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Teaching Quantitative Literacy through a Regression Analysis of Exam Performance

Andrew M. Lindner[1]

Abstract

Quantitative literacy is increasingly essential for both informed citizenship and a variety of careers. Though regression is one of the most common methods in quantitative sociology, it is rarely taught until late in students' college careers. In this article, the author describes a classroom-based activity introducing students to regression analysis in an introductory sociology course. Using a data set that draws on the students' quiz and exam scores, students learn the basics of interpreting regression analyses in a manner that is relevant to their own lives. The activity also encourages students to think critically about potential predictors of exam performance and how they could be measured.

Keywords

quantitative literacy, classroom-based exercises, data analysis, introduction to sociology

Over the past 15 years, educational and political leaders as well as organizations like the American Sociological Association (ASA) and National Science Foundation (NSF) have consistently called for curricula designed to develop students' quantitative literacy (McKinney et al. 2004; National Science Board 2004). Careers in business, politics, law, and public relations increasingly demand skills in the analysis of statistics. At the same time, with frequent references to the findings of polls and studies in news reports, quantitative literacy has become essential to informed citizenship. Despite the importance of quantitative literacy for both career and citizenship, even fairly basic skills of data analysis are not being taught in most sociology courses throughout the country.

In this article, I begin by briefly reviewing previous research and methods of quantitative methodology education. Then, I describe an in-class activity that introduces students in an introductory sociology course to regression analysis, one of the most frequently used methods in quantitative sociology. I argue that by using the students' own quiz and exam scores as the data set, the exercise becomes far more relevant to their lives. Finally, I discuss some outcomes and limitations of the exercise.

BACKGROUND

As Wilder (2009) has observed, the standard sociology curriculum sequesters nearly all data analysis within a token research methods and statistics course, often taken in the final few semesters of college. Meanwhile, few of the substantive courses seek to develop quantitative literacy, focusing instead on nurturing critical thinking and written communication abilities. In their 2006 study, Grauerholz and Gibson found that only 15 percent of syllabi featured in ASA collections included any type of data collection or analysis. Wagenaar (2004), in a study of 301 sociologists, found that

[1]Concordia College, Moorhead, MN, USA

Corresponding Author:
Andrew M. Lindner, Department of Sociology, Concordia College, 901 8th St. S, Moorhead, MN 56562, USA
Email: lindner@cord.edu

while most teachers saw statistical learning as an important part of the major as a whole, it was not widely considered essential content for introductory courses. "Disembodied" from the major's substantive courses, data analysis lacks relevancy to many students (Wilder 2009:152).

Moreover, given their lack of exposure to the interpretation of quantitative findings, it is no surprise that many students experience some degree of "statistics anxiety." The dozens of studies in *Teaching Sociology* offering tactics for managing students' fear of mathematics attest to instructors' anecdotal experience of this anxiety as a barrier to learning (Bessant 1992; Blalock 1987; Schacht and Stewart 1990). While DeCesare (2007) regards much of the rhetoric of anxiety or fear as overblown, his empirical study of students entering a research methods and statistics class found that a majority (58 percent) reported being either anxious or very anxious about statistics.

One way to decrease students' "statistics anxiety" while improving their quantitative literacy is by introducing basic skills of data interpretation at a much earlier point in their college career and reinforcing the lessons and degree of complexity throughout their course sequence. Just as students gain confidence by completing small writing assignments before writing major research papers, so too, sociology instructors need to create frequent but manageable data analysis assignments and activities. Incorporating quantitative literacy in the sociology curriculum has been an explicit goal for ASA (1990) for over 20 years. In their 2004 report, the ASA Task Force on the Undergraduate Major even more emphatically stated the need to better integrate data analysis throughout the sociology major, saying, "Sociology, then, must be viewed as a 'lab science.' . . . Departments need to infuse the empirical base of sociology into all courses" (McKinney et al. 2004:8). As a practical means of accomplishing these goals, the ASA and the Social Science Data Analysis Network developed the Integrating Data Analysis (IDA) project, which structures a series of data analysis modules into the substantive courses of the major. Initial evidence strongly suggests that courses with IDA modules significantly improve both students' quantitative literacy and interest in using data (Wilder 2009).

