Teaching How to Write about Numbers:
Suggested Courses and Exercises

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The ability to communicate effectively about numbers is a critical element of quantitative literacy – the ability to apply mathematical reasoning and computations to address issues on a wide range of topics. Books such as *Mathematics and Democracy: The Case for Quantitative Literacy* (Steen 2001) and *Achieving Quantitative Literacy: An Urgent Challenge for Higher Education* (Steen 2004) make a compelling case for the importance of quantitative literacy in occupations such as scientist, policy analyst, engineer, journalist, consultant, meteorologist and many others. They also argue that quantitative literacy (also known as "numeracy") is applicable in tasks of daily life related to personal finance, citizenship, health, and other activities that require using numeric information to make decisions. However, a series of books, including seminal works by Paulos (2001), Dewdney (1996), and Best (2001) suggest that many people emerge from school ill-equipped to apply quantitative literacy skills to the kinds of questions central to functioning in modern society.

Despite the widespread need for quantitative literacy, few students are formally trained to write about numbers. Scientists and others who routinely work with numbers learn to calculate and interpret the findings, but rarely are taught to describe them in ways that are comprehensible to audiences with different levels of quantitative expertise or interest. Communications specialists learn to write for varied audiences, but rarely are taught specifically to present numeric information effectively. Moreover, although the variety of topics named above demonstrates that substantive disciplines including the social sciences, STEM fields (science, technology, engineering and math), history, and many others have roles to play in developing and practicing quantitative literacy (Miller 2010), many students spend little time learning to work with numbers in such courses.

To address this pressing need, teaching how to write about numbers can be integrated into several types of courses and informal learning settings as part of an undergraduate or graduate curriculum. In this appendix, I discuss courses into which the material can be incorporated, including expository writing, statistics, and research methods courses as well as substantive and professional development courses and also points out informal settings that provide good opportunities for practicing quantitative literacy and communications. I then describe tested classroom teaching approaches, and illustrative exercises that can be used to provide practice applying those skills to course material or ongoing research projects.

Below are some examples of ways numeracy concepts and practices can be incorporated into existing courses in many fields.

Formal courses

- In *mathematics or statistics courses*, assign students short, self-contained exercises on how to report and interpret results of quantitative comparisons in simple sentence form. These tasks can be added to existing data analysis assignments. Such exercises help students develop the habit of thinking about how to communicate clearly about numeric results, and can also help reinforce the meaning of the underlying mathematical and statistical concepts.
- In *research methods courses*, ask students to identify the purpose of a statistical analysis for different topics and data (e.g., to test for confounding or mediating). These exercises help students reinforce their understanding of the reason for a particular type of analysis in the context of a given research question and data set.
- In either *research methods courses* or *substantive courses* such as sociology of the family, health psychology, public policy, environmental chemistry, or social history, ask students to evaluate and critique articles that use statistics to analyze data from different types of study designs, assessing whether causal arguments are plausible given the data and methods at hand. Such exercises provide

practice applying quantitative literacy concepts to topics in the discipline, helping to dispel the tendency of some students to want to divorce methods material from substantive material.

- In *substantive courses* for which students are writing papers in which they cite numeric facts in their introductory or concluding sections, require that they apply principles from *The Chicago Guide to Writing about Numbers, 2nd Edition* (Miller 2015) to those sections. This type of exercise entails students recognizing the importance of carefully selecting and interpreting numeric information, including context and units.
- In *substantive courses* for which students are writing papers involving their own analysis of data, require that they apply principles from *Writing about Numbers* as they plan and draft their methods and results section. This type of assignment forces students to think though how methodological and statistical issues affect the analytic plan designed to answer an underlying "word problem."
- In *writing courses*, assign students to decide among tables, graphs, and prose for specific tasks related to a paper they are writing about an application of numbers, and then to draft those materials according to guidelines provided in Miller (2015). These tasks help students understand the strengths and weaknesses of each of the tools for presenting numeric information, and to become proficient at designing effective versions of graphs and tables and writing the associated prose.
- In *advanced courses* such as professional development seminars or honors thesis courses, ask students to revisit concepts and skills related to quantitative communication while writing or revising their own papers, to provide practice identifying and explaining the big picture of how their quantitative analytic approach fits their topic and data. Such courses permit time to consider how writing about numbers fits into each section of a research paper, and to apply standard expository writing techniques to this specific type of academic writing.

