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ABOUT THE COVER IMAGE

About the cover image: James G. Needham with limnology students ca. 1925. The student diversity, both gender and ethnic, in the group is striking. At least eleven women obtained advanced degrees (four M.S. and seven Ph.D.) working with Needham. *Photo from the Rare and Manuscript Collection, Cornell University Library.*



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complies with the required guidelines – in some cases we can allow noncompliant proposals to be fixed, but some must be returned without review.

Once proposals are compliant, program officers read them to determine whether they are appropriate for the program to which they were submitted or are likely candidates for co-review with another program. Appropriate proposals are assigned to a managing program officer, who then chooses a set of *ad hoc* reviewers for each proposal. Simultaneously, a review panel is assembled that includes panelists with the range of expertise required to evaluate the submitted proposals. Individual panelists review some subset of these. Meetings of review panels occur at NSF approximately three to four months after proposals were received. At these meetings, panelists discuss all proposals and their associated reviews, and make recommendations on the quality of each proposal with respect to intellectual merit and broader impacts of the research proposed.

Panel recommendations are considered carefully by program officers, particularly with respect to our budgets and funds available. In developing a portfolio of proposals to recommend for funding, we also consider broadening participation (gender, ethnicity and experience of the investigators), geographical distribution, type of institution (research vs. undergraduate), the riskiness of the proposed research, and other factors. Our resulting portfolio must be approved by our Division Director before we can recommend a project for an award (and contact the investigators), or recommend that a proposal be declined. These same recommendations require the Division Director's signature before official action is taken. Investigators then receive an official letter of decline or, some four to six weeks later, an award letter prepared by the Division of Grants and Agreements.

These days, you are in good company if your proposal is declined. Depending on the tenor of your reviews, revision and resubmission can be viable next steps. First, read your reviews very carefully. Talk with the managing program officer. Do not resubmit immediately (for the very next target date) unless the concerns raised are very minor. You need to decide whether reviewers' concerns or the panel summary make sense, in light of your overall research goals. If you do not take time to think through reviewers' suggestions, you may well be subject to contradictory conclusions from successive panels, with the overall result that a previously promising study becomes weaker, more diffuse and perhaps unsupportable. Keep in mind that there is no strategic reason to submit a proposal to every target date or deadline (you do not necessarily increase your chances of being funded by doing this) and that the NSF does not guarantee that an official decision will be made, and reviews released, in order for you to submit to the very next target date.

WHO REVIEWS YOUR PROPOSAL, AND WHY?

NSF is proud of its peer review system, and members of the scientific community work hard to ensure that each proposal receives a fair and expert evaluation. Most proposals receive a mixture of *ad hoc* reviews and reviews from panelists. These two types of reviews differ. *Ad hoc* reviews are solicited from researchers who are experts in the particular area (conceptual, methodological) covered by a project. They evaluate a very small

number of projects (with luck, no more than two per funding cycle) for their intellectual merit and their broader impacts. Panelists review a proposal using both criteria, but can compare among proposals because they hear about all of them. The panelists reviewing your proposal may not be experts in your field. As a result, it is very important that you do not assume your reviewers are all experts in your field and are intimately familiar with your work and its importance. You must convince a general, intelligent, scientific audience that your research deserves support.

NSF asks reviewers to address two basic criteria. The first of these is a proposal's intellectual merit. Will your research advance knowledge and understanding in the field? Is it creative and original? Is the research design clear and comprehensive? The second major criterion is the project's broader impacts. NSF is very serious about the broader impacts of a study (proposals that do not address broader impacts will be returned without review), but this criterion rarely supersedes intellectual merit. There are several types of broader impacts, but no expectation that a single proposal should cover all of them. Choose the one(s) that best fits your research and for which you can make the most convincing case. As mentioned above, provide a plan (for example, how will you find/recruit minority undergraduate, or how will your results inform management and conservation). Don't rest on past accomplishments; we evaluate the broader impacts of the current proposal. And keep in mind that in the near future, NSF will require public access to your data within some reasonable period of time after it is collected.

Program officers are always available, either by e-mail or telephone contact, to answer questions that this short guide may not address or address adequately.