Of course, adopting IDA modules may not be feasible for every department due to limitations in institutional resources, existing norms of autonomy in course design, the irascibility of the faculty, and so on. In the absence of a clear one-size-fits-all program, teacher-scholars have introduced many assignments designed to expand quantitative literacy that can serve as a complement or alternative to IDA modules. Scheitle (2006), for example, suggests creating assignments that require students to analyze existing data sets using Web-based tools to create frequencies, cross-tabulations, and charts. Burdette and McLoughlin (2010) introduce an assignment in which students compare the demographic characteristics of two counties in their state using census data. Atkinson, Czaja, and Brewster (2006) offer a particularly useful approach, creating an assignment appropriate for an introductory-level course that develops competency in the construction and analysis of cross-tabulations with control variables. In addition to improving quantitative literacy, they found that this module also expanded their students' substantive understanding of race and gender inequalities. For a more thorough discussion of various approaches to teaching quantitative literacy, see Paxton (2006).

Even with so many creative ideas, few classroom activities or assignments aimed at improving quantitative literacy introduce regression analysis despite it being "the method of choice . . . in the past 20 years" within contemporary quantitative sociology (Raftery 2005:23). By my own count, it was used in more than two-thirds of the articles appearing in *American Sociological Review* in the first half of 2011. Far from being an exotic statistical technique, regression is widely used in political consulting, law, marketing, software development, and nonprofit organizations. It is referred to with some frequency in leading newspapers, popular periodicals, and bestselling nonfiction books. Regression is also one of the real stars of the 2011 movie, *Moneyball* (Miller 2011), starring Brad Pitt, which tells the story of how Major League Baseball teams began using advanced statistics in player acquisition decisions. And yet, most sociology students are introduced to regression in the final weeks of their methods and statistics course or in a senior seminar, if at all. Students in introductory sociology courses are very rarely taught to interpret regression outputs, perhaps in part because instructors view it as too challenging (even though it is based on early high school algebra). However, given the prominence of regression analysis in sociology, many top professional tracks, and popular intellectual texts, true quantitative literacy today requires more than cross-tabulations. Just as the ASA Task Force on the Undergraduate Major wrote of data analysis in general in 1990, sociology students should be exposed to regression analysis "early and often" (ASA 1990:8).

Another important feature of any successful classroom activity or assignment is that it feels relevant to students. Students tend to respond to concepts more enthusiastically and understand more fully when they are able to relate it to their own lives. As Renzulli (2000:249) argues, students better grasp difficult concepts when instructors "creat[e] assignments that make students critically evaluate their own local world and the local world of others." While many activities and assignments appearing in the pages of *Teaching Sociology* call on students to think critically about their own experiences, most quantitative activities draw on the responses of nameless, faceless survey responses. Students who feel passionately about issues of class, race, gender, religion, and so on often respond enthusiastically to such projects. However, for many students in introductory classes, less abstracted exercises with applicability to their own lives are more engaging and comprehensible. Some instructors have tried to make data analysis projects more directly relevant by using census data from their own counties or other community-level data (Burdette and McLoughlin 2010; Renzulli 2000). Few quantitative analysis exercises draw on data collected on the students themselves. By analyzing findings about themselves and their classmates, the activity simultaneously becomes more personally relevant and allows them to gain critical distance on their own experience.

In the exercise described in the following, I introduce introductory students to the concept of regression analysis and teach them how to interpret the results of output from statistical software. Using their quiz and exam scores as the data being analyzed, I encourage the students to reflect critically on their own performance, brainstorm unmeasured variables, and critique the method itself.

