A Sample Research Problem - The High School and Beyond (HSB) Study

Imagine that you are interested in the general problem of what factors influence mathematics achievement at the end of high school. You might have some hunches or hypotheses about such factors based on your experiences and your reading of the research and popular literature. Some factors that might influence mathematics achievement are commonly called demographics; e.g., gender, ethnic group, and mother's and father's education. A probable influence would be the mathematics courses that the student has taken. We might speculate that grades in math and in other subjects could have an impact on math achievement.[6] However, other "third" variables, such as students' IQ or parent encouragement and assistance, could be the actual causes of high math achievement. Such extraneous variables could influence what courses one took, the grades one received, and might be correlates of the demographic variables. We might wonder how spatial performance scores such as pattern/mosaic score and visualization score might enter into a more complete understanding of the problem and whether these skills seem to be influenced by the same factors as math achievement. Finally, students' attitudes about mathematics might be factors affecting these math achievement scores.

Before we state the research problem and questions in more formal ways, we need to step back and discuss the types of variables and the approaches that might be used to study the above problem. Think about what are the *independent/antecedent* (presumed causes) *variables* and what are the *dependent/outcomes variable(s)* in the above problem. Hopefully, it is obvious that math achievement is the primary dependent variable.

Given the above research problem, which focuses on achievement tests at the end of the senior year, the number of math courses taken is best considered to be an antecedent or independent variable in this study. What about father's and mother's education and gender? How would you classify ethnic group in terms of the type of variable? What about grades? Like IQ and parent encouragement they would be independent variables, but, as with any study, we were not able to measure all the variables that might be of interest. Visualization and mosaic pattern scores could probably be either independent or dependent variables depending upon the specific research question. Finally, the math attitude questions and the resulting composite or scale scores derived from them also could be either independent or dependent variables, but probably independent/antecedent variables in this study. Note that student's class or grade level is not a variable in this study because all the participants are high school seniors (i.e., it does not vary; it is the population of interest).

As we have discussed, independent variables can be *active* (given to the participant or manipulated by the investigator) or *attributes* of the participants or their environments. Are there

(regression) approach to data analysis. However, the practical implications are that most researchers adhere to the above dichotomy in data analysis.

[6] We have decided to use the short version of mathematics (i.e., math) throughout the book to save space, because it is used in common language, and because it is the name of several variables (e.g., *mathach, mathgr*) in the sample study.

any *active* independent variables in this study? No! There is no intervention, new curriculum, or something similar. All the independent variables, then, are attribute variables because they are attributes or characteristics of these high school students. Given that all the independent variables are attributes, the research approach *cannot be experimental or quasi-experimental*. The proposed study is basically an individual differences one that will use the *comparative, associational*, and *descriptive approaches*. This means that we will *not* be able to draw definite conclusions about cause and effect (i.e., we will find out what is related to math achievement, but we will not know for sure what *causes* math achievement).

Research Questions for the Modified HSB Study[7]

We will generate a large number of research questions from the modified HSB data set for Assignments A - L and N. Assignment M uses a different data set that you will enter. In this section, we will list one research question to be answered in each of the assignments to give you an idea of the range of types of questions that one might have in a typical research project like a thesis or dissertation. In addition to the *difference* and *associational questions* that are commonly seen in a research report, we have asked *descriptive questions* and questions about assumptions in the early assignments. Templates for writing the research problem and research questions/ hypotheses are given in Appendix A; it should help you write questions for your own research. The questions below correspond to the lab assignments in Chapters 4-18.

1) Often, we start with basic *descriptive questions* about the demographics of the sample. Thus, we could answer, with the results of Assignment A, the following basic descriptive question: "What is the average educational level of the fathers of the students in this sample?"

2) Additional basic *descriptive questions* about the sample will be answered in Assignment B. For example, "What percentages of the students are male and female?"

3) In Assignment C, we produce a number of new/transformed variables such as three summated scales assessing math attitudes. In this assignment we will examine whether the dependent and continuous independent variables (those that might be used to answer associational questions) are distributed normally, an *assumption* of many statistics. The question is, "Are the frequency distributions of the three math attitude scales markedly different from the normal curve distribution?"

