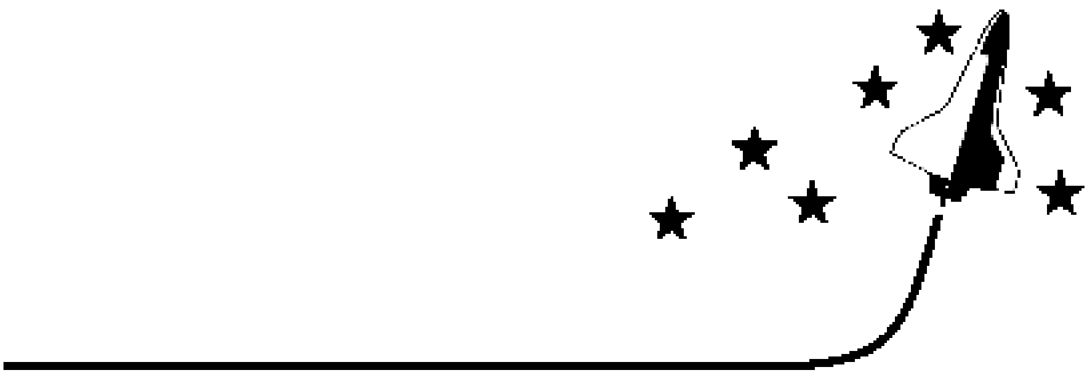
FACULTY NOTES

The LTAs and Spinoffs are designed so that each professor can implement them in a way that is consistent with his/her teaching style and course objectives. This may range from using the materials as out-of-class projects with minimal in-class guidance to doing most of the work in class. The LTAs and Spinoffs are amenable to small group cooperative work and typically benefit from the use of some learning technology. Since the objective of the LTAs and Spinoffs is to support the specific academic goals you have set for your students, the Faculty Notes are not intended to be prescriptive. The purpose of the Faculty Notes is to provide information that assists you to take full advantage of the LTAs and Spinoffs. This includes suggestions for instruction as well as answers for the exercises.



FACULTY NOTES

LTA 9

Work Sampling at the Kennedy Space Center

Outline

Overview of Work Sampling
- Motivation
- Background
- Getting Started
  - Activity: How a Typical Worker in the OPF Spends Her Day
  - Homework: Graph It!

Section 1 Collecting Data
- Activity 1: Understanding the Data Collection Sheet (Parts A, B, and C)
- Homework 1A: Work Sampling in the Grocery Store
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Section 2 Determining Sample Size
- Activity 2: How Many Observations Do We Need?
- Homework 2: How Many Observations Will Be Enough?

Section 3 Constructing Confidence Intervals
- Activity 3: Confidence Intervals for Technician Activities
- Homework 3: Confidence Intervals for Checker or Instructor Activities

Section 4 Creating a Data Collection Sheet
- Activity 4: Examine the OSPREY Data Collection Form (Parts A, B, and C)
- Homework 4: Design a Data Collection Sheet

Section 5 The Capstone Project
- Activity 5: Review, Rehash, Revisit NASA OPF Example
- Homework 5: Design a Work Sampling Study
  What Your Work Sampling Report Needs

Section 6 Generating Random Numbers
- Activity 6: How Random Are You?
- Homework 6: Determining Random Times

Overview of Work Sampling

LTA 9 is most appropriate for a course in elementary statistics. At some institutions this LTA may dovetail nicely with the liberal arts mathematics course. Pieces of it may be fun to use in an elementary algebra class (the sample-size formula and how it is used) or in a prealgebra course (the gathering of data, creation of pie-charts and calculation of percentages).

Each section of the LTA contains 3 parts - an explanatory narrative, an in-class activity, and homework to reinforce the student's learning of the material in the section. The in-class activities lend themselves well to collaborative group work.

Getting Started

Mathematical Topics

- Pie-charts
- Percentages

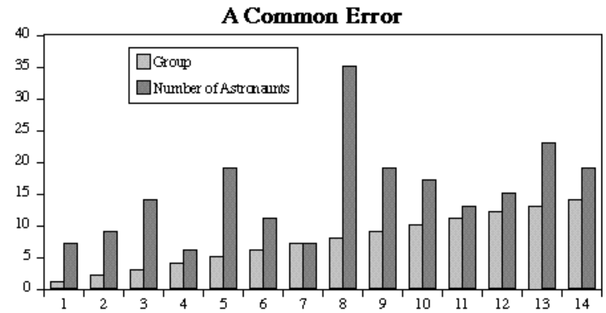
The Getting Started Activity and Getting Started Homework can be used either in a statistics course or in a prealgebra course. The data in the first homework problem is a simplified version of the type of data actually collected in a study of teachers. If you are interested in an actual work sampling study of teachers, one example is: "Utilization of Professional Manpower in the Teaching Profession" by Paul E. Christensen, Ph.D. Thesis, Wayne State University, Detroit, MI, 1955. Mr. Christensen surveyed elementary school teachers in Royal Oak, Michigan. The data in the second homework problem is factual and can be found in NASA, Astronaut Fact Book, Information Summaries, PMS-011E (JSC), 1995, p.53.