THE DATA

Data used in the exercise come from the students' own quiz and exam scores. In my introductory sociology courses, which meet three times a week and average 33.9 students in size, I assess students with 15 pop quizzes over the course of the semester. These five-question multiple choice quizzes are intended to test reading alone and are fairly simple if the student has completed the assigned readings for the day. Scored on a 10-point scale, students receive 5 points for simply being in attendance and 1 point for each of the five questions answered correctly. Thus, an attending student who correctly answers two of the five questions will receive a 7 out of 10 (70 percent). In the 10 introductory sections I have taught over the past three years, the mean quiz score is 80.1 percent. The students take three noncumulative exams over the course of the semester that include a mixture of multiple choice questions and short essay questions. Using my gradebook for the course (maintained in Microsoft Excel), I create a data set that includes the students' mean quiz scores and exam scores. I then import these data into SPSS, the statistical analysis software, in order to analyze the data. For complete descriptive statistics and regression analyses, see the Appendix.

The students taking part in the exercise (and whose grades are included in the data set) attend Concordia College (Moorhead, MN), a small private liberal arts college. Nearly all of the students are full-time residential students between the ages of 18 and 22. Overwhelmingly white (92.3 percent in the 10 sections represented here), willing to pay a premium for a private college, and hailing from Minnesota and neighboring states, many of the students have attended schools with relatively small class sizes and do not face substantial barriers to success in college classrooms. Among all Concordia College students, the average ACT score is 25. On the other hand, based on anecdotal evidence from conversations with students, many students attended rural high schools with limited resources and few AP courses. A substantial minority of students are first-generation college students. That said, in my experience, nearly all students have had sufficient exposure to basic algebra to understand the central concepts of regression analysis.

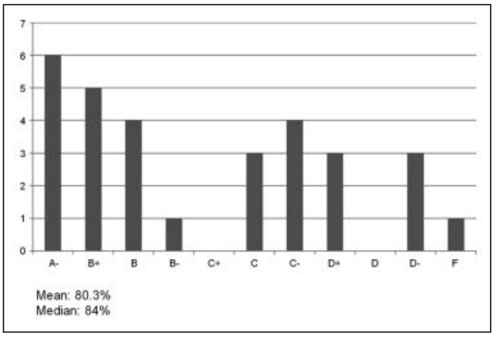

Figure 1. Distribution of grades PowerPoint slide

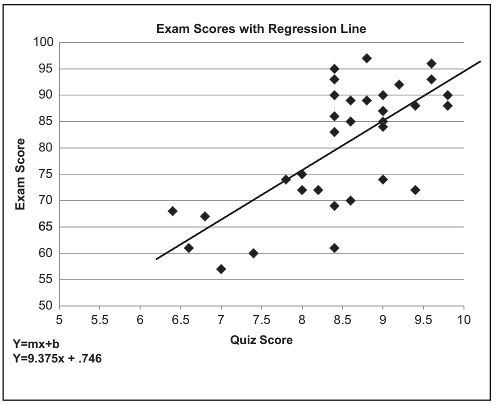

Figure 2. Scatterplot of exam scores and quiz scores PowerPoint slide

THE EXERCISE

This classroom activity uses the students' own quiz and exam scores to achieve the following learning outcomes. First, the exercise introduces students to the interpretation of linear regression. Second, through brainstorming, it encourages students to think sociologically about themselves. Third, the exercise pushes students to think like methodologists, considering how a researcher might measure important social factors. Finally, it helps students develop a higher degree of empathy for research subjects by making them into the data points in the analysis. I describe my classroom procedure next.

Exam 1

I conduct this two-part exercise after each of the first two exams of the semester. Shortly after the first exam, I assemble the current quiz averages and exam scores, conduct a regression analysis, and construct PowerPoint slides similar to the ones presented in Figures 1 through 3.[1] In class, after returning the exams and reviewing problematic questions, I begin by displaying mean and median exam scores as well as the distribution of grades (see Figure 1). In doing so, I review basic descriptive statistics, with which nearly all students are familiar.