A KERNEL OF TRUTH: MICROWAVE POPCORN MAKES IT EASIER TO TEACH BASIC STATISTICS

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For more information about this exercise, complete details (instruction manual, handouts and student assessment guidelines) for "Popcorn Statistics" visit: <http://people.southwestern.edu/~burksr/test/innovative/index.html>



Just like nutrients, recycling ideas about teaching occurs across large spatial scales from large Research I universities to small 4-year colleges. The use of popcorn in this example of biostatistics originated from a legendary course, "Statistics for Experimenters," taught by statisticians Bill Hunter and George Box at the University of Wisconsin (UW) in the 1970s

(Carpenter, personal communication). Their course eventually gave rise to the original textbook of the same name (Box et al. 1978). Given the prominence of several limnologists trained at UW, one can only speculate about the extent that this course has impacted the aquatic science community. To test their skills for application and interpretation, UW students performed their own experiment using common household goods. Past students found popping Jiffy Pop® on the stove for different durations or using different burners produced statistically differentiable and repeatable results. One of these students (S. Carpenter) eventually rose to the position of professor himself and repackaged the exercise to teach statistics to whole new generations of limnologists. Consequently, use of popcorn for teaching statistics has now popped up at several places with distant connections to the original UW course.

As the first food intentionally popped, popcorn occupies an important place among snack foods equaling a 1.28 billion dollar industry with Americans consuming 17 billion quarts annually (Malovany 2007). Having students literally consume the topic of statistics through an active learning approach, such as popping popcorn, may help overcome math anxiety (Connors et al. 2003) and create a more relaxed learning environment and better retention (McKeachie and Svinicki 2005). An intellectual skeptic might remark that “there are no new ideas, just old ones repackaged in new ways.” Along those lines, microwave popcorn serves as a great model for a statistical exercise because of its versatility in flavors and sensitivity to environmental factors. In addition, this exercise takes students all the way through the scientific methods, from hypothesis formation to data collection to analysis and interpretation. Rossman and Chance (1997) put together a top ten list for teaching statistical reasoning (Table 1) and this exercise uses popcorn to address each of the ten principles.

POPCORN STATISTICS *A PRIORI* CONSIDERATIONS

Microwave popcorn comes in enough varieties that this exercise can be tailored to meet class preferences, interests or product availability. This expanded exercise contains four parts (Tables 2, 3):

- 1) Conducting t-tests between two types (e.g. buttered versus 94% Smart Pop) of the same brand of popcorn (e.g. Orville Redenbacher®, OR) popped for the same amount of time (one minute and 30 seconds = 90 seconds) in the same microwave;
- 2) A one-way analysis of variance (ANOVA) using at least three brands (e.g. OR, Act II and Pop Secret), of the same type (e.g. Butter), popped for the same amount of time (90 seconds) in the same microwave;
- 3) 2³ factorial ANOVA (i.e. three factors, each with two levels) with two brands of popcorn (e.g. OR and Act II) of the same type (e.g. Butter) exposed to two different microwaves and two different popping times (75 or 90 seconds); and
- 4) Regression and correlation analyses with data from Part 3 (or all bags if desired).

Besides hypothesis testing, students can also conduct descriptive statistics to examine distributions. Instructors or student groups could also alter brand and type choices of popcorn to compare and contrast brand names versus generics, sweet versus salty versions or the yield compared to price of organic products. However, before beginning the exercise, the instructor should consider certain issues.

Student experience and time investment. It takes one lab period (two to three hours) to distribute the 50 bags for popping (Table 3), introduce a framework for conducting statistical analysis and discuss methodology. Depending on their experience and aptitude, students required one to three additional sessions to learn how to conduct analyses with statistical software. Sophomore students used more time for data synthesis, analysis and interpretation (3 hrs./week for 4–6 weeks) than upper-level students (3 hrs./week for 3 weeks). Therefore, the entire exercise easily involves considerable time investment.

Replication and Correction

Factors. Individual-sized servings of popcorn greatly cut down on the time it takes to count outcomes versus larger bags. A treatment replicate (N) represents the type of popcorn and the conditions under which popping occurs (e.g. OR® Butter, Microwave A, 90 seconds). The exercise involves a total of 11 treatments as one treatment from the first and third part of the exercise (e.g.

Table 1. Match between popcorn statistics and a “Top Ten” list of recommendations for teaching statistical inference.