4) We will produce cross-tabulation tables in Assignment D and ask "Is the association between gender and math grades statistically significant?" This is a basic associational question.

[7] The High School and Beyond (HSB) study was conducted by the National Opinion Research Center (1980). The example, discussed here and throughout the book, is based on 13 variables obtained from a random sample of 75 out of 28,240 high school seniors. These variables include achievement scores, grades, and demographics. The raw data for the 13 variables were obtained from an appendix in Hinkle, Wiersma, and Jurs (1994). Note that additional variables (ethnicity and math attitudes) with realistic but fictitious data have been added to the HSB data set in order to provide examples of common additional types of analysis (e.g., summated scales and Cronbach's alpha).

5) In Assignment E, we will answer additional basic *associational* research questions (using Pearson product-moment correlation coefficients) such as, "Is there a positive association/relationship between grades in high school and a math achievement?"

This assignment also will produce a correlation matrix of all the associations among seven key variables including math achievement. Similar matrixes will provide the basis for the answers to the issues raised in Assignments F, G, and H.

6) Assignments F and G are not really intended to provide answers to the research problem posed at the beginning of this section. Assignment F will deal with the issue of whether our conceptualization that there are three aspects of attitudes about mathematics (pleasure, motivation, and competence) is consistent with the ways the students answered the 13 attitude items. The research question might be phrased, "Using the SPSS factor analysis program, will the 13 math attitude items/questions cluster into the same three sets of questions that we proposed conceptually?" This is a complex descriptive question.

7) Whether there is internal consistency reliability of the summated scale scores (determined conceptually or from factor analysis) is another important *assumption* to test before proceeding with the formal research questions. This issue could be phrased, "Are the three scale scores computed from the math attitude questions internally consistent?" There are also other important measures of reliability that will be computed in Assignment G.

8) Assignment H will ask and answer a key research question which is a *complex associational question*: "Is there a combination of math attitudes (motivation, competence, and pleasure), grades, father's and mother's education, and gender that predicts math achievement better than any one of them alone, and, if so, what is the best combination?" Assignment I will answer similar questions.

9) Several basic *difference questions* will be asked in Assignment J. For example, "Do males and females differ on math achievement and grades in high school?"

10) *Basic difference questions* in which the independent variable has three or more values will be asked in Assignment K. For example, "Are there differences among Euro-American, African-American, Hispanic-American, and Asian-American students on math achievement?"

11) *Complex difference questions* will be asked in Assignment L. One *set* of three questions is as follows: (1) "Is there a difference between students who have fathers with no college, some college, and a BS or more with respect to the student's math achievement?" (2) "Is there a difference between students who had an A or B math grade average and those with less than a B average on a math achievement test at the end of high school?" and (3) "Is there an interaction between father's education and math grades with respect to math achievement?"

12) Assignment M will deal with repeated measures and mixed ANOVA questions using a different data set that you will enter into the computer.

13) Finally, Assignment N will answer *complex difference questions* similar to those in Assignments J and K when more than one dependent variable is considered simultaneously.

Another way to group these research questions that we have found useful is as follows:

a) Descriptive statistics about the *demographics of the sample*.
b) *Tests of assumptions* such as that the key variables are distributed normally and the instruments are assessed reliably.
c) Tests of the specific *research questions* posed by the researcher, based on the research problem. These can be *descriptive, associational,* and/or *difference* questions.
d) In addition, we often test other *supplementary questions*, which may be side issues or may arise after we have written the proposal or even after the data have been collected and analyzed.

This introduction to the research problem and questions raised by the HSB data set should help make the assignments meaningful, and it should provide a guide and examples for your own research.