In the next slide, I present a simple scatterplot of quiz scores and exam performance with a fitted regression line (see Figure 2). I quickly review the simple algebraic formula on which regression depends: $y = mx + b$ where m is the slope (the rate of increase or decrease in the fitted line) and b is the y-intercept (the value of y when x is 0). In my own experience, these concepts are not terribly challenging to students. I then ask them what patterns they observe in the scatterplot, and generally, the students fairly quickly point out the obvious: Students who perform better on quizzes also perform better on exams.

Then, I move on to a regression table (Figure 3), where we assess the *magnitude* of the effect by learning about: (a) the unstandardized coefficient, (b) significance levels, and (c) the R^2. Instead of focusing on the arithmetic required to compute these statistics, I simply teach the students how to interpret them (for a review of the interpretation of regression, see Babbie 2010:449-58). In Figure 3, for example, I explain that for every 10 percent increase in quiz average (or one more question correct per time on the quizzes), there is an almost 10 percentage point (9.37 percent) increase in exam score. I tell the students that the significant level ($p < .001$) indicates that our finding has a less than .1 percent chance of occurring just by chance (to be more precise, it has a 99.9 percent chance of the true value of the coefficient falling within the 95 percent confidence interval).[2] Finally, I point out the R^2, explaining that it refers to the percentage of the variation in exam scores explained by quiz scores.

I assess comprehension in two ways. I ask the students a number of questions about the regression table (e.g., What number could we look at in order to figure out how big the effect is?). I then

Regression of Exam 1 Performance on Quiz Scores

Predictor	Unstandardized B	Standardized Beta
Quiz Average	9.375 ***	.699
Constant	.764	-

R^2 =.489

Significance level: *** p<.001

Figure 3. Exam 1 regression PowerPoint slide

ask the students to plug in their own quiz average (or best guess of it), compute what exam score the model would predict, and then compare it to their actual score (i.e., compute their own residual). I circulate through the room to see that students are successfully computing their predicted values and help those who are confused.

Having established that the students understand how to interpret both the direction and magnitude of the effect, I ask what might explain the correlation between quiz scores and exam performance. Typical answers include preparation ("students who study for class every day do well"), test-taking aptitude ("some people just do better than others on tests"), confidence ("if you're doing better in the course, it might improve your confidence"), and so on. After allowing some discussion, I remind the students that regression only allows us to establish a correlation, not causation, and emphasize that their interpretations of the link between quiz average and exam score remain untested theories in the absence of variables that specifically measure class preparation, test-taking ability, or confidence.

We then brainstorm other variables that might be important in predicting exam performance. To stimulate the conversation, I usually ask the students, "If you did much better or worse than the model predicted, what might explain that? What isn't the model taking into account?" As their peers respond to this prompt, explaining how and why their scores differed from what the model predicts, students begin to see that the aggregate pattern does not apply to everyone (thus, undermining the "ecological fallacy"). Reflecting on their own experiences, students are usually able to think of a wide range of potential independent variables, usually including the amount of studying a student did for the exam, whether the student was part of a study group, whether the student is having difficulties in his or her personal life, and so on. Sometimes, a more enterprising student will suggest that there might be class, race, or gender differences in exam performance. While noting such differences is an essential part of the course, suggesting that inequalities might exist among *themselves* (e.g., having had fewer educational resources due to class or race) can create a significant debate within the class. For instance, during one session, a male student suggested that "girls try harder," leading to a discussion of whether male privilege allows men to get worse grades without fear of negative career consequences. In this way, the exercise has the capacity to make sociological concepts less abstract to students. As the class brainstorms potential unmeasured variables, I help them to clarify how each variable could be measured (e.g., number of hours of studying in the week prior to the exam, collected via survey). Finally, we discuss the shortcomings of the quantitative method of understanding exam performance as opposed to a qualitative method.

Exam 2

After the second exam, I repeat much of the exercise with a few additions. Prior to the exam, I run a regression analysis using quiz average and exam 1 score to predict exam 2 performance. In class, I begin by presenting the grade distribution and scatterplot, before turning to the regression and asking the students to remind me what the constant (y-intercept), unstandardized coefficients, significance levels, and R^2 are. Then, I explain that this time, I am using both quiz score and exam 1 performance as predictors (see Figure 4).