Getting Started Activity
How a Typical Worker in the OPF Spends Her Day

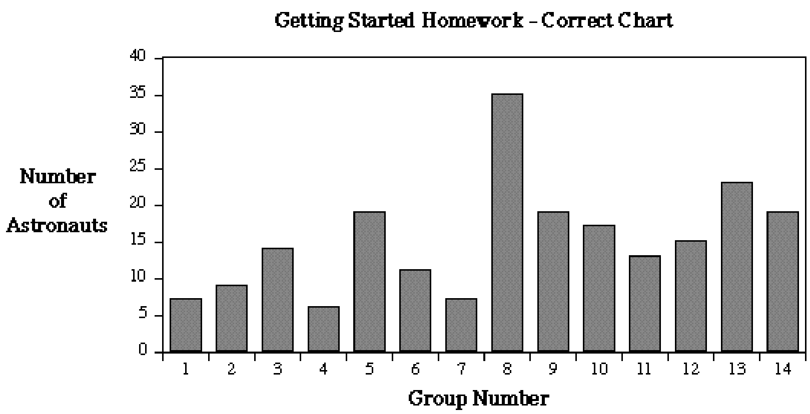
If your students have access to a computer lab, an instruction sheet similar to the following may be helpful. Remember to include any required passwords.

> In room 202 all of the machines have Windows 95 on them. Some of you may have to share a machine, but there should not be more than 2 people on one computer. If the computer is not on, take a seat, turn on the machine and monitor and wait.
>
> You will see the Windows 95 screen. Using the mouse, click on **start** at the bottom of the screen, select **programs**, then select **Microsoft Office**™ and then **Excel**™.
>
> Please make some pie charts and bar charts using Excel™. Here is what you need to do:
> 1) Type in the data and the labels from the worksheet you have or from a problem in your textbook.
> 2) Use the "chart wizard", the icon with a bar chart and a magic wand with fairy dust located on the right-hand side of the toolbar at the top of the screen. Your first step after clicking on this is to move the mouse arrow on to your worksheet and click and drag to set up the rectangle where the chart will be. You will now begin making the choices in the dialogue box.
> 3) To answer the first question, you need to know where you have typed in your data. For example, if there were 6 items of data that were in locations A1 through B6, you would type "a1:b6".
> 4) Continue following through the chart wizard instructions. To go on, press "Next" or "Finish". If you make an error, you can go "back"! Try it and see what happens.

Getting Started Homework This work is fairly straightforward. Students may have the the most difficulty with the bar chart for astronauts and their group numbers. Using Microsoft Excel™ students can easily make the error of creating a bar chart with double bars, one bar showing the group number and the adjacent bar showing the number of astronauts in that group:



The chart above is worth examining with your students. You can ask your students to decide whether it is really important to place bars that represent group numbers in pairs with bars that represent group frequencies. Why would we want to compare the data like that? Isn't the group number given on the horizontal axis? When might it be useful to have double bars? (Responses classified by gender or income group or….). The correct bar chart is shown below



Section 1

Mathematical Topics

- Data collection
- Interpreting data

Activity 1 Be sure in **Part A**, Questions 4, 5, and 6 that students do not just count the actual tally marks showing on the Activity Table, but also use the summary totals in Table 1.

1) 8	2) 2	3) No	4) 55
5) 215	6) 390, 390	7) 400	8) 390

Part B Activity Table: Two checks in Setup, one check in Training/Meetings, 1 check in Miscellaneous ("talk to tour guide"). Roster Table: One check in each cell in the run row, "4" in the Total Number column.

Part C Activity Table: Run 1 has two checks in the Process Videos row and one check in the Waste Time row, Run 2 has two checks in Cleanup and one in Process Video. Roster Table: One check in each cell for both runs, "3" in each Total Number cell.

Homework 1 The instructor should decide which of the two possible homework assignments (1A or 1B) the class will do. Either one can serve as the pilot study to be used in calculating the sample size in Homework 2. You will need to determine the totals collected by the whole class for use in Homework 3.

It is best to make a large Activity Table and compile the results from the entire class in it. Students can transfer the tally marks from their homework papers to the large Activity Table and then check their names off on the class roster when they are done. In order to avoid mistakes in transferring the data, the instructor would either have to observe each student tally his/her results on the large Activity Table, or collect the results from each student and then personally transfer the tally marks to the large Activity. It is worthwhile for students to see how difficult it is to get "clean" data the first time through.

