A Start-up Manual for Undergraduate Research Students in Microbiology: Active Learning from the Very Beginning

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Abstract

This start-up manual accomplishes two main goals: time effectiveness and education through active learning. By having a research manual, the time professors spend on training students decreases. Through active learning, the retention rate of students increases. The manual is used before research activities begin and serves as an immediate reference throughout students' time in lab.

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Guide for the Instructor
Introduction
Research experience for undergraduate students. Research experience is no longer vigorously sought only by those undergraduate students who are interested in research as a career option. The experience also provides an advantage for those who pursue advanced studies in a variety of areas including medicine, veterinary sciences, and even law. Hence, more and more undergraduate students seek opportunities to join research programs to gain valuable experience.

Research expectations for professors in liberal arts colleges. Expectations of research productivity used to focus on professors in research-oriented universities where there are graduate students, postdoctoral fellows, and technicians. However, in recent years, research has also been emphasized in four-year liberal arts colleges in order to involve undergraduate students as colleagues in research projects. In some colleges, research productivity is not only expected, it also plays a major role in evaluation for salary, promotion, and tenure.

Challenges faced by students and professors. The challenges for students and professors in this specific environment then arise. One Hope College student wrote, "As a student entering a new lab, I feel completely overwhelmed. There is so much to learn: not only details of our specific project but also more general techniques and concepts. I can't remember everything after watching a professor do something once or just telling me how to do a procedure. I need to do them myself to retain."

As a professor, training a new undergraduate student can be very frustrating and time consuming. Lots of time is spent showing the students around the lab and teaching them concepts that they often forget later. Furthermore, if a research supervisor demonstrates a technique which students don't use for a while, or don't write down when they are shown, or if students fail to read their own notes, often the research supervisor will have to teach the student again. Professors are limited in the number of students they can take and train because the training process, and the repetition, are very time consuming.

There are many students who want to be involved in research activities. How does the professor accommodate as many students as possible? Most of the techniques used in the research projects are not incorporated in the lab activities associated with a class. How does the professor teach all the basic yet necessary concepts and techniques, which are new to students, in a short period of time without overwhelming students? Most of the undergraduate students join research laboratories in their junior year. How does the professor spend less time in training and more time in obtaining meaningful data? The solution to these challenges will lead to successful student training as well as career satisfaction for professors.

The proposed solution: A start-up manual for undergraduate research students.
The key is to spend less but more effective time with each student. The traditional passive learning approach demands a lot of time from a research supervisor and retention rate of students is low. An active learning approach will re-direct the responsibility of learning to students so the retention rate is higher, which decreases the necessity of repetitive training and explaining.

In response to the frustrations expressed by research students and supervising professors, we developed a start-up manual for incoming research students. Our manual presents most of the concepts and techniques that a student with limited microbiology experience must learn to start independent research safely and effectively. Since research requires active investigation, a self-motivated, hands-on learning approach will stimulate the student to become actively involved from the start. Also, by performing certain lab techniques instead of being shown how, the student will learn faster and retain more of the information.

The manual includes instructions for operating equipment, basic techniques in microbiology and molecular biology, issues on laboratory safety, problem sets for determining solution concentrations and serial dilution, exercises on "decoding" research articles into a regular laboratory protocol, information on chemical/supplies ordering and inventory, and other common knowledge and skills that are essential for a successful research experience. The manual also includes hands-on exercises and quizzes to ensure the student is properly prepared before embarking upon the first day of research. Students are given one week to accomplish the assignments in the manual.

Such an approach builds the confidence of research students and encourages them to work independently. The manual also serves as a valuable reference throughout their time in lab. The self-learning method creates more time for professors, allowing them to provide opportunities to more students and to devote their expertise to the research rather than the preparation.

A Start-up Manual for Undergraduate Research Students in Microbiology can be found at http://facweb.furman.edu/%7Eliaomin-ken/Start-up-Manual/Start-Table-of-content.html

Note:
Some sections of the manual can be used as-is, however, other sections cannot (e.g., different institutes have different models of autoclaves). The manual is a work in progress and it is to serve as a model for other faculty members to develop a manual for their research students. Ideally students would review the exercises on their own soon after the start of research. The manual therefore serves to 1) promote active learning; 2) serve as a resource; and 3) eliminate the need for the instructor to repeat methods and instructions when a new research student shows up or old students don't remember.