Informal settings

Informal teaching settings can also provide opportunities for teaching and reinforcing issues related to effective design, execution, and communication of quantitative analyses applied to substantive research questions. Such settings include research seminars, collaborative research involving students on teams with faculty or post-doctoral or graduate students, and individual meetings of students with faculty who are supervising course or qualifying papers or doctoral dissertations. These settings pertain especially to graduate students, but are also relevant for advanced undergraduates who are participating in honors theses or other advanced independent research projects.

Seminars

Brown bag seminars of research in progress provide opportunities for students to hear how experienced researchers plan, conduct, communicate, and critique numeric analyses. Aspects of research thinking and writing that are often discussed in these settings include:

- *Research methods issues* that affect quantitative analyses, such as whether the choice of data set, sampling strategy, and analytic sample were appropriate for the research question; and whether the variables are adequate measures of the underlying concepts.
- *Statistical issues* such as suitability of the type of statistical procedure for the variables involved; whether key variables were omitted from the analysis; and the choice of analytic strategy to address the particular research question (e.g., three-way analyses to see whether a bivariate pattern is consistent across subgroups defined by a third variable).
- *Substantive issues* such as whether the research question is interesting and important to people in that field or profession; whether results are credible (and if not, why not); whether there are alternative explanations for the findings; and whether the limitations of the data were taken into account in the interpretation of results.
- *Communications issues* such as clarity of graphs, tables, and prose used to convey the purpose, results and implications of the study; how experienced researchers organize tables to convey their analytic plan and statistical findings; how they interpret the information in those tables to answer the

underlying research question; and how they perform live oral presentations of numeric material in the context of a "real-world" question.

Early in each academic year, it is useful to orient students about how to listen to and participate in seminar experiences so that they don't simply focus on the substantive conclusions. Point out the importance of also paying attention to the kinds of issues raised by members of the audience, how the presenter answers those questions, and how the feedback received by the presenter might affect his or her work on the topic. Encourage students to develop and ask questions during the seminar. Suggest that they think about which aspects of the presentation were effective (e.g., clear explanation of why the particular choice of statistical method was used for this topic and data), and which aspects perhaps should be avoided in their own future written and oral research presentations (e.g., too many digits on the slides; overly technical descriptions of the results that obscure substantive meaning).

Collaborative research settings

Meetings and written feedback on drafts of quantitative research projects by a team of researchers can also provide insight into many of the issues outlined above, with the added advantage that the student is an active participant in that research and is familiar with the topic and data. Hearing how each member of a collaborative team contributes their own perspective, how they complement one another's strengths, critique one another, and resolve conflicts about issues that arise during the project also provide valuable opportunities for students to learn about the wide range of tasks and skills involved in writing about research involving applications of numeric analysis.

Individual research projects

Work on individual research papers or dissertations is another type of opportunity that for students to receive feedback on their thinking process, analytic approach, interpretation, and writing related to applications of numbers to topics in the social sciences, STEM fields, public policy, health, and other fields. The individualized nature of these meetings is invaluable for ensuring that each student receives guidance in the particular issues they are facing in their own projects at the moment, and how the principles for writing about numbers apply to their specific project.