Section 2

Mathematical Topics

- Statistical accuracy
- Confidence levels
- Formula usage

It is important for the instructor to note that the variable **s** is defined differently in this context than it is in most statistics textbooks. In this LTA, **s** is defined to be "relative accuracy." In statistics classes, however, the variable **s** represents the sample standard deviation. As the instructor, you could choose another variable name for the relative accuracy. However, NASA engineer, Ms. Mitskevich, used **s** for relative accuracy, as is consistent with resource texts on work sampling. Because of this, **s** is used for relative accuracy in this LTA.

This different definition for **s** leads to a new formula for the margin of error, which we will term **E**. Since **s** is our tolerable relative accuracy, this means that if we multiply it by the proportion, then we obtain the tolerable margin of error. For example, if the relative accuracy **s** is 10% or 0.10, and the sample proportion $\hat{\mathbf{p}}$ is 0.40, the margin of error **E** would be (0.40)(0.10) or 0.04. This is an example of the "plus or minus 4 percentage points" quantity that is seen so often in the press. From this it can be seen that $\mathbf{s}\hat{\mathbf{p}}$ is simply another name for **E**, i.e. $\mathbf{E} = \mathbf{s}\hat{\mathbf{p}}$.

This equivalency can be used to convert the standard formula for sample size for a proportion, $\mathbf{n} = \left(\frac{\mathbf{z}}{\mathbf{E}}\right)^2 \hat{\mathbf{p}}(1-\hat{\mathbf{p}})$, to the formula given in Section 2 by substituting $\mathbf{s}\hat{\mathbf{p}}$ for **E** and simplifying. Of note is that when using the formula given in Section 2, the largest sample sizes will occur as $\hat{\mathbf{p}}$ approaches zero. This differs from the standard formula, where the largest sample size occurs when $\hat{\mathbf{p}}$ = 0.5. (This makes an interesting curve sketching comparison at the calculus level!)

It may be well to emphasize to students that an important part of working with mathematical formulas is to check the source materials and determine which quantities are used and *how* they are used.

Activity 2

1) $\mathbf{s}$ = 0.1, $\mathbf{z}$ = 1.96, $\hat{\mathbf{p}}$ = 0.22, so $\mathbf{n}$ = 1362.02 or 1363 observations. (You always round up to obtain the number of observations.)
2) $\mathbf{z}$ = 2, $\mathbf{s}$ = 0.10, $\hat{\mathbf{p}}$ = 0.15, so $\mathbf{n}$ = 2266.66 or 2267 observations.
   Second part of Ex.2: To do this with $\mathbf{n}$ = 2267 and (15)(20) = 300, we find 2267/300 = 7.6. Using 8 runs per day for 20 days gives 2400 observations, 133 more than the minimum.

Homework 2

1) Assume that all your students selected "Teaching."
2) Assume that "housekeeping" is selected as the key activity of a teacher. If 19 out of 108 observations were for housekeeping then $\hat{\mathbf{p}}$ = 19/108 = 0.18.
3) $\mathbf{n}$ = 1750.06 which is rounded up to 1751 observations.
4) To do this with $\mathbf{n}$ = 1751, and (15)(20) = 300, we find 1751/300 = 5.84, so we will need 6 observations per day for 20 days.
5) Here, 1751/50 = 35.02, so we would need to observe 36 workers during each run.

Section 3

Mathematical Topics

- Revising the estimate of time spent on key activity
- Determining relative accuracy
- Determining absolute accuracy
- Constructing confidence intervals

This section introduces yet another term specific to the work sampling field. The absolute accuracy $\mathbf{a}$ is used to represent $\mathbf{s}\hat{\mathbf{p}}$. Since students may not make the connection, it would be helpful to point out that $\mathbf{a}$ is another name for the margin of error, $\mathbf{E}$.

In the example using Work as the key activity, the calculated value for $\mathbf{s}$ was smaller than the 10% level established by NASA. This will not necessarily occur if a different key activity is chosen. If the calculated value for $\mathbf{s}$ is too large, then another work sampling study can be done, this time using the revised estimate of the proportion to determine a new value for the sample size, $\mathbf{n}$.

In Activity 3, students are asked to construct confidence intervals for Cleanup and Setup. Since the calculated values for $\mathbf{s}$ are both larger than 10%, it may be worthwhile to have the students compute new sample sizes for both Cleanup and Setup using their proportion estimates. Both of the estimates for proportions are small, so the sample sizes will be large as indicated in the note in Section 2.

