Experiential learning using rapid-cycling *Brassica campestris* L.

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ABSTRACT

Experiential learning strategies let students discover concepts rather than passively acquire and integrate knowledge. A semester-long experiment was designed to promote experiential learning in an undergraduate plant breeding course. The learning objectives of the experiment were that students should be able to (i) calculate and interpret heritability, (ii) create and use a computer database for storing and manipulating their data, and (iii) feel confident in their ability to breed plants. By using rapid-cycling *Brassica campestris* L. as the model organism, heritability of open flower number 4 wk after planting and other characteristics could be estimated by parent-offspring regression. Pooling of student data resulted in significant heritability estimates for flower number ($h^2 = 0.49$ $P < 0.05$ in 1989), whereas estimates obtained by students individually were generally nonsignificant. Student responses to an end-of-course evaluation indicated that the experiment was helpful in understanding principles of quantitative genetics, appreciating plant breeding, and maintaining interest in the laboratories during the semester.

The learning process has been visualized by Lewin (1951), Kolb (1984), and Bawden (1985), among others, as a cycle where students alternate between concrete experience and abstract conceptualization. Concrete experience includes experiment and observation of experimental results. Abstract conceptualization involves reflection, hypothesis building, and designing new experiments to test hypotheses.

Experiential learning strategies differ from conventional strategies in that problem-solving exercises give students the chance to discover concepts rather than passively acquire and integrate knowledge. Lecture and tutorial sections of a conventional biology or agriculture course typically provide basic information. They may also exercise inductive reasoning skills necessary for integration and abstract conceptualization. But experiments conducted by students in a laboratory section where the students are active investigators may provide the concrete experience that is missing in lecture and tutorial sections.

I teach a plant breeding course to biological and agricultural science students who are in their third or fourth year of study. The course format is traditional, with three 1-h lectures and one 2-h laboratory each week. I designed a laboratory that I hoped would provide the experiences that, coupled with information from the lectures, would allow students to pursue the cyclical learning process visualized earlier. The key component of the laboratory was a semester-long quantitative genetic experiment where each student was responsible for building hypotheses; contributing to the experimental design; and gathering, analyzing, and interpreting data from his or her own set of plants. The learning objectives for the experiment were that by the end of the semester the students should be able to (i) calculate and interpret heritability, (ii) create and use a computer database for storing and manipulating their data, and (iii) feel confident in their ability to breed plants.

Rapid-cycling *Brassica campestris* L. (Hawk and Crowder, 1978; Williams and Hill, 1984; Edwards and Williams, 1987) was chosen as the model organism for the experiment because (i) two generations of these plants can be grown during a 13-wk semester, which allows students to estimate heritability by regression of offspring on parent, (ii) the plants and seeds are of a reasonable size for students to handle, and (iii) the plants resemble canola (*Brassica napus* L.), an important oilseed crop in Ontario, and may seem more relevant to agricultural students.

In this article, I outline the structure of the semester-long experiment and evaluate its effectiveness in (i) helping students understand principles of quantitative genetics, (ii) helping students understand and appreciate the integration of disciplines involved in plant breeding, and (iii) maintaining student interest in the laboratory section throughout the semester. General performance of the rapid cycling stocks under our growth conditions is also reported.

METHODS

Experiment Structure

Week 1. Each student filled two nine-cell multipacks with Metromix (Horticultural Products, Ajax, ON), sowed three seeds of rapid-cycling *Brassica campestris* L. stock CrGC-1 (Williams and Hill, 1984) in each cell, and covered the seeds with vermiculite. The pack were placed in light facilities consisting of growth racks in 1987, a growth room in 1988, and a growth chamber in 1989. The growth racks used in 1987 were equipped with residential-type light fixtures with 2, 40-W fluorescent tubes and 2, 25-W incandescent bulbs. The growth room and growth chamber used in subsequent years were equipped with a combination of incandescent and fluorescent lights that supplied a photon flux density of approximately 300 μmol/m² per s for a 16-h day (1988) or continuous light (1989), and were maintained at about 24°C.

Week 2. Students thinned seedlings to one plant per cell.

Week 4. Students counted the number of open flowers 4 wk after planting on each of their 18 plants and also measured three additional characteristics of their own.