INSTRUCTIONAL METHODS FOR TEACHING HOW TO WRITE ABOUT NUMBERS

There are several steps to teaching how to write about numbers in coursework or for independent study, honors thesis, or dissertation writers. First, assign readings that cover key principles about statistical research writing, such as Miller (2015), Pyrczak and Bruce (2011), Treiman (2009), or other books or articles on writing or professional research practice. Second, in lecture briefly cover the principles and associated skills for writing about numbers, followed by in-class demonstration using such as the "poor/better/best" technique (shown below) to present examples of how to translate abstract writing principles into concrete sentences or paragraphs. Third, reinforce those concepts by assigning students to apply them to their own work or to evaluating existing published work, using one of several types of exercises, such as those shown below. Fourth, have students use checklists such as those at the end of each chapter in Miller (2015) to plan and evaluate their work.

Other useful teaching methods include the use of color coding on slides and other exhibits, and the "Vanna White" technique for explaining a table, chart, or other diagram during a live presentation, which is described on pp. 306-310 of Miller (2015). Videos on those methods are available on the web site of supplemental online materials.

Poor/better/best teaching device

One useful technique to add to your teaching toolkit is the "poor/better/best" device that I developed to illustrate how to apply the various principles and skills involved in writing about numbers. It seeks to remedy the problem that many people find it challenging to apply new abstract ideas to specific situations – an essential step in writing about numbers. Willingham (2009) describes the importance of seeing new, abstract ideas in the context of things we already know, and points out that what we already

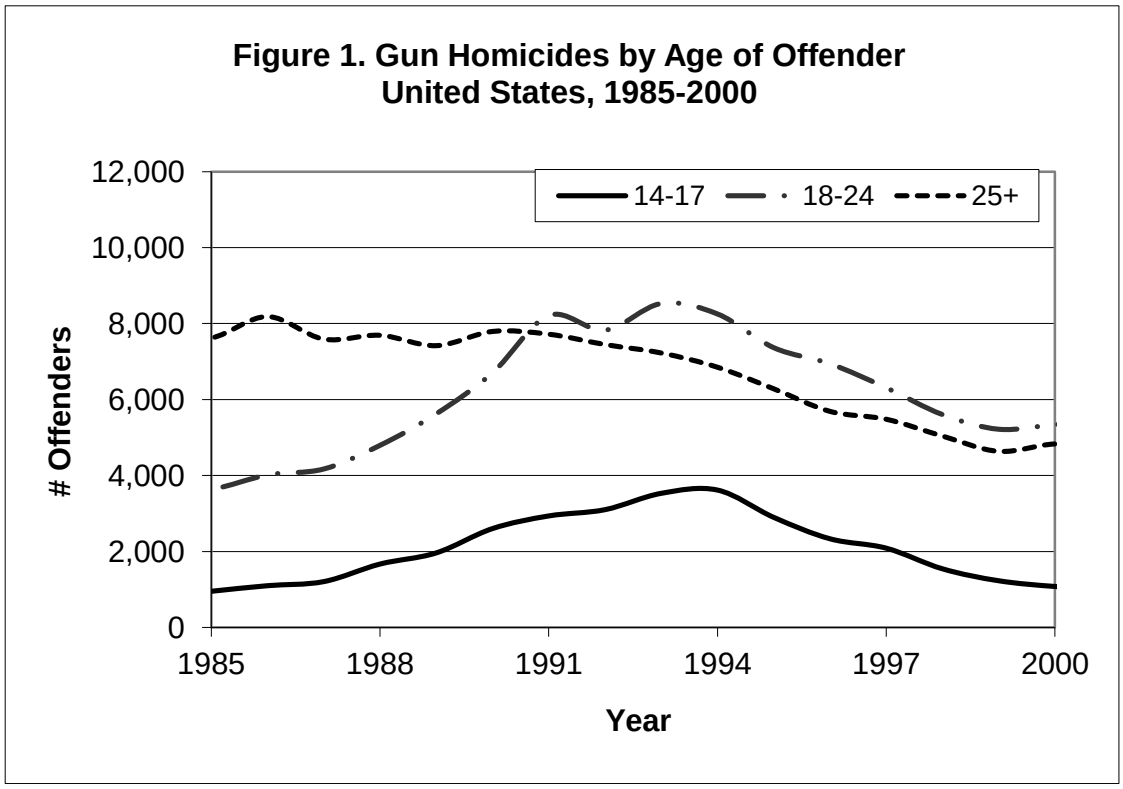
know is concrete. To address the challenge of learning to master abstract principles, I provide examples of how to apply a principle or skill such as "specify direction and magnitude" (Miller 2015, chapter 2), illustrated with a concrete, familiar topic. I start by presenting a "poor" version of a prose description, table, or chart that did *not* follow that principle. I annotate that example to point out the specific aspects that were ineffective, along the way illustrating some of the most common errors I have observed when teaching that skill. I then provide "better" and "best" versions of that prose, table, or chart, annotated to explain why those versions represent improved applications of that principle.

