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MAKING BIOLOGY LAB LOVABLE

Biology is the science that studies living organisms and has practical applications in agriculture, biotechnology, and medicine. Biology lab is a critical component of biology students' professional portfolios. However, it is apparent that many students do not value the labs, as evidenced by their coming unprepared; having unrealistic expectations about what they should accomplish there; and exhibiting a dislike for solving practical problems, working in groups, conducting data analysis (especially using statistical analysis tools), completing lab write-ups, and/or participating in open-ended discussions.

However, most biology majors go on to biotechnology companies and professional schools where they are expected to be well prepared; have clear and accurate expectations; define, analyze, and solve problems; exhibit excellent writing and communication skills; work well with others; and keep an open mind. Therefore, a major challenge for biology lab education is to motivate students to become enthusiastic lab participants and develop multidimensional skills.

Traditionally, students come to the lab with an unread lab manual, listen to the instructor about the lab, watch some demos and videos, work on their labs, and write lab reports. Because they come unprepared, the knowledge and techniques taught at the beginning of the lab may sometimes become information overflow, difficult to master in a short time period. Students do not have accurate expectations about the lab and are struggling to get the "right" results. They do not like to work in groups because they may get less hands-on time and must spend additional time completing their lab assignments. Finally, many students come to class looking for clear answers; they do not expect, nor are they prepared, to tackle any "still under investigation" issues.

Based on the concept of "prior preparation prevents poor performance," we switch the instructional emphasis from *during and after the lab* to *before the lab*. Rather than bringing lab manuals, students are required to develop protocols for the lab and come with *only* the protocols—a major change in the traditional approach.

The lab protocol consists of an appropriate and informative title in proper format; a clear, one-sentence hypothesis; the justification for and background of the lab (which contains a literature search, references, and citations in appropriate format, background followed by hypothesis, and justification of the research design); a description of the experimental approach and controls (which includes a broad view of the experiment, provides information to answer the question being asked, and includes appropriately designed and explained controls); a description of the expected results and data manipulation (which includes the expected data to be recorded, presented in appropriate format and using statistical analysis); and a step-by-step protocol with materials, equipment, the order of steps and time instructions, plus material safety data sheet summary (regarding lab safety and handling hazardous substances), if necessary. This exercise involves critical thinking, researching, defining and solving problems—all essential components of our students' future professional portfolios.

At least one week before the lab, the instructor gives the class an overview of the topic and provides some leads and suggestions. Students will be led through the lab to get an idea about what is going to happen and what materials and equipment are available. Based on the introduction from the instructor and information from the lab manual, students search for information on the topic, in libraries and/or online—including about how to tackle the problem and develop a detailed plan, the protocol. They are encouraged to work around what is provided and be flexible—even trade biomaterials if they can provide a manageable request ahead of time. (For example, they can use pumpkins instead of carrots for osmolarity lab if they have a well-designed plan.)

Students are required to work out protocols with their lab partners so that they have opportunities to brainstorm with at least one of their peers and to compare and complement their protocols. Each pair must develop one protocol, so students can spend more

time thinking than writing. But to make sure that everyone has the opportunity to write, students are required to take turns writing the protocols. Students are required to change their lab partners every two or three weeks, depending on class size; thus, each student might well have opportunities for working with half of the students in the class. In addition, students are required to evaluate every lab, including their partner's and their own performance (including background research, protocol development, experimental procedure, and feedback). To monitor the quality of the protocols, students are encouraged to e-mail the protocols in advance of the lab and discuss them with the instructor and other students. After they gather comments and suggestions, students are encouraged to make any changes to their work that might improve their protocols before they come to the lab.

At the beginning of the lab, at least one group of students makes a ten-minute PowerPoint presentation of their protocols. Peers criticize their protocols and provide additional comments/suggestions for improvement. Sometimes, students are required to use other groups' protocols to perform experiments and make modifications; interestingly, they always tend to modify others' protocols to improve their own. These assignments help develop students' presentation and peer-review skills, as well.

To improve the work conditions and make the job easier and intriguing, an Excel program is used for data analysis. The computer programs release students from mathematics' boring equations, and they can focus on how to analyze and present their data better.

Before leaving the lab, students are required to explain and discuss their results with the instructor and their peers. They compare their results with those from the literature and from others in the class, and they brainstorm about improvements and future directions. Thus, they develop a clearer picture of the topic, the results, and options for future reference.

Lab write-up is also a critical component of the students' work. To make sure that students focus on the quality of their writing, but not spend so much time that they become bored with the process, they write only part of a full lab report every time. [A full lab report usually consists of an abstract, introduction, materials and methods, results, discussions, and references. Students must write only two of these components for each lab. Of course, they may write on some components, such as results and discussions, more often than on others, such as abstracts.] A detailed grading scale ensures that students are paying attention to every detail of their writing and that they are developing their abilities to develop each section of a full lab report.

A comprehensive final examination may provide insights into students' abilities, but the final lab serves as a clear indicator of their actual abilities to perform—the summit of the course. Students have the freedom to choose their favorite partner, select a topic, and design the experiment. They talk to the instructor about the topic at least four weeks prior to the final lab and prepare a detailed supply list at least two weeks before. After their experiment, they write a full report and make a 20-minute PowerPoint presentation. Their reports and presentations are graded by the entire class, the instructor, and invited guests (usually faculty members and graduate students from the same or similar fields).

Overall, having students develop protocols helps improve their skills and the quality of their labs. The lab prepares students to use the libraries, search for online literature, summarize and integrate information, work in groups, criticize peers' work, and use PowerPoint, Word, and Excel programs. It is a multi-dimensional development of students' skills to help them meet future professional expectations.

Student feedback about this strategy has been positive, and some have written the words "fun" and "joy" on their feedback and evaluation forms. Instead of asking, "Why do I need to take this class?" students frequently ask, "Is there any other class that uses a similar format?"

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