CHAPTER 3

Measurement and Descriptive Statistics

According to S. S. Stevens (1951), "In its broadest sense measurement is the assignment of numerals to objects or events according to rules" (p.1). As we have seen in chapter 1, the process of research begins with a problem that is made up of a question about the relationship between two, or usually more, variables. Measurement is introduced when these variables are operationally defined by certain rules which determine how the participants' responses will be translated into numerals. These numbers can represent nonordered categories in which the numerals do not indicate a greater or lesser degree of the characteristic of the variable. Stevens went on to describe four scales or levels of measurement that he labeled: nominal, ordinal, interval, and ratio. Stevens and most writers since then have argued that the level or scale of measurement used to collect data is one of the most important determinants of the types of statistics that can be done appropriately with that data. As implied by the phrase "levels of measurement," these types of measurements vary from the most basic (nominal) to the highest level (ratio). However, since none of the statistics that are commonly used in social sciences or education require the use of ratio scales we will not discuss them to any extent.

Nominal Scales/Variables

These are the most basic or primitive forms of scales in which the numerals assigned to each category stand for the name of the category, but have no implied order or value. Males may be assigned the numeral 1 and females may be coded as 2. This does not imply that females are higher than males or that two males equal a female or any of the other typical mathematical uses of the numerals. The same reasoning applies to many other true nominal categories such as ethnic groups, type of disability, section number in a class schedule, or marital status (e.g., never married, married, divorced, or widowed). In each of these cases the categories are distinct and nonoverlapping, but not ordered, thus each category in the variable marital status is different from each other but there is no necessary order to the categories. Thus, the four categories could be numbered 1 for never married, 2 for married, 3 for divorced, and 4 for widowed or the reverse, or any combination of assigning a number to each category. What this obviously implies is that you must *not* treat the numbers used for identifying the categories in a nominal scale as if they were numbers that could be used in a formula, added together, subtracted from one another, or used to compute an average. Average marital status makes no sense. However, if one asks a computer to do average marital status, it will blindly do so and give you meaningless information. The important thing about nominal scales is to have clearly defined, nonoverlapping or mutually exclusive categories which can be coded reliably by observers or by self-report.

Qualitative or naturalistic researchers rely heavily, if not exclusively, on nominal scales and on the process of developing appropriate codes or categories for behaviors, words, etc. Although using qualitative/nominal scales does dramatically reduce the types of statistics that can be used with your data, it does not altogether eliminate the use of statistics to summarize your data and

make inferences. Therefore, even when the data are nominal or qualitative categories, one's research may benefit from the use of appropriate statistics. We will return shortly to discuss the types of statistics, both descriptive and inferential, that are appropriate for nominal data.

Dichotomous Variables

It is often hard to tell whether a dichotomous variable, one with two values or categories (e.g., Yes or No, Pass or Fail), is nominal or ordered and researchers disagree. We argue that, although some such dichotomous variables are clearly nominal (e.g., gender) and others are clearly ordered (e.g., math grades--high and low), all dichotomous variables form a special case. Statistics such as the mean or variance would be meaningless for a three or more category nominal variable (e.g., ethnic group or marital status, as described above). However, such statistics do have meaning when there are only two categories. For example, in the HSB data the average gender is 1.55 (with males = 1 and females = 2). This means that 55% of the participants were females. Furthermore, we will see in Chapter 12, multiple regression, that dichotomous variables, called dummy variables, can be used as independent variables along with other variables that are interval scale. Thus, it is not necessary to decide whether a dichotomous variable is nominal, and it can be treated as if it were interval scale.

Table 3.1. ***Descriptions of Scales of Measurement With Dichotomous Variables Added***

Scale	Description
Nominal	= 3 or more unordered or nominal categories
Dichotomous	= 2 categories either nominal or ordered (special case)
Ordinal	= 3 or more ordered categories, but *clearly unequal intervals* between categories or *ranks*
Interval	= 3 or more ordered categories, and *approximately equal intervals* between categories
Ratio	= 3 or more ordered categories, with equal intervals between categories and a true zero

Ordinal Scales/Variables (i.e., Unequal Interval Scales)

In ordinal scales there are not only mutually exclusive categories as in nominal scales, but the categories are ordered from low to high in much the same way that one would *rank* the order in which horses finished a race (i.e., first, second, third, ...last). Thus, in an ordinal scale one knows which participant is highest or most preferred on a dimension but the intervals between the various ranks are not equal. For example, the second place horse may finish far behind the winner but only a fraction of a second in front of the third place finisher. Thus, in this case there

are unequal intervals between first, second, and third place with a very small interval between second and third and a much larger one between first and second.

