E-ISSN No. 2582-7073

SHORT COMMUNICATION

Pradeep Kumar Burma
GPG Journal of Science Education
Vol. 2 Issue 2 2021 : pp 8 - 11

An alternative approach to how biology practicals are currently conducted in the Indian education system

Pradeep Kumar Burma
Department of Genetics
University of Delhi South Campus
Benito Juarez Road, New Delhi 110021, India

Abstract
In the current Indian education system, science practical demonstrations or experiments have been reduced to tasks performed by the students in predetermined structured fashion for evaluation at the end of a semester. In most cases the expected result is known before the task is completed. Through this method the students may develop an understanding of and learn new techniques but are not challenged to evaluate experimental observations and discover the underlying concepts. In the current communication, using two examples, I propose an alternate approach, wherein students are not informed about learning outcomes or the aim of the activity before performing the experiment. The observations made are then discussed through a set of questions, to highlight its usability in biological experiments or in understanding a concept.

Keywords: School practical work, Capture-recapture method; Population size; Mendel's Laws and Probability

(Received 6 February, 2021; Accepted 21 July, 2021; Published 25 July, 2021)

'Practicals' are integral part of the Indian science education at every level beginning at school level. However, in a majority of cases the practical component has been reduced to a set of tasks to be performed by students, reported in practical sheets (colloquially called as 'practical copy') in a predetermined structured manner to be evaluated at the end of a semester. The predetermined structure consists of reporting the (i) aim of the experiment, (ii) material needed (iii) procedure in a point wise manner (iv) observations as tables, figures or graphs (v) discussion and (vi) precautions. In several cases, the outcome of the task is already known and the student simply goes through the motion of completing the task presented to him/her. While this strategy expose students to different methods of analysis (as proposed in the aim), the essence of building concepts through experimentation or an in-depth analysis of observations made, is not enhanced. While the proposed approach is based on the observation of the Indian education system, the same can be adapted for other countries.

In this article, two simple examples are proposed as alternate methods of conducting a biology practical. The cited examples in this paper are aimed mainly at students in Grades 11 and 12 (of about 17 – 18 years of age) but the approach is applicable to higher levels of education. In this method, students are not informed about learning outcomes or the aim of the activity but are first required

email: pburma@south.du.ac.in

to perform the activity. The outcome of the activity is then discussed through a set of questions, to highlight its usability in biological experiments or in understanding a concept. The first activity entitled 'Counting Beans' is a demonstration of estimating the population size by a well-established 'Capture and Recapture' method [1]. While demonstration of this strategy using inanimate objects like beans is available, the current activity envisages an approach where in the conclusions are not predetermined. The second activity titled 'Flipping Coins' can be used to explain the concept of probability involved in the Laws of Inheritance [2]. Further, the second activity can be integrated while discussing the topic of inheritance in a 'theory' class.

ACTIVITY I: COUNTING BEANS

A. Materials:

i. Beans in a container: Each student is given a container full of beans (preferably light colored) or any type of seeds which are large enough to be distinctively marked using nail polish. A minimum of a 1000 beans would be envisaged as a good starting point count. The actual number of beans given to every student can be varied. The size of the container should be large enough so that the beans can be properly shaken in it and allow students to randomly draw out beans during the exercise.
Other objects of similar size could also be used.

ii. A small cup that can hold around 60 to 70 beans.
iii. Nail polish or marker pen.

B. Method:

i. Before proceeding with the experiment read the steps below and decide on the format of a suitable table to record the observations.
ii. Using the cup draw a cupful of beans from the container in which it is stored. Count the number of beans. This step can be referred to as CAPTURE.
iii. Mark the beans with nail polish and ensure that it is properly dried. This step can be referred to as MARK.
iv. Return the beans to the original container and shake vigorously to ensure uniform distribution of the marked beans in the container. This step can be referred to as RELEASE.
v. Note the number of beans that was initially drawn out, marked with nail polish and returned to the container. This is referred to as C.
vi. Take cupfull of beans from the container as done so in step ii. You may refer to this step as the RECAPTURE. Count the total number of beans/ seeds (R) that you have re-drawn and record the number in the designated table. Now count the number of beans that are marked in the re-drawn sample (M) and record the number in the table. This is referred to a Sample Set 1.
vii. Repeat the steps iv and v at least four more times (Sample Sets: 2 to 5) and record the observations as previously done.
Depending upon the time available, students may be permitted to carry out further sampling.
viii. Calculate the mean (average) value of the number of recaptured beans ($R_{avg)}$ for sample sets 1 to 5 as well as that of the number of marked beans (M_{avg}) in these samples.
ix. Note the values for C, R_{avg} and M_{avg}.
x. Based on the values in step ix calculate the total number of beans (N) present in the box.
xi. Count the total number of beans in the box and

calculate the percentage error between the estimated and the actual number of beans in the box.

C: Questions that can be posed:

i. What question in biology can be answered using the above strategy?
ii. Based on the interpretations from the above activity how reliable is this method?
iii. Can the estimated number change with change in the total number recaptured?
iv. What are the various ways by which different animals (e.g., grasshopper, birds, tigers) can be marked?
v. What are the assumptions that would make this strategy successful?
vi. Can this method be used to estimate population sizes for sedentary animals or plants?