The poor examples are adapted from ones I have encountered while teaching research methods, writing and reviewing research papers and proposals, or attending and giving presentations to academic, policy, and business audiences. These examples may reflect lack of familiarity with quantitative concepts, poor writing or design skills, indoctrination into the jargon of a technical discipline, or failure to take the time to adapt materials for the intended audience and objectives. The principles and better examples will help you plan and evaluate your writing to avoid similar pitfalls in your own work.

The "poor/better/best" ("PBB") approach can be used to introduce and practice applying new principles about how to write about numbers, encouraging students to draft, evaluate, and revise sentences, tables or charts as a participatory exercise. Here is a suggested sequence of steps for applying poor/better/best in a classroom setting.

1. Introduce a general principle such as generalizing a pattern based on many numbers. Students should have been assigned a reading on the topic, in this case, pages 33–36 and 220–225 and Appendix A for guidelines and examples on summarizing patterns.

2. Walk students through one complete PBB exercise, using examples from the article or book, or ones you have written based on an assigned substantive article.



Source: Fox and Zawitz, 2004.

Sample poor/better/best teaching example for generalizing a pattern

Poor: "In 1985, 14-17 year-olds committed 952 gun-related homicides. In 1986 and 1987, persons in that age group committed 1,099 and 1,207 gun-related homicides, respectively (Figure 1)… [***Description continues by reporting annual statistics for each of the three age groups***]."

Comment: Individual statistics on the number of homicides in each of fifteen years for each of several age groups force readers to do the math to figure out whether homicides are rising, falling, or level, and whether the time trend is similar for the three age groups being compared. All those sentences reporting numbers will also obscure the general pattern and tire your readers.

Poor [version 2]: "Between 1985 and 1986, the number of gun-related homicides committed by 14-17 year olds increased from 952 to 1,099. Between 1986 and 1987, it increased again, to 1,207… (Figure 1)… [***Description continues by reporting one-year changes in the number of homicides for each of the three age groups***.]"

Comment: Although this version presents single-year changes in homicides committed by one age group instead of merely reporting the value of each data point, it fails to paint the overall shape of the time trend across the period shown or to compare across age groups.

(Somewhat) better: "Among offenders aged 14-17, gun-related homicides nearly quadrupled between 1985 and 1994 (from 952 to 3,617 homicides), and then declined to 1,079 in 2000. Among offenders aged 18-24, gun-related homicides more than doubled between 1985 and 1994 (from 3,633 to 8,253), then decreased through 2000. Among offenders aged 25 and older, gun-related homicides declined slightly throughout the period from 1985 to 2000 (Figure 1)."

Comment: Although this version describes the shape and size of the time trend for each age group, it doesn't compare time trends across age groups, requiring readers to figure out for themselves whether all three age groups followed the general time trends observed in Figure 1 or whether the patterns varied.

Best: "As shown in Figure 1, in the two youngest groups of offenders, gun-related homicides increased substantially between 1985 and 1994, and then decreased steadily until 2000. In contrast, the number of gun-related homicides committed by older offenders decreased slowly throughout the time period shown."

Comment: This description points out that the time trend in gun-related homicides was similar for two of the three age groups, and then describes the general shape of pattern. The phrase "in contrast" is used to emphasize the fact that the time trend for the third age group was different from the other two, before going on to describe the shape of that pattern.