In addition to reinforcement, in this round of the exercise, I demonstrate how controls function in multivariate regression and introduce the standardized beta. By this point in the semester, they have already learned about control variables, but I repeat earlier lessons by explaining that regression allows us to examine the independent effect of each by holding the other variable constant. Once again, I have the students compute their own predicted score and compare it to their actual score. I

Regression of Exam 2 Performance

Predictor	Unstandardized B	Standardized Beta
Quiz Average	5.148*	0.377
Exam 1	.357*	0.375
Constant	5.009	-

R^2 =.461
Significance level: * p<.05

Figure 4. Exam 2 regression PowerPoint slide

ask them why we might want to see the independent effect rather than simple correlations to encourage them to consider intercorrelation among the three variables. I also introduce the standardized beta as a statistic useful in comparing the relative magnitude of each independent variable's effect (here, quiz score is nearly always the stronger predictor).

After introducing these concepts, I lead the students in a discussion of how we ought to interpret the findings. Typically, several students conclude that the findings suggest that even controlling for a "good test-taker" effect (as measured by exam 1 performance), students who come to class prepared each day (as measured by quiz average) perform better. I attempt to challenge the assumptions in that assessment and ask about what kinds of independent variables we would need to be more convincing in that claim.

OUTCOMES

While no single classroom exercise can breach all the barriers to enhancing the quantitative literacy of sociology students, it is important to take every opportunity to promote new learning. Because I employ a variety of tactics in my introductory courses to teach many of the same skills introduced in this exercise, it would be difficult to conduct any meaningful assessment that would isolate long-term lasting effects of this single activity. Though this classroom activity can serve as an introduction or to reinforce existing quantitative skills, ultimately, like any exercise, it must act as a complement to a broader curriculum. That said, in my own experience, this exercise has achieved several key goals.

As a means of introducing the basics of ordinary least squares regression, I believe the exercise has been quite successful. On the final exam for the course, I have included several different questions that assess students' ability to correctly identify what kind of information the unstandardized coefficients, standardized beta, and R^2 provide. Consistently, three-quarters or greater of the students correctly answer these questions. Anecdotally, I find that using this two-part exercise substantially increases the students' understanding of articles that employ regression that we read later in the course. Additionally, in my interactions with the small number of students who subsequently self-select into my upper-level courses, I have observed a higher degree of comprehension when we first encounter regression analyses.

As has been noted by several scholars, students tend to understand concepts better when they are able to relate it to their own lives (Burdette and McLoughlin 2010; Renzulli 2000). Because the exercise draws on their own quiz and exam scores, it strengthens the students' understanding in a few ways. First, because the exercise focuses on their grades and analyzes why some students perform better than others, most of the students pay closer attention than they otherwise would, perhaps hoping to pick up easy tips to get a higher grade. More importantly, when I ask them to brainstorm other possible variables, they can hypothesize with genuine knowledge since they are talking about themselves. For this reason, a student might know, for example, that he or she got a lower exam score because the student was up late partying the night before. Therefore, the student might suggest adding a "partying the night before" variable. The students may not be initially conscious of how their race, class, or gender may affect their exam performance. However, through the brainstorming process, students begin to reflect sociologically on themselves and think like a methodologist about how best to measure those social factors.

By using their own data, the exercise forces students to treat themselves like research subjects. The students often remark on how "weird" or "creepy" it is that there are structural factors shaping their exam performance occurring below their conscious awareness (e.g., a gender effect). Though we discuss how social contexts affect individuals every day in the classroom, topics like educational disadvantage of inner-city youth may be too distant for my students at Concordia College to realize that they, too, are social creatures. At times, some students balk at the idea that any patterns might apply to them (and, perhaps, they are the outliers). In this regard, the students are not alone. Many people react poorly to being told their lives are patterned because it seems to reduce their own free will. Being treated as "cases" in a data set in this way encourages the students to remember that respondents in data sets are also individuals with their own sense of free will.