	Rossman and Chance (1999)	Components of “Popcorn Statistics”
10	Have students perform physical simulations to discover basic ideas of inference.	Students physically pop the popcorn, measure pieces and count popped versus unpopped.
9	Encourage students to use technology to explore properties of inference procedures.	Students can build the components of variability into a spreadsheet and then later a statistical analysis program.
8	Present tests of significance as <i>p</i> -values versus rejection ranges.	Students answer questions within the exercise with supporting <i>p</i> -values.
7	Accompany tests of significance with confidence intervals whenever possible.	When measuring popcorn sizes, students observe how replication yields a more accurate representation of the mean.
6	Help recognize that insignificant results give useful information.	Students learn differences between statistically significant and scientifically meaningful.
5	Stress limited role that inference plays in statistical analysis.	Students create several populations, sample randomly and discuss the difference between true replication and pseudoreplication.
4	Always consider the issues of data collection.	Students brainstorm about how they will standardize methods or what decisions in data collection might include unintentional bias.
3	Always examine visual displays of the data.	Students can graph both relational and categorical data.
2	Help students to see the common elements of inference procedures.	Students gain a sense of what it means to reject or fail to reject null hypotheses through repeated analyses and annotation of their analysis.
1	Insist on complete data presentation and interpretation in the context of the data.	Students complete four exercises that include data presentation and analysis. In addition, the data sets can be used repeatedly.

OR® Butter and Act II Butter, respectively, Microwave A, 90 seconds) can be used again in the 2³ factorial design.

The majority of this exercise employs five replicates, for popcorn pieces or bags for calculating yield (although see exception in Part 1). From pilot data, five represented the minimum sample number that provided reasonable estimations of means (± 1.5 SD). In addition, a minimum of five replicates (i.e. five individual bags) provided enough degrees of freedom for statistical analyses of whole bag measures.

Contents of individually-sized bags of popcorn vary both within and across brands. For example, Orville Redenbacher® makes two types of individually-sized bags of popcorn, Butter Flavor (1.5 oz) and the Smart Pop (1.2 oz). Kernel size (popped) does not likely depend on bag size, and yield represents a percentage that can be compared across bags. However, quantitative components of yield (i.e. number of popped kernels) depend on bag size. Because initial package weight differs, students should calculate and apply correction factors by using basic ratios to convert smaller sizes to the largest size (Table 3).

PROCEDURES

After popping a bag of popcorn under conditions belonging to a specific treatment (i.e. brand, type, duration and microwave), students then measure five things: 1) Number of burned pieces of popcorn (B); 2) Total number of popped kernels (P);

3) Number of unpopped kernels (U); 4) Total weight of bag contents; and 5) Maximum length of five pieces of popcorn (using digital calipers for better precision). Students should work together to come to consensus on criteria for a whole or burned piece of popcorn and consistent approaches for counting and measurement. Although not edible, a burned piece of popcorn still counts as popped. From these data, they can determine edible yield [= (P-B) / (P+U) *100] and average kernel size.

Framework for statistical interpretation. While introductory courses provide the basic mechanics behind statistics, students may not connect the material directly with their discipline. Popcorn statistics asks students to identify specific components of experimental designs and link the concept of treatments with the null hypotheses tested by parametric statistics. During the exercise, instructors should repeatedly ask students this series of 10 questions to build their framework for statistical interpretation (Table 2):

- 1) What is your scientific question? (Context)
- 2) What did you measure?
- 3) How many groups did you use?
- 4) How many things varied in this experiment (i.e. how many factors and levels)?

Table 2. Summary of statistical analyses, popcorn required, experimental designs, example scientific questions, scientific hypotheses or predictions, statistical hypotheses for main factors, post-hoc tests and interactions for each of four sections. NS = not significant. Levels for time include 75 and 90 seconds. Criteria for rejection of null hypothesis = $p \leq 0.05$.