3. Hand out a table or chart with numeric information for an association among three variables, and then give students a few minutes to work individually to write a sentence to report and interpret those numbers. See "Problem Sets" below for examples of the types of tasks that can be used for this exercise.

4. Solicit an example sentence and write it on the board, then ask the class to use the mental checklist for that principle to evaluate the sentence and provide constructive criticism on how to improve it. See "Checklists" below.

   HINT: Try wording your request "Can someone give me a poor sentence to report that information?," which tends to make students more willing to hazard a suggested sentence than if they are asked to state their best attempt at an effective sentence that they fear might contain errors.

5. Write the revisions on the board in a contrasting color. Point out that revision is a normal part of the writing process and is to be expected especially when tasks such as summarizing a complex pattern are attempted for the first time.

6. Ask the students whether they feel prepared to apply the principle on their own. If not, have them identify the aspects of the principle that they don't understand, or the steps of the approach where they became stuck.

7. Have a second example table or chart at hand in case they want to practice again as a group.

Checklists

At the end of each chapter in *The Chicago Guide to Writing about Numbers, 2nd Edition* (Miller 2015) is a checklist that summarizes the key steps to conducting a particular task. These checklists can be used to help students plan, draft, and evaluate their writing about numbers. For example, the checklist for summarizing a complex pattern (from Chapter 2) reads:

- To describe a pattern involving many numbers, summarize the overall pattern rather than repeating all the numbers.
- Create a graph to illustrate the pattern. It doesn't have to be perfect but should be to scale and labeled so you can identify the variables involved and their categories and units.
- Find a generalization that fits most of the data, specifying direction and magnitude of the association.
- Report a few illustrative numbers from the associated table or graph;
- Describe exceptions to the general pattern – how some parts deviate from the shape and size of the pattern described in your generalization.

EXERCISES FOR TEACHING HOW TO WRITE ABOUT NUMBERS

The online study guide to *The Chicago Guide to Writing about Numbers, 2nd Edition* includes two different general types of exercises that students can use to practice applying the concepts and skills in the book: (1) Self-contained problem sets, and (2) suggested course extensions.

Problem sets

The first type of exercise involves use of problem set questions that provide practice for specific skills, working from data provided in text, table, or graph form. Solutions to these example problems are given at the end of this appendix.

Problem Set A: Write a description of the distribution shown in Table 1, following the guidelines in chapter 9 of *Writing about Numbers, 2nd Edition* for writing about univariate distributions.

Table 1. Total Amount Borrowed by 2009 by US Students Beginning Postsecondary Education in 2003-04

Amount borrowed	Percentage of students	Percentage of borrowers
Did not borrow	43%	NA
$1 to $10,000	25%	44%
$10,001 to $20,000	16%	28%
$20,001 to 30,000	8%	14%
$30,001 to $50,000	5%	9%
More than $50,000	2%	4%

Source: College Board Advocacy and Policy Center. 2014. Figure 11C.

Problem Set A might be used in an introductory statistics course.

Problem Set B: For each of the following data, methods and objectives, write a short discussion of strengths and limitations for the concluding section of a general interest newspaper article.

a. Study: twenty subjects were interviewed at the Snooty Golf Club at noon on a Friday in early April regarding their preferred color and fit of jeans. Objective: a marketing study by the Abercrombie and Fitch clothing store chain.

b. Study: two classes of second graders in the two different schools were given a math test in September. One school was then taught with a new math curriculum, the other with the standard curriculum. The students were tested again in June. Objective: an evaluation of the new math curriculum.

Problem Set B could be assigned to students in a research methods course, to help them understand about causation, reverse causation, and confounding.

A series of problem sets related to Miller (2015) is available at http://www.press.uchicago.edu/books/miller/numbers/index.html, along with solutions to the odd numbered questions that can be used to assist in grading if those problems are assigned for homework or exams. These problem sets have been tested out in undergraduate and graduate-level courses for students in a range of social science and health fields. Exercises from the problem sets can be used in class immediately after teaching a skill or concept, with associated graphs or tables inserted onto slides for group discussion and/or given as handouts for students to write on as they answer the question. Other uses for problem sets include assigning them as homework or using them as exam questions.

