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ASSESSING LABORATORY INSTRUCTION IN BIOLOGY

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Biology curriculum developments of the last decade have emphasized the importance of laboratory instruction in the learning environment. Not only do most students enjoy laboratory work but it provides them with an opportunity to make first hand observations, manipulate equipment, collect data, organize data, and draw their own conclusions concerning this information. One teaching strategy for laboratory instruction developed by the Biological Sciences Curriculum Study (BSCS) creates a setting in which a question can be formulated that may be answered as a result of laboratory work. Special instruction is given for specific laboratory techniques and skills when necessary but major emphasis is directed toward solving a problem or answering a question. The student then performs the laboratory investigation by making observations, collecting data, and interpreting results to obtain answers to the question. There is evidence to suggest that laboratory experiences should be designed as problem solving experiences, and should be directed toward specified learning outcomes (Ramsey and Howe, 1969).

The success of this teaching strategy depends, to a great extent, on the ability of students to observe critically, make accurate measurements, and organize data for analysis and interpretation. For these laboratory experiences to be most meaningful, students must develop certain basic laboratory skills and become confident and comfortable in the laboratory setting. A great deal of time, effort, and material is lost when observations and measurements are highly inaccurate and inconsistent. Many problems can be identified early if careful assessment of basic laboratory competencies is a part of the biology laboratory program.

Laboratory Evaluation

Effective testing and evaluation is considered to be one of the most needed areas for improvement in biology teaching at both the high school and college level (Lee, 1969). Creative methods for evaluating laboratory instruction would be especially useful. Jeffrey (1967) in an article describing science laboratory instruction evaluation suggests that the laboratory test should be much more than a pencil and paper test and should involve a practical association with actual laboratory apparatus and experiments. Robinson (1969) developed and analyzed a laboratory practical examination designed to assess laboratory work in high school biology. Results of this work indicate that many students do not master even the most basic skills required in the laboratory. This points to a serious weakness in the assessment system as it is usually practiced and this notion is reinforced by a study at the University of Maryland.

The introductory zoology course at the University of Maryland has laboratory studies associated with it which emphasize investigations in molecular biology and animal physiology. A laboratory pretest was constructed to assess laboratory competencies believed necessary for a student to succeed in this particular laboratory environment. Information derived from this pretest could be used in planning laboratory instruction. Ten items on the pretest are common to most all courses in biology and these items will be described and analyzed.

Laboratory Pretest Analysis

The pretest was administered to 715 students enrolled in the introductory zoology course at the beginning of the Spring 1974 Semester. These were mainly first year college students and they did not have prior knowledge that the pretest would be given. A complete description of ten items selected from the pretest with objectives, laboratory set-ups, and questions is included at the end of this paper. An item analysis was performed on each of the selected items and the results are summarized in Table 1.

TABLE 1

Objectives and Percent Correct for 10 Items of a Laboratory Pretest. N = 715

	Objective of Item	*Percent Correct*
1.	Read thermometer scale	89
2.	Read balance scale	85
3.	Read graduated cylinder	85
4.	Measure length in millimeters	41
5.	Observe fly characteristics	49
6.	Select appropriate glassware	55
7.	Identify experimental control	87
8.	Determine magnifying power	47
9.	Convert millimeters to microns	46
10.	Interpret graph	55

The students performed near the 90 percent level on items one, two, three, and seven. The performance on the other items however, would not be acceptable in collecting useful data for reaching realistic conclusions if classroom data is pooled for analysis. This low level of performance provides a clue for describing why many laboratory investigations never seem to work for a number of students. Item four appears to be a very simple task but only 41 per cent of the students could demonstrate this competency. Careful observation of students completing this task exposed three common mistakes. First, the ruler used in this measurement was scaled in inches, centimeters, and millimeters. Students made the error of reading the scale in inches or centimeters but not millimeters. Second, students used the correct scale but did not bother to carefully line up the end of the ruler with the end of the object. Third, students used the correct scale and careful alignment but read their measurement from the one centimeter mark and then did not subtract one centimeter from the indicated length. Of course some errors resulted from a combination of the mistakes described above.

Students also had difficulty in interpreting the graph in item 10. This was not expected since students are exposed to graphs in a number of high school courses. On this task students became confused when they had to use a combination of two points for proper interpretation. Not being able to interpret similar graphs could present a serious handicap for students when involved in the higher level processes resulting from laboratory work. Other points could be elaborated on but it is clear that even college students do not possess many of the competencies usually assumed.

A survey of the 715 students participating in this study deserves mention here. In terms of courses taken by these students while in high school, four percent had not completed biology or chemistry, 15 percent had completed biology but not chemistry, 63 percent had completed biology and chemistry, and 18 percent had completed biology, chemistry, and advanced biology. Thus a total of 96 percent had completed a course in biology and 81 percent had completed both biology and chemistry. As a result, the overall performance of these students on the 10 items becomes extremely important when considering the very large sample of college students with what would appear to be good backgrounds in high school science.

Ideas for Laboratory Evaluation

Many science educators believe that laboratory work may be assessed, to a great extent, by a well planned and constructed pencil and paper test. This no doubt is true for certain laboratory outcomes and items 9 and 10 on the laboratory pretest described earlier reflect this attempt. Even so there probably are dimensions of manipulatory skills and certain problem-solving skills that may best be approached only through tests involving actual laboratory operations. As an example, a student may be able to answer a question about using a microscope and still not be able to use the microscope for simple observations. Also just because a student can answer a multiple-choice question concerning an experimental control does not mean that the student can successfully plan an experimental design and execute it in the laboratory.