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choice. I suggested that they choose characteristics that appeared to show plant-to-plant variation. Number of open flowers was measured by all students because it was easy to determine unambiguously and was heritable in preliminary experiments (data not shown). In addition, having one characteristic common to all students provided the opportunity for students to analyze pooled data for this characteristic; this eased marking of the final reports by making some answers uniform from student and, by increasing the sample size, increased the likelihood of significant heritability for that characteristic. Popular choices for the additional characteristics included plant height, stem diameter, leaf area, and branch number. Each student identified and tagged the superior plant within their 18 plants for each characteristic, and the packs were returned to the lighting facility. The students entered their data into a spreadsheet-type computer database. The database consisted of a line for each plant, a designation of the location of each plant within the nine-cell packs, individual plant data for each of the characteristics measured by the plant, and an indication as to whether the plan had been selected. The same database software was not used by all students because some of the students had their own computers and software. The rapid-cycling Brassica campestris L. used in this study was self-incompatible. Therefore, feather dusters in 1987 and 1989 and leaf cutter bees (Megachile rotundata) in 1988 were used to promote random mating among the class’ plants.

Week 8. Students harvested seeds from each of their parent plants and sowed offspring seeds in new multi-packs. Three seeds from each parent plant were used to sow one offspring cell. The students also sowed an additional three cells with the seeds from each of the selected plants.

Week 9. Students thinned seedlings to one plant per cell.

Week 11. Students evaluated offspring plants for open flowers and the same additional characteristics that were evaluated for the parent plants, and added these new data to their computer databases.

Student Analyses

The students pooled their data for number of open flowers in 1987 and 1989, but relied only on data from their own 18 plants in 1988. They regressed offspring values on parent values to obtain an estimate of half of narrow sense heritability. The students estimated realized heritability by calculating the selection response/selection differential ratio based on the performance of their selected plants. Although the exercise focused on heritability, students were also asked to compare a number of means using t tests and to predict gain from selection given a hypothetical selection intensity. The statistical techniques used in the laboratory were reviewed in the intervening laboratory sessions. The students were encouraged, but not required, to do these analyses on the computer. Finally, the students prepared and submitted a written report of their experimental results, a discussion of their findings, and suggestions for subsequent experiments.

At the end of the course the students were asked to evaluate the semester-long experiment by responding to three statements (Table 1). These statements were appended to the standard end-of-course questionnaire. The students responded using a 1 (complete disagreement) to 5 (complete agreement) scale.

Table 1. Responses to course evaluations completed by students at the end of the semester.

<table>
<thead>
<tr>
<th>Statement type</th>
<th>1987</th>
<th>1988</th>
<th>1989</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific statements regarding semester-long experiment</td>
<td>3.51</td>
<td>4.41</td>
<td>4.11</td>
<td>4.01</td>
</tr>
<tr>
<td>The laboratories were very helpful in understanding principles of quantitative genetics</td>
<td>3.9</td>
<td>4.7</td>
<td>4.1</td>
<td>4.2</td>
</tr>
<tr>
<td>The hands-on aspect of the laboratories was important to understanding and appreciating plant breeding</td>
<td>4.1</td>
<td>4.8</td>
<td>4.3</td>
<td>4.4</td>
</tr>
<tr>
<td>Having a series of interrelated sessions helped me maintain a greater interest in laboratories throughout the semester</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>3.8</td>
<td>4.6</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>General statements regarding course and instructor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>4.4</td>
<td>4.7</td>
<td>4.3</td>
<td></td>
</tr>
</tbody>
</table>

† Mean of responses on a 1 (complete disagreement) to 5 (complete agreement) scale. n = 55, 35, and 28 students in 1987, 1988, and 1989, respectively.
† Mean of responses to 17 positively worded statements.

RESULTS AND DISCUSSION

Laboratory Results

Lighting facilities influenced growth of the rapid-cycling Brassica stock. The growth racks resulted in plants that grew about 20 mm horizontally along the surface of the multipacks before beginning to grow vertically. The total stem length was about 350 mm. Seed set was poor and the plants lodged. Both the growth room (1988) and growth chamber (1989) resulted in sturdy stems of approximately 3 mm diam. at the base and upright plants standing approximately 300 mm high. Seed set was much higher than in 1987. Regardless of lighting facilities, the plants began flowering in approximately 18 d.

Narrow sense heritability of flower number based on pooled 1987 data was 0.59, but was not significantly different from zero at the 5% probability level. Realized heritabilities were not calculated in 1987. In 1988, heritabilities for flower number based on data from individual students ranged from −1.29 to 0.70 and were not significantly different from zero. Realized heritabilities ranged from −1.57 to 1.05. In 1989, heritability for flower number based on pooled data was 0.49 and was significantly different from zero at the 5% probability level. The realized heritability based on pooled data was 0.09.