Interval and Ratio Scales/Variables (i.e., Equal Interval Scales)

Interval scales have not only mutually exclusive categories that are ordered from low to high, but also the categories are equally spaced (i.e., have equal intervals between them). Most physical measurements (length, weight, money, etc.) are ratio scales because they not only have equal intervals between the values/categories, but also have a true zero, which means in the above examples, no length, no weight, or no money. Few psychological scales have this property of a true zero and thus even if they are very well constructed equal interval scales, it is not possible to say that one has no intelligence or no extroversion or no attitude of a certain type. While there are differences between interval and ratio scales, the differences are not important for us because we can do all of the types of statistics that we have available with interval data. As long as the scale has equal intervals, it is not necessary to have a true zero.

Distinguishing Between Ordinal and Interval Scales

It is usually fairly easy to tell whether three categories are ordered or not, so students and researchers can distinguish between nominal and ordinal data, except perhaps when there are only two categories, and then it does not matter. The distinction between nominal and ordinal makes a lot of difference in what statistics are appropriate. However, it is considerably harder to distinguish between ordinal and interval data. While almost all *physical* measurements provide either ratio or interval data, the situation is less clear with regard to psychological measurements.

When we come to the measurement of psychological characteristics such as attitudes, often we cannot be certain about whether the intervals between the ordered categories are equal, as required for an interval level scale. Suppose we have a five-point scale on which we are to rate our attitude about a certain statement from strongly agree as 5 to strongly disagree as 1. The issue is whether the intervals between a rating of 1 and 2, 2 and 3, 3 and 4, and 4 and 5 are all equal or not. One could argue that because the numbers are equally spaced on the page, and because they are equally spaced in terms of their numerical values, the subjects will view them as equal intervals. However, especially if the in-between points are identified (e.g., strongly agree, agree, neutral, disagree, and strongly disagree), it could be argued that the difference between strongly agree and agree is not the same as between agree and neutral; this contention would be hard to disprove. Some questionnaire or survey items have response categories that are not exactly equal intervals. For example, let's take the case where the subjects are asked to identify their age as one of five categories: 21 to 30, 31 to 40, 41 to 50, 51 to 60, and 61 and above. It should be clear that the last category is larger in terms of number of years covered than the other four categories. Thus, the age intervals are not exactly equal. However, we would consider this scale and the ones above to be at least *approximately interval*.

On the other hand, an example of an ordered scale that is clearly not interval would be one that asked how frequently subjects do something. The answers go something like this: every day, once a week, once a month, once a year, once every 5 years. You can see that the categories

become wider and wider and, therefore, are not equal intervals. There is clearly much more difference between 1 year and 5 years than there is between 1 day and 1 week. Most of the above information is summarized in the top of Table 3.2.

Table 3.2. ***Selection of Appropriate Descriptive Statistics for One Dependent Variable***

	Level/Scale of Measurement of Variable		
	Nominal	**Ordinal**	**Interval or Ratio**
Characteristics of the Variable	- Qualitative data - Not ordered - True categories: only names, labels	- Quantitative data - Ordered data - Rank order only	- Quantitative data - Ordered data - Equal intervals between values
Examples	Gender, school, curriculum type, hair color	1st, 2nd, 3rd place, ranked preferences	Age, height, good test scores, good rating scales
Frequency Distribution	Redhead - III Blond - IIII Brunette - II	Best - II Better - III Good - III	5 - I 4 - II 3 - III 2 - III 1 - II
Frequency Polygon/ Histogram	No	Yes	Yes
Bar Graph or Chart	Yes	Yes	Yes
Central Tendency			
Mean	No	Mean Rank	Yes
Median	No	Yes	Yes
Mode	Yes	Yes	Yes
Variability			
Standard Deviation	No	of Ranks	Yes
Range	No	Yes, but[1]	Yes
How many categories	Yes	Yes	Yes
Percent in each	Yes	Yes	Yes
Shape			
Skewness	No	No	Yes
Kurtosis	No	No	Yes

[1] The range of ordinal data may well be misleading