Suggested course extensions

A second type of exercise provided on the supplemental materials site for *The Chicago Guide to Writing about Numbers, 2nd Edition* (Miller 2015) is so-called suggested course extensions. Those exercises ask students to apply the concepts and skills related to writing about numbers to the published literature or papers they are writing as part of courses in statistical methods, research methods, research writing, or professional development seminars. The suggested course extensions come in four general types (1) reviewing published literature; (2) applying statistical analysis to one's own data; (3) writing new material; and (4) revising previous drafts of material. Chapters refer to *The Chicago Guide to Writing about Numbers, 2nd Edition* (Miller 2015).

Reviewing published literature exercises involve using the principles for writing effectively about numbers as part of a course in which students are asked to critique applications of numbers to research questions in their field.

Example for a research methods course or a substantive course:

From Chapter 3: Statistical Significance, Substantive Significance, and Causality: Find a journal article that uses statistics to analyze a policy problem and proposes one or more solutions to that problem.

a. Evaluate how well the article addresses each of these aspects of "importance." Does the article

i. specify a cause-and-effect type of relationship?
ii. provide a plausible argument for a causal association?
iii. review measurements issues for the outcome and key covariates?
iv. discuss bias, confounding, or reverse causation?
v. report results of statistical tests for that association?

vi. assess whether the expected benefits of the proposed solution are big enough to outweigh costs or otherwise matter in a larger social context?

b. Given your answers to part a, write a short critique of the appropriateness of the proposed solution.

Such exercises can be incorporated into courses on any of a wide range of topics such as history, sociology, biology, or public policy, requiring students to integrate concepts from their research methods and statistics courses with knowledge about the specific content area covered in the course. That approach also provides practice in the kinds of critical reading and analytic skills that graduate students must develop as the basis for future professional activities such as reviewing grant proposals and articles.

Applying statistics involves having students apply these planning and writing principles to results from their own analyses.

Example for a research methods or statistics course: From Chapter 5: Types of Quantitative Comparisons: Find a problem from a statistics or research methods textbook that involves comparison of two or more numbers.

a. Identify a pertinent comparison value for the variables and units under study.
b. Choose two ways to compare the numbers. Explain your choice of types of quantitative comparisons, with reference to a related research question or issue.
c. Calculate the pertinent comparisons (e.g., rank, difference, ratio, percentage difference).
d. Write a paragraph that interprets the results of the comparisons from part c.
e. Use the checklist at the end of chapter 5 in *Writing about Numbers, 2nd Edition* (p. 120) to evaluate completeness and clarity of your writing.

Writing exercises ask students to apply principles for communicating numeric information to plan and execute new sections of papers based on analysis of their own topic and data, using checklists such as those provided at the end of chapters in Miller (2015).

Example for a statistics course: From Chapter 9: Writing about Distributions and Associations: Using frequency distributions on one nominal, one ordinal, and one interval or ratio variable in your data set:

a. Write a brief description of each distribution, emphasizing the modal value using the criteria in chapter 9 of *Writing about Numbers, 2nd Edition*. Summarize the overall shape of the distribution, and then report key indicators of central tendency.

b. Write a second description of each distribution, this time highlighting a value of interest other than the mean or mode, such as a minority group, unusual value, or most recent value.

Revising exercises require students to use principles for writing about numbers to evaluate and revise sentences, paragraphs, tables, graphs, or slides from their own previously written papers or speeches as part of a writing course or professional development seminar. This type of activity works well as a peer-editing exercise in which students exchange initial drafts with one another, mark them up according to the principles described above, and then return them to the original author to revise the material accordingly.

Examples for a public speaking course or professional development seminar: From Chapter 12: Speaking about Numbers

1. Evaluate the slides you have previously created for a 15–20 minute speech to a scientific audience, using the criteria in chapter 10. Revise the slides to rectify any shortcomings you identify.

