Investigative laboratory—An approach to teaching crop growth and development in agronomy

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ABSTRACT

Introductory agronomy courses traditionally have a lecture-laboratory structure. The laboratory was uncoupled from the lecture in Washington State University’s beginning agronomy course providing the opportunity to develop a separate laboratory course and engage the student in the process of investigation as the major technique for learning. The first 5 weeks, or approximately one-third of the course is devoted to preparing students for investigation, experimental methodology, library use, and written reports. The latter two-thirds of the course is divided equally into two phases—exercises on crop growth and development, and student investigative studies.

Additional index words: Teaching improvement, Teaching concepts, Laboratory technique, Teaching procedure.

Several years ago the laboratory portion of our beginning course in agronomy was discontinued because of a rapid enrollment increase and the lack of teaching assistants to aid in the increasing number of laboratory sections required to accommodate the students. This increasing number of students overloaded our facilities and placed 30 or more students in each laboratory section. Laboratory sessions were used primarily for illustrating a few selected principles discussed in the lecture portion of the class. Such circumstances prevented a detailed study of the topics and thus, students received superficial coverage of the material given in the laboratory. Laboratory procedures quickly became reduced to an exercise in manual dexterity rather than developing individual student skills.

Because the pressures of increasing enrollments required a change in teaching procedures, it was decided that the lecture alone was adequate for teaching beginning agronomy to a large audience of students with considerable diversity in background. Another conclusion drawn was that it is not necessary to spend a considerable length of time on the botany of crop plants in an introductory lecture course that is designed to survey the broad field of agronomy from a production point of view. However, detailed study into crop growth and development is important for majors in agronomy, especially when courses in botany or biology fail to give sufficient coverage to this subject. Consequently the teaching staff agreed to uncouple the lecture and laboratory and allow a laboratory course centered around crop plant growth to be designed.

The laboratory course offered an excellent opportunity to try a different teaching approach since course content was to be completely revised. It was decided to emphasize principles of crop growth in a series of exercises followed by application of these principles through student projects. Student project activity would be employed as a major part of the laboratory study technique. Audio-tutorial was considered but dropped because this technique appears most illustrative in its approach and requires considerable expense. The need for a learning center to be used only for this course can lead to space problems also. After reading several articles (Kirk, 1971; Thompson, 1971; Thornton, 1972; Von Blum, 1973), I decided to establish an “investigative laboratory” mainly because this teaching technique appeared to be an effective way for students to build skills rather than have everything prepared for them.

Thornton (1972) described the basic concept of the investigative laboratory as a means of teaching students by utilizing the “project” or “inquiry” approach. The laboratory begins with a series of sessions designed to prepare students for investigation and to present basic principles of the subject matter. Investigational work is carried out over the latter time period in the course and terminates with submission of a written or oral report by each student. Modifications of this approach can lead to a variety of different class schedule designs, but all have nearly the same goal—investigation.
FACILITIES

Laboratory facilities should be large enough to handle an enrollment of approximately 20 students. Students should be encouraged to work and conduct exercises together; this provides an open laboratory atmosphere and a chance for interaction with other students. Such interaction is an important key to the learning success of the investigative laboratory. Because of the nature of the projects, considerable greenhouse or field plot space is needed. However, the atmosphere in working with real plants is a significant improvement over the “dry lab” situation encountered in many agronomy courses, and it is well worth the investment in or use of extra facilities such as a greenhouse.

COURSE FORMAT AND PROCEDURE

The laboratory-based course as now offered at Washington State University focuses upon student involvement through investigation and the use of living plant material to cover the basic principles of growth and development (Table 1). The course is required for all agronomy majors regardless of their chosen option of study, but many students from other departments are also enrolled. The class consists mainly of sophomore students with a few at the freshman and junior levels. The course is taught for one semester of approximately 15 weeks and involves 2 two-hour meetings per week. There is no lecture, and we are currently operating with three sections each containing 20 students.