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Sample Application(s)

1. **Laboratory Safety and Housekeeping**

    Objectives:

- Acquire basic concepts and knowledge of lab safety.
- Locate safety equipment.
- Read HMIS label.

- Learn dish-washing and waste disposal techniques.

Exercise:

- Interpret the labels given below (attach a marked HMIS label in the manual).
- Locate the nearest safety shower and mark it on the building map provided below.
- Locate the "sharp box" and a biohazard bag in the lab and record their locations.
- Find (insert laboratory supervisor's name) home phone number in case of emergency and record it here.

2. **Preparation of Solutions**

Objectives:

- Make stock solutions and working solutions.
- Understand and use $C_1V_1 = C_2V_2$

Exercise:

- How many mole(s) of potassium phosphate are needed to make 1 liter of 0.2 M solution?
- What is the molecular weight of potassium phosphate?
- How many grams of potassium phosphate are needed to make a liter of 0.2 M solution?
- Determine the final concentrations of the monobasic and dibasic potassium phosphate solution in a working solution made by combining 300 ml 0.3 M $NaHPO_4$, 125 ml 0.4 M $Na_2H(PO_4)_2$, and 600 ml H_2O.

3. **From Research Articles to Lab Protocols**

Objectives:

- Translate the "Methods" in a scientific paper into a useable lab protocol.
- Identify the ingredients in media/solutions.
- Determine the final concentrations of each ingredient**.**
- Prepare the stock solutions.
- Use supplier's catalogs.
- Review basic calculations in general chemistry.

Exercise:
...Cells were thawed and suspended in 300 ml of buffer A [50 mM sodium phosphate (pH 7.0), 5 mM b-mercaptoethanol]...

- Let's make buffer A. What ingredients are needed?
- What are the final concentrations of each?
- How do you make a 100 ml 0.5 M sodium phosphate monobasic (pH 7.0) stock solution? Show your calculations.
- To make 300 ml of buffer A, how many milliliters of 0.5 M sodium phosphate monobasic will you need? Show your calculations.
- b-mercaptoethanol comes in liquid form and you need to know the density to figure out the molarity. On the bottle you can find information on molecular weight (FW) and purity, but not the density. However, you can find it in the catalog of the supplier. We order our chemicals from Sigma. The easiest way to find b-mercaptoethanol in the catalog is by the "product number", which can be found in the upper left corner of the label. In this case, the product number for b-mercaptoethanol is ______________________________. At the end of the Sigma catalog, there is a section called "product index." Find the product number of b-mercaptoethanol and it will tell you on what page you can find the product. And right there it tells you the density of b-mercaptoethanol is ____________ g/ml.
- You know the molecular weight (g/mole, how many grams per mole) and the density (g/ml, how many grams per milliliter) of b-mercaptoethanol. Determine how many mole(s) in one milliliter (mole/ml). What is the molarity of the b-mercaptoethanol (mole/l)? Show your calculations.
- Now you know the stock concentration. Let's go back to our "methods" section. The recipe calls for 50 mM. If you want to make 300 ml of buffer A, how many milliliter of b-mercaptoethanol will you need? Show your calculations.
- For 300 ml of buffer A, we need ________________ ml of 0.5 M phosphate buffer and ___________________ ml of b-mercaptoethanol. How many milliliters of dH_2O will you need to make 300 ml of buffer A?

Summary.
For students, this manual provides the following advantages:

1. Simple explanations of basic microbiology techniques,
2. Illustrations and photos,
3. Hands-on exercises and quiz questions in each section which increase the student's understanding and confidence in doing research,
4. Requires students to be self-motivated and finish the assignment independently, and
5. Allows students to work at their own pace.

For professors, this manual provides the following advantages:

1. No ineffective first-day lecture and tour needed,
2. Students exhibit greater retention of techniques and knowledge than in traditional one-on-one training,
3. Less repetition is required because of the availability of written instructions,
4. Allows professors to provide research opportunities to a greater number of students, and
5. Can be customized to specifics at different colleges and labs.