Using seashells to teach statistics through experimental design

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We have found that placing the instruction of statistics in an experimental design context helps students to more easily understand the material. Seashells have proven to be excellent subjects for these lessons. They are inexpensive, durable, familiar, interesting and easy to adapt to scenario-based exercises. We have successfully used shells in both introductory and graduate level courses.

Learning Objectives

1. Data types
2. Hypotheses
3. Mean
4. Std. deviation
5. t test
6. X^2 test
7. Experimental design
8. Sampling
9. More advanced tests

Introductory Course

Scenarios are used to provide a controlled exercise to introduce students to basic concepts in statistics and the mechanics of calculating t and X^2 tests.

Objectives 1-5

Scenario: We have samples of marine snails (*Bullia)* from two different populations. The "natural" population comes from a pristine bay with no obvious human impact. The "impacted" population comes from a nearby bay on which there are a number of factories. Snails in this bay are variously colored because they absorb pigments from the textile factories along the shore. The textile dyes themselves are not considered toxic, but because they are associated with many other substances from the mills, you are curious to see whether size distributions in these two populations differ.

Outcome

Students learn about continuous data, generate summary statistics (mean ± standard deviation), create null and alternative hypotheses, and test these with a t test.

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Objectives 1 & 6

Scenario: Suppose you are an ecologist studying the biology of ark clams. Your years of research have established that in healthy populations with normal birth and death rates, the ark clams consist of 60% one-year-olds, 30% two-year-olds, and 10% three year olds. In a nearby bay, where a salmon farm has been operating for several years, residents are reporting fewer large ark clams and ask you to investigate.

Outcome

Students learn about discrete data, create null and alternative hypotheses, and test these with a X^2 test

Graduate Course

Objectives 1 & 8

On the first day of class, students are given two boxes of dyed *Bullia* and are asked to devise ways to determine if these two populations are different. Students actively engage in the discovery of many of the problems that arise when designing and conducting research. After they have had time to work through it on their own, the groups compare their results. This allows the instructors to introduce technical terms (e.g. continuous and discrete data) and lead a discussion of the problems with generating true random samples.

Outcome

The students learn that the different ways that they devise to measure and categorize the shells are relevant to the analysis that they will perform later. They also get a good sense of the difficulties in sampling and the difference between haphazard and random sampling.

Sources for Shells

If you are fortunate to be near the water, shells can be collected in the wild. They can also be scrounged from the corners of biology department storerooms or purchased from commercial sources. Tourist shops and craft stores are also good places to look. For the best selection, a web search for "shell wholesaler" will provide numerous places to buy large quantities of specimens.

Objectives 2, 7-9

After students are more familiar with sampling and basic tests, they are given two bags of assorted tiny shells and asked to devise an experiment to determine if they come from similar populations. There are dozens of different species represented and thousands of shells in each sample making counting everything impossible. Each group designs and conducts an experiment. This usually results in them performing numerous preliminary studies to finalize their design. An interesting situation that arises is that groups often arrive at different answers. This provides a great opportunity for discussion about research finding the "right" answer.

Example Data

1. Empty the bag of shells into a rectangular container (39 cm wide x 54.75 cm long x 8 cm deep).
2. Divide the area into a 3 x 3 grid. Label the plots on the grid 1 through 9, starting in the upper left corner and proceeding left to right.
3. Generate random integer through random.org to select test plot sample.
4. Fashion a 10.75 cm x 9.5 cm paper mask to cover the randomly selected plot.
5. Separate shells based on shape and rib pattern.

Types	B	A
Ivory Ribbed clam	15	11
Dark Ribbed clam	20	19
Darkish Eliptical Clam	62	56
Ivory unribbed clam	5	10
White/Brown Conical snail	67	54
Tight Spiral Snail	45	81
Bulbous Spiral Snail	61	68
Cinnabon Snail	13	6
Purple Conehead Snail	19	20
Smooth Conehead Snail	12	22
Discus Spiral Snail	118	118
Round Snail	76	133
other snail	1	1
other clam	0	1

$X^2_{calc} = 35.99 \quad df = 13 \quad p < 0.001$

Outcome

By this point in the course, students have learned about hypotheses and are able to design an experiment and conduct it. They struggle with achieving random sampling and this provides an excellent platform for discussion. They often start with complex designs and soon learn that a simpler, valid approach is needed to answer the question.

Summary

Seashells have proven to be excellent subjects for the design of exercises for teaching statistics and experimental design. For introductory courses, they are inexpensive and durable materials that can be used in well-defined exercises. In a graduate course, the wide variety of shells available has made it relatively easy to replace traditional lectures with active exercises, allowing students to work thorugh the material in a much more engaging manner.