Before assigning Homework 3, make sure that the class has the results from their surveys for Homework 1. Because the choice of teachers or grocery clerks to be observed was based on convenience and student schedules, the results of the study will not be statistically reliable. Nevertheless, it is important to use the data collected by the students. The data must be compiled so that the homework can be completed.

Activity 3

1) For Setup, $\hat{\mathbf{p}}$ = 55/390 = 0.14, $\mathbf{s} = (1.96)\sqrt{\dfrac{0.86}{(390)(0.14)}} = 0.25$, and
   $\mathbf{a} = \mathbf{s}\hat{\mathbf{p}}$ = (0.25)(0.14) = 0.035. Thus our 95% confidence interval for the true proportion of time spent in Setup is 0.14 ± 0.035 or (0.105, 0.175). The proportion of time spent in Setup is between 10.5% and 17.5% at the 95% confidence level.

2) For Cleanup, $\hat{\mathbf{p}}$ = 31/390 = 0.08, **s** = 0.34 and **a** = (0.34)(0.08) = 0.03. Thus our 95% confidence interval for the true proportion of time spent in "Cleanup" is 0.08 ± 0.03 or (0.05, 0.11). The proportion of time spent in Cleanup is between 5% and 11%.

Homework 3 Obviously, answers will vary. The following results are based on actual data obtained from a class field test of the LTA.

Teacher Activity in HW1	Totals (from the 3 observation times)
Housekeeping	19
Lecture	47
Direct Interaction	16
Resource Person	7
Off Task	4
Proctor	15
Miscellaneous	0
TOTAL	108

If Lecture is selected as the key activity, then $\hat{\mathbf{p}}$ = 47/108 = 0.44,

and $\mathbf{s} = (1.96)\sqrt{\dfrac{0.56}{(108)(0.44)}} = 0.21$. (This is over 10%.) The value of **a** is obtained from using

$\mathbf{a} = \mathbf{s}\hat{\mathbf{p}}$ = (0.21)(0.44) = 0.09. Thus, the 95% confidence interval for the true proportion of time spent lecturing is 0.44 ± 0.09 or (0.35, 0.53). This means that, based on these survey results, we may conclude that the proportion of time a teacher spends lecturing is between 35% and 53%. If we had to guess a single value of the proportion, we would say 44% of the time is spent lecturing.

Since 0.21 is an unacceptably large value for **s**, we can treat this as our pilot study and use this value of $\hat{\mathbf{p}}$ to revise our sample size estimate. To keep **s** at 10% or less, we need to make 489 observations where **n** is calculated as follows:

$$\mathbf{n} = \left(\frac{z}{\mathbf{s}}\right)^2 \frac{(1-\hat{\mathbf{p}})}{\hat{\mathbf{p}}} = \left(\frac{1.96}{0.10}\right)^2 \frac{(1-0.44)}{0.44} = 488.93$$

Section 4

Mathematical Topics

- Logic
- Mutual exclusivity
- Defining tasks

Answers will vary. Discussing these answers as a whole class is very effective.

Section 5

The students now get a chance to conduct their own work sampling studies. It is easiest if you set aside enough time throughout the semester for this to be done, so there is not a big rush during the last couple of weeks of class. For example, the students can turn in their topics along with a list of the activities they will be observing any time after the class has completed Section 1, or after Sections 1 and 4 have been completed. The instructor may want to have the students share their work in groups to check that their categories of activities are mutually exclusive and exhaustive. The next step would be for them to calculate the necessary sample size (if it is over 200, let the student make between 100 and 200 observations) and to generate the random times for their observation days. These steps can be done any time after Sections 2 and 4 have been done. The last step is the actual analysis of the data, and this follows step 8 in Section 5 very closely.

Section 6

Mathematical Topics

- Random numbers
- Using the calculator
- Translating the random numbers into times

The instructor may introduce random numbers in his or her favorite way. Most statistics textbooks have random number tables available for use. Random number generators are also readily available on scientific and graphing calculators. Be sure to provide time for students to work some examples using calculators.

In preparation for this class session, check out how the calculators you will be using work. If everyone in the class is using a brand new calculator, the random numbers may not be random. For example, the TI-82™ comes from the factory set to the same place in the random number "generator." To correct this, you can have your students enter a 3 digit number of their choice, then press the **STO** key and then the command **rand**. **Rand** is found under **Prb** in the **Math** menu. Now each student should have a different starting spot in the calculator's random number list. Each student should make notes on the keystrokes for his or her calculator. Have the students work in pairs to do Activity 6.

Answers will vary. The difficulty will be in helping your students who may have all types of calculators. The instructions for several Texas Instruments calculators are given in Section 6. Microsoft Excel™ will also generate lists of random numbers for you. The student may have to do some extra work to convert those into times.