Where then can a teacher go for information to improve assessment of laboratory performance in biology? The material available on this topic is not extensive but there are useful sources. Perhaps the best approach is for the teacher to search for tests that have already been developed and then use these as examples of the types of things that can be done. One model has already been described in this paper and Jeffrey (1967) and Robinson (1969) provide other models which go beyond simple operations. Tamir and Glassman (1970) describe a practical examination developed for BSCS students in Israel which provides a unique approach to laboratory evaluation. An ERIC Clearinghouse publication titled, *Unpublished Evaluation Instruments in Science Education: A Handbook* (Mayer, 1974) describes a number of unpublished instruments designed to assess the processes and skills of science. A section in the teacher's edition of *Interaction of Man and the Biosphere* (Abraham *et al.*, 1970) discusses laboratory tests constructed to measure basic laboratory skills. *Testing and Evaluating Student Success with Laboratory Blocks, – A Resource Book for Teachers* (Lee, 1969) contains some thirteen hundred test items for assessing laboratory outcomes. An evaluation sourcebook for biology developed by the Commission on Undergraduate Education in the Biological Sciences, *Testing and Evaluation in the Biological Sciences* (Nelson *et al.*, 1967) would prove to be a valuable resource for any biology teacher. Although not specifically concerned with evaluation in the biology laboratory, this sourcebook contains over thirteen hundred test items and questions on a broad spectrum of biology topics. A more general sourcebook is *Measurement and Evaluation in the Classroom* (Nelson, 1970). This book provides a wealth of information on strategies for testing.

It is now more apparent than ever that assessment of laboratory instruction in biology deserves careful attention. Many ideas are already available and new and improved models can and should be developed by creative biology teachers.

Laboratory Pretest Items

1. **Objective:** Given a Celsius thermometer and a flask containing a liquid, the student will be able to determine the temperature of the liquid to the nearest degree.

Laboratory Station Set-Up: 500 ml flask containing water and a Celsius thermometer.

Question: What is the temperature of this solution in degreesCelsius?

2. **Objective:** Given an object in balance on a triple beam balance, the student will be able to determine the weight of the object to the nearest 0.1 g.

Laboratory Station Set-Up: 100 ml beaker on a triple beam balance and balanced.

Question: What is the weight of this beaker in grams?

3. **Objective:** Given a graduated cylinder containing a liquid, the student will be able to determine the volume of the solution to the nearest ml.

Laboratory Station Set-Up: 100 ml graduated cylinder containing a light blue colored water solution up to the 53 ml level.

Question: How many milliliters of solution is contained in this graduated cylinder?

4. **Objective:** Given an object and a millimeter ruler, the student will be able to determine the length of the object to the nearest millimeter.

Laboratory Station Set-Up: Plain microscope slide and millimeter ruler.

Question: What is the length of this microscope slide in millimeters?

5. **Objective:** Given several fruit flies with different eye characteristics, the student will be able to sort these flies into groups with identical eye characteristics.

Laboratory Station Set-Up: Four freshly killed fruit flies in focus on the stage of a stereo-microscope with a fly having sepia eyes and other traits wild type labeled "A", a fly having wild type eyes and other traits wild type labeled "B", a fly having white eyes and other traits wild type labeled "C", and a fly having sepia eyes and other traits wild type labeled "D".

Question: Which two flies are most similar in appearance if size is disregarded?

6. **Objective:** Given several pieces of glassware for measuring, the student will be able to select the piece of glassware which will provide the most accurate measurement of a solution.

Laboratory Station Set-Up: 10 ml volumetric pipette labeled "A", 10 ml graduated cylinder labeled "B", 10 ml graduate pipette labeled "C", and 10 ml graduated beaker labeled "D".

Question: Which piece of laboratory glassware would be best for measuring 9.5 ml of a solution most accurately?

7. **Objective:** Given several labeled flasks as part of an experimental design, the student will be able to select the control and experimental flasks.

Laboratory Station Set-Up: Four flasks containing the following solutions and labels: A – yeast cells, water and glucose, B – yeast cells, water and sucrose, C – yeast cells, water and starch, D – yeast cells and water.

Question: If flask "A" is an experimental flask, which flask is the control in this experiment?

8. **Objective:** Given a microscope with the 10X ocular and 5X objective in position, the student will be able to determine the magnifying power of this lens system.

Laboratory Station Set-Up: Microscope with 10X ocular and 5X objective in position with slide on microscope stage.

Question: If you were to examine a specimen on a slide through this miscroscope, how many times larger would the specimen appear with this lens system in position?

9. **Objective:** Given the diameter of a microscopic field in millimeters, the student will be able to determine the diameter of the field in microns.

Laboratory Station Set-Up: None.

Question: The diameter of a microscopic field was measured and found to be 1.2 millimeters. What is the diameter of the field in microns?

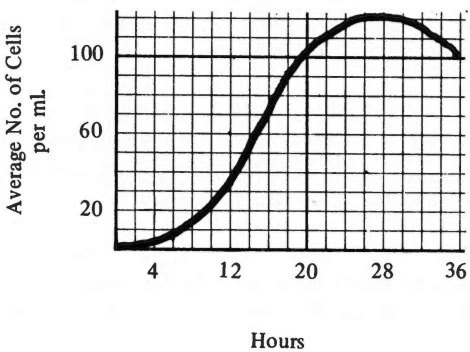
A. 0.00012 microns
B. 0.0012 microns
C. 1200 microns
D. 12000 microns

10. **Objective:** Given a graph illustrating cell population growth, the student will be able to determine the period of most rapid population growth to nearest hours.

Laboratory Station Set-Up: None.

Question: Examine the graph below illustrating cell population growth. The period of most rapid population growth occurs between the hours of –

A. 4 and 12
B. 16 and 24
C. 24 and 32
D. 32 and 36



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As part of its Bicentennial Year activities, the National Science Teachers Association is sponsoring a prize competition for papers on the history of science education in the United States.

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