Framework to Teach Students	Independent t-test	One-way ANOVA	2 ³ factorial ANOVA	Regression
Popcorn Required	OR®SmartPop, OR®Butter	OR®Butter, PopSecret and ActIIButter	OR®Butter, ActIIButter	OR®Butter, ActIIButter
Factors	1 (Type = T)	1 (Brand = B)	3 (B, T, Microwave)	NA
Levels	2	3	2	NA
Treatments	2	3	8	NA
Replicates	5	5	5	40
Scientific Question(s) (X and Y= dependent variables; underline = independent factor)	Does the type of popcorn influence X?	Does the brand of popcorn influence X?	Does X depend on brand, time popped, microwave or a combination of factors?	Does a predictive relationship exist between X and Y?
Scientific Hypotheses (Predictions)	Because it contains less butter, OR®SmartPop will exhibit a higher X.	Because it costs more to produce, OR®Butter will exhibit a higher X.	Because it is written on the package, X will depend significantly on the microwave used and time.	Average size (X) exhibits a positive and predictive relationship to bag weight (Y) because larger pieces weigh more.
A Prior Statistics	one-sample KS Test	one-sample KS Test	one-sample KS Test	one-sample KS Test
Statistical Null Hypotheses for Main Factors	$\bar{X}_{OR\&SP} = \bar{X}_{OR\&B}$	$\bar{X}_{OR\&B} = \bar{X}_{PS} = \bar{X}_{ACTII}$	$\bar{X}_{OR\&B} = \bar{X}_{ACTII}$ $\bar{X}_{75s} = \bar{X}_{90s}$ $\bar{X}_{MicroA} = \bar{X}_{MicroB}$	m (slope) = 0
Statistical Null Hypotheses for Post-hoc Statistics or Interactions		$\bar{X}_{OR\&B} = \bar{X}_{PS}$ $\bar{X}_{OR\&B} = \bar{X}_{ACTII}$ $\bar{X}_{PS} = \bar{X}_{ACTII}$	$\bar{X}_{BRAND} * \bar{X}_{TIME} = NS$ $\bar{X}_{BRAND} * \bar{X}_{MICRO} = NS$ $\bar{X}_{TIME} * \bar{X}_{MICRO} = NS$ $\bar{X}_{BRAND} * \bar{X}_{MICRO} * \bar{X}_{TIME} = NS$	
Post Hoc Statistics		Tukey's		R2

- 5) How many treatments versus replicates occurred (Methods)?
- 6) Based on this experimental design, what statistics should you perform?
- 7) What are your null hypotheses for each of the statistics performed?
- 8) What does your resulting p -value tell you about rejecting or failing to reject the null hypothesis for each statistic performed (Results)?
- 9) How do you now use the word significant in answering your original question?
- 10) What mechanisms at play (i.e. biological, chemical, or physical) might have contributed to your results (Discussion material)?

Investigation of how cumulative means change with sample size. Students can also perform ‘sub-sampling’ by measuring pieces of popcorn from each bag. For purposes of data analysis, using the average size of five pieces measured avoids artificially inflating degrees of freedom. Consequently, use of individual bags of popcorn as treatment replicates provides instructional chances to talk about replication versus pseudo-replication (Hurlbert 1984). To further illustrate the idea of how narrower confidence intervals (CI) occur with increasing sample size, students should measure 15 pieces of popcorn from a single bag of the two OR® types used in Part 1 of the exercise.

To avoid bias, students set aside every fifth piece counted for measurement. When graphed, students can identify at which point adding one more sample does not alter the interval substantially. Consequently, from this investigation, students may find that measuring more than 5 pieces might have provided them with less variable data in the overall exercise. They can then discuss the merits of measuring more pieces considering the additional time required.

Additional key points for emphasis. To meet the assumptions required for parametric statistics, students first need to test each dependent variable for normality using non-parametric one-sample Kolmogorov-Smirnov (KS) tests. In contrast to comparison between means, students learn that they do not want to reject the null hypothesis that the data meet a normal distribution. They must identify appropriate p -values ≥ 0.05 , learn how to transform data or consider non-parametric statistics.

During Part 1, students should explore the relationship between the calculated t from their t -test and the probability value based on a critical t statistic for a given number of degrees of freedom. The use of a critical t value table offers another opportunity to emphasize the importance of replication in experimental designs. Furthermore, requiring students to first calculate a t -test by hand gives them a better context for the origin of the p -values they see immediately when using a statistical program.

Use of three different brands in Part 2 gives the instructor the opportunity to reinforce the idea that the results of a one-way ANOVA only inform whether or not a significant difference existed among the three (or more) groups, but not where the actual significant differences occurred between groups. For that, students need post-hoc tests. Zar (2007) identified Tukey’s multiple comparison tests as a more conservative choice.

Part 3 of this exercise allows students the change to test the scientific validity of the disclaimer that typically occurs on the back of any package of microwave popcorn. Popcorn makers caution that “popping times will vary depending on microwave.” The jump from a one factor to a three factor ANOVA eliminates some redundancy and gives more opportunity to examine potential significant interactions (Table 2). As each factor (i.e. brand, time and microwave) has only two levels, this experimental design makes interpretation easier because each independent factor does not require post-hoc tests. The output then yields 7 p -values for students to interpret (three for the main factors, three for the two-way interactions, and a three-way interaction). This example provides repetitious training in annotating results.