The first 5 weeks are used for preparing students for investigations, teaching them experimental methodology, and writing written reports. Students are first introduced to experimental design and procedures such as randomization, replication, and analysis of variance. A replicated experiment showing the effect of bleached seed upon the seedling establishment and growth of two varieties of peas (*Pisum sativa* L.) is set up in the laboratory just before school begins. Student pairs are asked to begin observing the experiment and collecting data starting the first week of school and continuing for approximately 2 weeks. The experiment is discussed in class during the fourth laboratory session, which occurs about midway through the data collection period (Table 1). The instructor and class listen to individual student presentations rela-

<table>
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<th>Week</th>
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| 1    | Exercise 1—Scientific Approach  
      | Exercise 2—Experimental Design and Analysis |
| 2    | Exercise 3—Composition of Written Reports for Agronomic Experiments  
      | Exercise 4—Evaluation and Discussion of Experimental Procedure |
| 3    | Exercise 5—Writing Experimental Results  
      | Exercise 6—Literature Survey and Library Use |
| 4    | Tour —Spillman Research Farm  
      | Exercise 7—Trial Experiment |
| 5    | Exercise 7—Trial Experiment  
      | Project Conferences |
| 6    | Begin Projects  
      | Begin Projects |
| 7    | Exercise 8—Embryonic Growth—Seed Structure  
      | Project Activity |
| 8    | Exercise 9—Vegetative Growth Phase I—Germination and Seedling Development  
      | Project Activity |
| 9    | Exercise 10—Vegetative Growth Phase II—Juvenile Development to Induction  
      | Project Activity |
|      | Thanksgiving Vacation |
| 10   | Exercise 11—Reproductive Growth Phase I—Post Inductive Development  
      | Project Activity |
| 11   | Exercise 12—Reproductive Growth Phase II—Gametogenesis, Pollination, and Seed Development  
      | Exercise 13—Plant Genetics—Inheritance |
| 12   | Exercise 14—Plant Breeding I—Crossing Wheat and Barley  
      | Exercise 14—Plant Breeding I—Crossing Peas and Alfalfa |
| 13   | Exercise 15—Plant Breeding II—Hybridization  
      | Project Activity |
| 14   | Exercise 16—Plant Physiology I—Growth Regulators (proposed)  
      | Tour —Greenhouses, Growth Chamber Area |
| 15   | Exercise 17—Plant Physiology II—Growth Analysis (proposed)  
      | Open |

* The first line for each week represents activity for the first meeting in that week and the second line for the second meeting.
tive to hypotheses, controls, materials and methods, and data collection. At the conclusion of this session each pair of students is asked to prepare a complete written report (coauthored) on the experiment following the format of *Agronomy Journal* or *Crop Science*. The necessary background information for composition of written reports will have already been given and actual writing will follow in the next laboratory meeting (Table 1, exercises 3 and 5).

To provide training in the write-up of experimental results, two bar graphs showing results of an actual experiment are given as homework for the next laboratory session. Students are expected to interpret these data and to also devise an alternative means of presenting them in tabular form. During this session several students are asked to orally give their written summary of the data or to write their table on the board. Each individual presentation is openly discussed by the class and constructively criticized as necessary. Following the class discussions and individual presentations, students begin to formulate ideas about how the data should have been summarized and can now use this information to present the data previously collected from the pea experiment.

Effective use of the science library for locating, reading, and summarizing journal articles when students are provided with key words or volume numbers, etc. is taught through a laboratory assignment in exercise six. A tour through the science and agricultural libraries is included at this time. Students become acquainted with several formats for writing articles and citing references. This exercise not only provides a useful background for the literature review required for each independent project, but also teaches procedure for obtaining printed knowledge that can benefit the students throughout their career.

After the preliminary exercises have been completed, two laboratory sessions (exercise 7) are devoted to selecting and conducting a “mini-experiment.” Seed of several crop cultivars of Alaska and Perfection fieldpeas; ‘Nugaines’, ‘Leeds’, ‘Wandel’, and ‘Burt’ wheat (*Triticum aestivum* L.); ‘Himalaya’ and an unknown barley (*Hordeum vulgare* L.); and ‘Colusa’ and ‘Zenith’ rice (*Oryza sativa* L.) which differ in sensitivity to growth regulators, and several growth regulators are provided for student use. Students must define the scope, objectives, hypotheses, and procedures for their selected mini-study and hand in a one-page project proposal. The experiment is started immediately and must be set in motion by the next laboratory period. Students collect data for a given period of time depending upon the scope of their particular study. Limitations are placed upon this exercise to force the groups to cope with a given situation when designing an experiment. Limitations commonly used specify that the experiment must be conducted in a growth chamber or on the small growth bench located in the teaching laboratory, thus limiting experiment size. A written report of results and conclusions is required.

