of their study. This gives them practice with clear, concise writing (to complement their experience with oral presentation). We copy one abstract from each group for distribution to all students, so they will have a permanent record of the experiments (and so they can see the variety of ways in which similar material can be presented).

The challenges are considerable but so are the rewards.

This approach to laboratory instruction sets an entirely different tone for the classroom than the traditional approach. By challenging the students to ask their own questions and design their own experiments, we are cultivating their creative abilities, and allowing them to participate in what practicing scientists usually regard as the most challenging and rewarding aspect of "doing science." At the same time, students seem to better appreciate the value of clear thinking and sound methodology. Carelessly formulated predictions, or inappropriate techniques, result in an unsatisfactory answer to their question.

Our students have responded well to their new responsibilities. In fact, the shift in format solves numerous problems often encountered in undergraduate science laboratory classes (Table 1).

We have implemented the minds-on approach in laboratories in both our majors and non-majors courses. In addition to the laboratory exercises mentioned above, we have developed investigative exercises dealing with: enzyme activity; photosynthetic pigments; metabolism; microbiology; natural selection; taxonomy; plant physiology; and animal behavior. At the onset of our laboratory revision, we confronted the same problem reported by Medve and Pugliese (1987); we found no existing laboratory manuals that met our needs. We overcame this dilemma by following Tinnesand and Chan's (1987) suggestion of throwing out the instructions from our favorite cookbook exercises. Students were provided only the protocol for needed assays; we allowed them to experience the satisfaction (and occasional frustration) of refining experimental methods.

So far, we are very pleased with the results, and the positive comments of students reinforce our impressions of success. In a poll of students at semester's end, 92 percent (n=76) of the students in our majors course and 81 percent (n=179) of the students in the non-majors course preferred the First of all, we have not tracked our students in a systematic fashion. In addition, more than half our students in introductory-level biology courses either change majors or transfer to another school before their junior year.

*When students have the freedom to explore a question and design an experiment, the instructor's role as a "teacher" changes to that of a facilitator and consultant.*

Our approach has not been widely accepted by other members of the science faculty. The biggest problem is time. The "minds-on" approach is very time demanding on instructors and teaching assistants. Many faculty simply do not welcome the extra work associated with such a laboratory experience; it is much easier to use a published laboratory manual with step-by-step instructions and established results. We have been encouraging students to ask for some "freedom to explore" in other science classes. We have also been encouraging faculty to allow for creativity in at least a few laboratory exercises each semester. We hope that if faculty will try this approach once, they will share our excitement.

Those who have visited our labs in session have been impressed with the intensity of student involvement and intensity of student interaction with instructors and each other. Because students are fully engaged in the scientific process, (including identification of the questions) they find a real purpose in thinking, sharing, critiquing, discussing, and writing. If you want your students to experience science, if you enjoy gaining new understanding through the experiments of your students, if you do not mind creative chaos in your laboratory—give the "minds-on" approach a try. ❑

Acknowledgment

We wish to acknowledge the generosity of Dr. Jon Glase, Division of Biological Sciences, Cornell University, for allowing the senior author to experience his investigative laboratories. We especially thank Dr. Verne N. Rockcastle, Department of Education, Cornell University, for opening our eyes to the excitement of "discovery" science.

References

Johnson, D.W., R.T. Johnson, E.J. Holubec, and P. Roy. 1984. *Circles of Learning.* Alexandria, VA: Association for Supervision and Curriculum Development.

Medve, R.J. and F.A. Pugliese. 1987. Science as a Process. *The American Biology Teacher* 49:277-281.

Rhyne, P.J., and B.R. Golden. 1986. Science Process Activities for the Introductory Biology Laboratory. *Journal of College Science Teaching* 15:539-541.

Stewart, B.Y. 1989. Merging Scientific Writing with the Investigative Laboratory. *Journal of College Science Teaching* 19:94-95.

Tinnesand, M. and A. Chan. 1987. Step 1: Throw Out the Instructions. *The Science Teacher* 54:43-45.