Pooling class data, as in 1987 and 1989, seemed to contribute to calculation of positive heritability values for flower number, whereas heritability estimates in 1988 based on individual student’s samples of 18 or fewer data
points were quite variable from student to student, and were often negative. These variable results in 1988 were unsatisfactory from a teaching perspective because the concept of heritability was not uniformly reinforced for all students. Although some students recognized that the variable heritability and poor plant growth were primarily technical problems associated with growing conditions or experimental design, others were concerned that the negative or nonsignificant values in some way were the result of their own mistake or lack of skill as a plant breeder. This latter perception was obviously very detrimental to morale and particularly threatened the achievement of the third learning objective for the laboratory: confidence in their ability to breed plants. In an effort to build student morale and confidence, more lecture and laboratory time was spent discussing experimental problems in 1988 than in the other 2 yr. Although I did not want the results of the experiment to be completely predictable, it became apparent that the experimental procedure should be refined so that the results meet at least some of the students’ expectations. The significant heritability estimate in 1989 may have been associated with the higher-quality lighting and climate control supplied in the growth chamber and pooling of the students’ data. Only 15% of the students in 1989 reported significant regressions when they used their own data only.

All students entered their data in a computer database and included the database as part of their final report. All students also did at least some of their analyses using the functions included in the software.

Student Perceptions

Students on average agreed with the positively worded evaluation statements specifically relating to the semester-long experiment. They also agreed with statements regarding the course in general (Table 1). According to the first statement, students perceived that the laboratory helped them better understand quantitative genetics. This may be associated with the hands-on nature of the laboratory as evaluated by the second statement. I observed that the students seemed to enjoy growing and evaluating their own plants, and seemed more committed to interpreting the data they obtained from their plants over the course of the semester than to interpreting data presented to them in homework assignments. According to the second question, the students perceived that the semester-long experiment helped them understand and appreciate plant breeding. Student agreement was highest in all years with the third statement regarding maintenance of interest throughout the semester. This agrees with my observation that absenteeism from laboratories was lower than in plant breeding courses I taught in 1985 and 1986.

The mean of responses to the general course evaluation statements in each year are a baseline index of student satisfaction. The mean of the experiment-specific statements can be compared to the baseline. The difference between responses to general and experiment-specific statements was least in 1988, which could be interpreted to mean that student satisfaction with the experiment was highest in that year. This was the year in which morale initially appeared to decline. Additional efforts to discuss problems with students may have resulted in the greater level of overall satisfaction with the experiment than in other years. It was also the year, however, in which the class data were not pooled. The students may have been more satisfied with the experiment because they relied on their own data. The difference was greatest in 1987, when, as a result of the lighting facilities, plant growth was the poorest. The lodging and intertwining of the plants resulted in shattering and loss of the few seeds that had set as the dry, mature plants were separated prior to seed harvest. When students were asked to comment on the laboratory in the questionnaire, they often mentioned that the rapid-cycling *Brassica* experiment provided the opportunity and motivation to use and better understand the statistical analysis skills that they learned in intervening laboratory sessions and in previous courses.

Based on review of the laboratory reports that were received, the first two learning objectives were attained. The level of satisfaction with the specific and general statements suggested that the third objective may also have been achieved. The semester-long experiment attempted to provide concrete experiences that would allow students to discover concepts for themselves. Unfortunately, as the experimental procedure was refined over the years, some of the opportunity for individual discovery may have been lost as spontaneity, as well as the potential for failure, declined. In retrospect, I realize that the experiment should not be so predictable as to be only a demonstration of concepts, but should be sufficiently refined that the plants grow normally and the data are reasonable. Some frustration is good, but too much reduces motivation.

Experiential learning by means of a student-run experiment that spans the semester might contribute to the overall impact of other courses. The advantages are that complex subjects can be investigated, the students have the chance to discover concepts on their own, and student interest in the laboratory sessions is maintained throughout the semester. Also, the impact of intervening sessions is which other related skills are exercised can be augmented if the students find that these new skills are relevant and may help them interpret the results they obtain in their main experiment. If the instructor designs a laboratory that includes concrete experiences, and also encourages abstract conceptualization in the course, then students will be able to cycle through the process that leads to effective learning.

**REFERENCES**


