Do Small Classes in Elementary School Improve Student Outcomes?

(Based on Frederick Mosteller, "The Tennessee Study of Class Size in the Early School Grades," *Future of Children* 5, no.2 (1995): 113–27.)

Let's answer this question by analyzing the data from Project STAR, where students in Tennessee were randomly assigned to attend either a small class or a regular-size class from kindergarten until third grade. (See Chapter 2 of DSS for further details.)

The dataset is in a file called *STAR.csv*. Table 1 shows the names and descriptions of the variables in this dataset, where the unit of observation is students.

variable	description
classtype	class size the student attended: "small" or "regular"
reading	student's third-grade reading test scores (in points)
math	student's third-grade math test scores (in points)
graduated	identifies whether the student graduated from high school: 1=graduated or 0=did not graduate

Table 1: Variables in "STAR.csv"

In this problem set, we practice estimating average treatment effects using data from a randomized experiment and a linear model, and determining whether the estimated average treatment effect is statistically significant at the 5% level.

As always, let's start by loading and looking at the data:

```
## load and look at the data
star <- read.csv("STAR.csv") # reads and stores data
head(star) # shows first six observations
##   classtype reading math graduated
## 1     small     578  610         1
## 2   regular     612  612         1
## 3   regular     583  606         1
## 4     small     661  648         1
## 5     small     614  636         1
## 6   regular     610  603         0
```

Then, we run the following code to create our treatment variable and confirm that it is created correctly:

```
## create variable pressure inside dataframe voting
star$small <- # stores return values in new variable
        ifelse (star$classtype=="small", # logical test
         1, # return value if logical test is true
         0) # return value if logical test is false
```

```
## look at the first observations again to ensure small was created correctly
head(star, n=3) # shows first three observations
##   classtype reading math graduated small
## 1     small     578  610         1     1
## 2   regular     612  612         1     0
## 3   regular     583  606         1     0
```

1. First, let's estimate the average causal effect of attending a small class on the three different measures of student outcomes we have in the dataset: (i) third-grade reading test scores, (ii) third-grade math test scores, and (iii) probability of graduating from high school.

   a. To estimate each of the three average treatment effects, fit a linear model to the data in such a way that the estimated slope coefficient is equivalent to the difference-in-means estimator you are interested in and store the fitted model in an object. Call the three objects *fit_reading*, *fit_math*, and *fit_graduated*, respectively. Then, run the names of the objects, *fit_reading*, *fit_math*, and *fit_graduated*, so that R will provide you with the contents of each object. Do you arrive at the same estimates as we arrived in Chapter 2 when we computed the three difference-in-means estimators directly? (See page 43 of DSS.) A yes/no answer will suffice. (10 points)

   b. For each of the three linear models above, create a visualization of the relationship between X and Y and add the fitted line. (Hint: The functions `plot()` and `abline()` might be helpful here.) (R code only.) (5 points)

   c. Now, let's answer the questions: (i) What is the estimated average causal effect of attending a small class on third-grade reading test scores?, (ii) What is the estimated average causal effect of attending a small class on third-grade math test scores?, and (iii) What is the estimated average causal effect of attending a small class on the probability of graduating from high school? Provide a full substantive answer for each (make sure to include the assumption, why the assumption is reasonable, the treatment, the outcome, as well as the direction, size, and unit of measurement of the average treatment effect) (10 points)

2. Second, let's figure out whether the effects are statistically significant at the 5% level?

   a. For each of the three treatment effects, specify the null and alternative hypotheses. Please provide both the mathematical notations and their meaning. (5 points)

   b. For each of the three treatment effects, what is the value of the observed test statistic, z^{obs}? (Hint: the code `summary()$coeff` might be helpful here.) (5 points)

   c. For each of the three treatment effects, what is the associated p-value? (5 points)

   d. For each of the three treatment effects, answer the question: Is the effect statistically significant at the 5% level? Please provide your reasoning. (10 points)

3. For a discussion about the internal and external validity of this study, see subsection 5.5.4 on page 156 of DSS.