D: Points for discussion:

i. For step (i) of the method, the students should be introduced to different formats of presenting their observations, without explicitly mentioning which format is appropriate for the current activity.
ii. Instead of proposing a formula for calculating the total number of beans (step x in methods) the students should be asked to work out a way of doing so. They could however be helped by suggesting that while M_{avg} is a subset of R_{avg}, C is a subset of N.
iii. In response to question (i) the utility of the method of estimating population sizes of animals can be discussed.
iv. This task can then be followed by a cumulative analysis of the values obtained by different students of the class. In this exercise, the percentage error obtained by the different students can be tabulated followed by a discussion on usability and reproducibility of this method.
v. Answer to question (iii) can be tested by asking students to recapture different quantities of beans.
vi. In response to question (v), the following can be discussed regarding the important points for the success of the strategy in an actual experiment: (a) That there has been no death, birth, emigration, or immigration between the time of capture and recapture (b) Proper distribution of the marked individual in the population following its release (c) That the mark on the animal is not lost.
vii. Following the experiment the instructor could share videos of on this application, several of which are available on the internet e.g. Ant Course Presents: Mark-recapture Technique (https://www.youtube.com/watch?v=lKyj7gEAAS8)

ACTIVITY II: FLIPPING COINS

This activity supplements the concept of probability while teaching Mendel's Law of Segregation leading to the phenotypic ratio of 3:1 and the genotypic ratio of 1:2:1. While flipping a coin is used as example in several textbooks [e.g. 2] to explain the concept of probability, the proposed activity to be carried out by students is likely to help in a better understanding. In India this is taught in the 12th grade (final year of school) for students under Central Board for Secondary Education (CBSE, New Delhi). This activity need not be part of the practical but can be done in the theory class while discussing the Law of segregation.

A. Material:

i. Two coins per student (all coins to be used in the exercise should be of same size and weight)

B. Method:

There are two parts to this activity.

Part I: Flipping of a single coin

i. Flip the given coin 20 times and record the observed number of heads and tails in a table. This is referred to as student sample 1. Determine the ratio of heads (H) to tails (T).
ii. Record the observation by other students in the class referring them as student sample 2, 3, 4 and so on.
iii. Record the total number of heads and tails for student sample 1 and 2. Determine the ratio of heads to tails of the cumulative value.
iv. Repeat step iii to record the cumulative value of heads and tails for student samples 1, 2 and 3 and determine the ratio of heads to tails.

v. Continue the above step till the cumulative total of all the students is recorded.

Part II: Flipping of two coins:

i. Flip or toss two coins simultaneously. Carry out 20 flips.
ii. Record in a table the number flips with (i) both coins showing head (HH), (ii) both coin showing tail (TT) and (iii) one coin showing head and one showing tail (HT).
iii. Determine the ratio of HH:HT:TT.
iv. Repeat the steps ii to v as in part A noting the values for HH, HT and TT and the ratio of HH:HT:TT in a step by step cumulative manner.

C: Questions that can be posed :

i. What is the expected ratio of heads to tails when one coin is flipped (Part I of the activity)?
ii. What is the expected outcome of HH:HT:TT when two coins are flipped simultaneously (Part II of the activity)?
iii. From the above observation what is the minimum number of flips required to obtain the expected probabilities in questions (i) and (ii)? If an exact match is not observed identify the minimum number of flips which is the closest match to the expected ratio.

D: Points for discussion:

i. The first question posed (in part C above), can be used to discuss the probability of getting a head or a tail on flipping a single coin is 50% or $\frac{1}{2}$.
ii. Through the second question posed (in part C above) the expected ratio of 1:2:1 for HH:HT:TT can be explained by the two rules of probability, the product and the sum rules. The product rule states that the probability of independent events both occurring together is the product of their individual probabilities. Thus the probability of getting HH and TT is 25% ($\frac{1}{4}$) for each. The probability of getting HT is also $\frac{1}{4}$, but there are two ways of getting HT. Head, in the first coin and tail in the second coin or tail in the first coin and head in the second. Thus, the probability of HT is defined by the sum rule, which states that the probability of the two mutually exclusive events occurring together is the sum of their individual probabilities (i.e. $\frac{1}{4} + \frac{1}{4} = \frac{1}{2}$ in this example).
iii. As there may not be any exact match between the expected and observed ratios the students can also be introduced to the importance of statistical tests to ascertain if the observation meets the expected ratio. Students who have already been introduced to statistics can be asked to perform the chi-square test [3] to identify minimum number of flips required to get the expected ratios in the two activities.
iv. The role of probability in Mendel's Law of Segregation can be finally discussed. A point that should be highlighted in this discussion is that in observations based on probability a minimum number of outcomes have to be analyzed to get the expected results. This concept can be strengthened through the first activity where individual students (using 20 tosses) may not get a ratio of 1:1 for H:T but a cumulative result of more tosses gives one the expected ratio.

This approach of conducting practicals may help in reinforcing the skills of analyzing observations rather than completing a required task.

REFERENCES

1. Odum EP and Barett GW (2005) Fundamentals of Ecology 5th Edition Thomson Brooks/Cole.

2. Campbell NA, Reece JB, Urry LA, Cain ML, Wasserman SA, Minorsky PV and Javkson RB (2015) Biology: A global approach 10th Edition Pearson Education Limited pg. 330 - 331.

3. Griffith JF, Wessler SR, Lewontin RC and Carroll SB (2008) Introduction to Genetic Analysis 9th Edition W.H. Freeman and Company pg. 97-99.