The fourth part of popcorn statistics opens the door for students to ask their own questions about the relationships between variables. One goal includes teaching students how correlation and regression differ. A second goal emphasizes the importance of graphing. Rossman and Chance (1999) argue that students should always look at visual outputs of their data, and modern statistical programs offer countless graphing options. Students can also build descriptive

Table 3. Summary of popcorn required for exercise and how each brand and type contributes to the statistical tests. The factor applied to kernel count refers to the correction factors described in the methods.

Microwave Popcorn Brand	Type	No. boxes to buy/ bags per box	No. bags used/ bought	Bag Weight (oz)	Factor applied kernel count	Part of exercise in which data contribute: statistical test
OR® Smart Pop	94% Fat Free Butter	1 box/ 10 bags	5/10 bags	1.2	1.5	1: t-test 2: one-way ANOVA
OR® Butter	Butter	2 boxes/ 10 bags	20/20 bags	1.5	1.2	1: t-test 3 and 4: 2 ³ Factorial ANOVA
Pop Secret	Butter	1 box/ 10 bags	5/10 bags	1.5	1.2	2: one-way ANOVA
Act II	Butter	3 boxes/ 8 bags	20/24 bags	1.8	1	2: one-way ANOVA 3 and 4: 2 ³ Factorial
Total		7 boxes	50/64			

statistics using Excel™. The broad availability of the program furthers its appeal as a teaching tool. To allay any anxiety about learning spreadsheets, students should have access to a “master” spreadsheet to check their formulas after they have built their own spreadsheet. In contrast, sole use of a statistical program, such as SPSS, only allows students to acquire cursory knowledge of formulas behind statistics. Consequently, they depend too much on the ease of point and click. The act of deriving the formulas first in Excel™ and then verifying results in SPSS promotes deeper understanding.

EXPANSION OF POPCORN STATISTICS AND CONCLUSIONS

The ease and versatility of this exercise allows for multiple possibilities for revision or personalization. For example, one could test if a “popcorn” button on certain microwaves yielded a better outcome than the time advised on the package. Popping individual bags allows each student to contribute a “piece” to the complete data set puzzle (Perkins and Saris 2001) and the requirement of lab exercises from each individual encourages students to be more active in group work. Using data from different experimental designs used in this exercise also helps teach students how to make high-quality appropriate figures.

Besides providing a context for future independent or group experiments, the collective process of popcorn statistics can also serve as a launching point for any number of discussions including scientific ethics, inter-measurer variability (achieved by examining coefficient of variation between different metrics), extrapolations (examined by comparing individual versus full size bags) or even truth in advertising. Mark Twain once famously paraphrased Benjamin Disraeli’s opinion “there are lies, damn lies and then statistics.” Too often, statistics can be easily manipulated to tell different versions of the same story and students need to consider presentation when they evaluate other work and analyze their own data.

For this aquatic scientist, the kernel of truth in this exercise revealed that microwave popcorn made it easier to teach basic statistics. Interestingly, we found that yield usually did differ significantly by microwave, just as the packages suggested. From the instructor’s own perspective, students seemed to enjoy the process of data collection and appeared to retain the basic ideas of experimental design throughout the course. Hopefully, more targeted quantitative assessment will accompany further iterations of popcorn statistics. Exercises like popcorn statistics encourage students to learn to ask questions, define problems, formulate hypotheses and definitions, design experiments, collect data, explore variation, summarize data and communicate their findings. This dedication to active learning styles (McKeachie and Svinicki 2005) increases the probability of creating competent student statisticians.

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EU SCIENCE GAINING BY MANY COUNTS, STAGNANT IN OTHERS

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In 2000, the European Council committed to the Lisbon Agenda with the goal of becoming “the most dynamic and competitive knowledge-based economy in the world.” A new report from the European Commission provides a wealth of information on how much progress has been made towards that goal between 2000 and 2006. Upon release of the 2008 Science, Technology and Competitiveness (ST&C) key figures report, EU Commissioner for Science and Research Janez Potočnik noted the importance of research and development in light of the current economic crisis. “In a time of crisis, it is not the moment to take a break in research investments and in innovation. They are vital if Europe wants to emerge stronger from the economic crisis and if it wants to address the challenges of climate change and globalization.” Potočnik believes the Commission’s initiatives have put the EU “on the right tracks,” but warns there is still work to be done.

The report provides 150+ pages of metrics on R&D investment, mobility, and competitiveness. In terms of investment in research and development (R&D), the news is mixed. European investment in R&D grew in real terms by 14.8% (as compared to 10.1% in the US in the same time period). The range in growth between EU countries, however, is substantial. Spain, for