2. Pick one large table from the results section of your paper. Revise it into several simpler table slides or chart slides using the guidelines in chapter 10, and incorporate those slides into the presentation used in the preceding question.

3. Write "Vanna White" notes to introduce and explain one table and one chart from your revised presentation, using the guidelines in chapter 10. Incorporate them into your speaker's notes.

The suggested course extensions typically require more time to complete than do the problem sets, so they are best used either as in-class exercises during lab or writing time of at least an hour, or assigned as homework. Additional suggested course extensions can be found at http://www.press.uchicago.edu/books/miller/numbers/index.html for each chapter in Miller (2015). The above exercises might also provide ideas for faculty to develop their own suggested course extensions to meet the needs of their students and courses.

The online materials also include two longer exercises to help acquaint students with their own data sets and variables: "Getting to Know Your Variables," and "Planning How to Create the Variables You Need from the Variables You Have." Both involve in-depth work with the students' own data sets, ideally across a period of several weeks or a full semester course. Each of the extended exercises includes templates of grids that can be downloaded and distributed to students so they can fill in specific information about their variables and data sources. The assignment instructions and templates are complemented by downloadable text appendixes to teach instructors why these skills are important and ways to incorporate them into existing courses or projects. In addition, slide sets and podcasts for teaching these concepts are available from the supplemental online materials web site.

Getting to know your variables

This extended exercise covers concepts covered in Chapters 4 and 10 of Miller (2015) to help students become familiar with attributes of the specific variables in their data set, including levels of measurement, units and/or categories, plausible range of values, skip patterns and other missing values that are critical for making informed choices about how to analyze those variables and present the associated results in tables, charts, and prose.

Planning how to create the variables you need from the variables you have

This exercise has students conduct "behind the scenes" planning to create variables needed for their own analysis from variables that are available in the data set they will be using for their analysis. It is designed to help students anticipate and plan whether they need to create any new variables to analyze data for their research question, including steps such as finding variables in their data set that measure the concepts they plan to study; becoming acquainted with the units and categories for available variables; consulting the published literature on their topic to see how their concepts have been measured or classified by other researchers; and writing out the logic on how to get from existing variables to the versions they will analyze.

SUMMARY

This appendix provides guidelines about ways to incorporate teaching how to write about numbers into undergraduate and graduate curricula in a variety of fields that use quantitative analysis to answer substantive questions. Ideally, faculty members will work together to ensure that these concepts and skills are introduced and reinforced throughout the curriculum, to provide students with the opportunity to apply and practice these essential aspects of research communication.

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Solutions to problem set questions:

Problem set A: Write a description of the distribution shown in Table 1.

1. As of 2009, more than half (57%) of US students who began their post-secondary education during the 2003-4 academic year had borrowed money to pay for their education. Of those, more than 4 out of 10 (25% out of 57%) had accumulated a total educational debt of less than $10,000 during the five years after starting their post-secondary education, while the remaining borrowers were approximately equally split between those with debt between $10,000 and $20,000, and those with debt of $20,000 or more (28% and 26% of all borrowers, respectively).

Problem set B: Discussion of strengths and limitations for the concluding section of a newspaper article.

a. "The findings from this study are probably of little use for the average Abercrombie and Fitch store, which is aimed at the teen and young adult population. Because the data were collected during a weekday at an exclusive golf club, the opinions likely represent those of relatively affluent, nonworking adults—a fairly small share of the Abercrombie and Fitch market. Future studies should sample younger persons from a range of income and employment groups, as well as students—the groups that comprise the target audience."

b. "Strengths of this study include its longitudinal nature, with testing both before and after adoption of the new curriculum in schools with each type of curriculum. However, it isn't clear whether random assignment was used to decide which school followed which curriculum, or whether schools made their own choices of curriculum. In addition, possible differences in socioeconomic, demographic, and educational characteristics that might explain observed differences across schools or changes across time were not included."