The fifth and sixth weeks, while students are working on their mini-experiment, are set aside for project conferences and starting investigative studies (Table 1). Students meet with the instructor to plan their topics and procedure for study; they conduct projects in pairs to reduce the individual work load and make data collection easier. Once a project has been approved, students are free to begin preparation immediately and should have their project well under way by the end of the sixth week. Projects are conducted in greenhouses, growth chambers, and in various research laboratories within the agronomy and soils department. Occasionally, students from other areas may conduct their projects in their respective departmental facilities. A project proposal, which outlines the problem, hypotheses, and details to be used in conducting the study, is required during the early part of the investigation. Such a proposal is essential to 1) insure that students have a reasonable plan for investigation relative to scope, purpose, etc and 2) provide information for the instructor to maintain a check on the progress of the experiment throughout the semester.

The investigative phase, which continues to the end of the semester, lasts for approximately 8 to 10 weeks, with the last 2 weeks for writing reports. The second laboratory period of each week is held open for student project activity (Table 1). After completing their investigation, all students must prepare some type of written report. Three types of reports are accepted. The students may present 1) the results of their experiment only, 2) a thorough discussion of results with data in table or figure form, or 3) a complete formal report consisting of an introduction, a brief literature review,
a materials and methods section, and discussion of results patterned after Agronomy Journal or a similar journal. Students choose the depth in which they want to complete the written part of the project. They are not penalized for a minimum written report, but rather, they are given a bonus for a more detailed report.

The first laboratory session during each of the last 8 to 10 weeks of the semester is devoted to study of the basic principles of crop plant growth and development, emphasizing grasses and legumes (Table 1). A laboratory manual was written for the course that contains the learning objectives, procedures, and required assignments for each exercise and is used as the primary text. Laboratory illustrations or drawings of the various structures being studied, film loops, microscope slides, actual living material, and a reference publication entitled “Development and Structure of Plants—A Photographic Study” by Lee and Heimsch are used as supplemental study guides. The growth and development phase of study begins at the seed stage and continues through gametogenesis and plant breeding. In the plant breeding exercise students make crosses of several selected crops in the greenhouse.

Students are not bound to regular laboratory attendance for the second meeting each week when conducting their project activity. They are expected to conduct the investigative studies on their own at their own speed. This is an active part of the semester and the student’s progress is monitored by the instructor through conferences, consultation, and guidance. Considerable time outside of class is required to keep student projects going smoothly. This informal teaching activity is more than that required for the conventional laboratory experience. However, with one class period per week not structured this does provide some compensation.

Final grades in the course are based upon, two take-home exams, reports on routine exercises (reports are mandatory for 12 and optional for 5), and the student project.

CONCLUSIONS

In summary, the investigative laboratory is an exciting and satisfying way to teach concepts of crop growth and development, because:

1. It removes the student from the lecture-laboratory routine apparent in most other courses and frees them from the usual listening-memorization-testing procedure of learning.

2. It builds student skills through a combination of cooperative and independent study by teaching discipline, responsibility, hard work, and the team approach. It is an excellent place for interaction among students and between the instructor and students.

3. It requires students in many cases to consult with experts in the area from which they have selected a project. This develops a contact with students and other faculty who normally have no association with undergraduates.

4. It shows how scientists investigate problems and gives students an appreciation for an “open-ended” type of study different from the “cookbook” approach with predetermined answers.

Some limitations on the investigative laboratory are:

1. It requires a large amount of space for experiments and considerable effort to procure material needed for the various studies.

2. It requires a precise timetable for growing plant materials used in the growth and development phase.

3. There is a limit to how many investigative laboratories undergraduates need. Thus, overall curriculum planning within a department is necessary to insure that not all laboratory exposure is of this type.

4. Student numbers must be limited to about 20 students per laboratory for it is difficult to handle any more unless teaching assistance is available.

5. Unfortunately, a few students tend to disappear during the project activity or never complete their project and attempt to blame the unstructured nature of the project activity phase for their incompetence or inability to pace themselves.

Finally, yearly class evaluations by the students are more than 90% in favor of the teaching techniques employed. The students major complaint is that the course requires considerable time and should be worth more credit hours. However, proper use of the weekly project activity time will reduce out-of-class time to a minimum.

LITERATURE CITED