Implementation

Students enter sociology courses with profound differences in their abilities in critical thinking, writing, and quantitative literacy. However, in the same way as instructors mentor students with even the most rudimentary skills in writing to produce more lucid prose, it is important to encourage the development of quantitative literacy even (perhaps, especially) among students with limited backgrounds in mathematics. Though the students I teach are relatively privileged, this exercise, with some modifications, could be used in many sociology classrooms.

The analysis of regression results requires math that is typically introduced in late middle school or early high school. In California, for example, it is a required part of the eighth-grade math standards (Common Core State Standards Initiative 2010). Nonetheless, many students (mine included) need a review of graphing and linear equations.

For instructors whose students seem anxious or confused by regression, it may be useful to spend extra time examining a scatterplot of the results (see the example in Figure 2). Begin by identifying the x and y axes (quiz average and exam score, respectively) and pointing out some specific data points (e.g., "This person has a quiz average of 8.5 and got an 80 percent on the exam"). One possibility would be to ask the students to locate mentally their data point on the scatterplot. Then, introduce the concept of fitting a line to the data to best represent the relationship between quiz average and exam score. Review or introduce the terms *slope* ("rise over run") and *y-intercept* ("where the line meets the left axis") and write out the formula as "Predicted Exam Score = Slope × Quiz Score + Y-Intercept." Assess comprehension by asking the students to figure out how much we would expect the exam score to increase based on a one-point increase in quiz average. If this material seems new to most students in the class, instructors also could consider saving the actual regression outputs until a later exam and simply focusing on the scatterplot in the first phase.

This activity could also be modified for use in upper-level or substantive courses. In an upper-level class where students have some experience with statistical analysis software, I might construct the data set and assign the students to analyze it. In such a situation, one possibility would be to ask a few survey questions (e.g., measuring number of hours studied) and include them as potential independent variables in the data set.

Limitations

The exercise described previously uses a portion of a couple of class sessions over the course of the one semester and should not be expected to educate thoroughly the students in the use of regression. It does not teach them how to compute the statistics, nor does it give them the skills to run a regression analysis using statistical software package. It is intended merely to introduce them to the concept of regression and provide them with the basic skills necessary to interpret regression results. It should be used to augment an existing curriculum in quantitative sociology.

This activity also does not address any sociological issues of great public interest like poverty, gender inequality, or the corporatization of mass media. Its immediate relevancy to the students stems in part from the drastic localism of its scope. For some instructors, the exercise may seem more like a mathematical detour than a direct pathway to sociological learning. With adequate discussion of potential variables of sociological interest, however, it is possible to tie this activity into larger social issues like gender or racial divides in academic performance.

Still, this exercise may not match every instructor's course goals. In my own introductory courses, I aim to maximize critical thinking, writing, and scientific literacy skills through discussions, several formal writing projects, as well as both qualitative and quantitative data collection and analysis assignments. This approach comes at the cost of conveying more sociological knowledge including theory and theorists' names, specific jargon, coverage of all subfields, and so on. Other instructors might prize knowledge of the field or the further development of another skill over quantitative literacy. For these instructors, teaching regression may not serve their course goals and therefore would not be worth the portion of two course days that this exercise takes.

One risk of this exercise is the possibility of misleading the students. As previously mentioned, many students are inclined to believe that the results indicate that students who prepare for class every day perform better on the exam. This is an extremely convenient belief for the students to hold if it spurs them to prepare better for class. Unfortunately, this belief is built on faulty assumptions. It could well be that students with greater educational advantage prior to college do better on both quizzes and exams. Alternatively, a devious instructor could bias both the quizzes and the exams in the same direction. For students with physiological, psychological, or sociological barriers to exam performance, believing that their poor exam performance is due to inadequate efforts in preparing for class may dent their self-esteem. For this reason, it is important for the instructor to stress that the *meaning* of the results is not entirely clear and that we cannot adopt the "hard work" hypothesis without measuring a variety of other factors. Despite such reminders not to make assumptions, some students will continue to cling to their own interpretation of the correlation. Still, even with such imperfect comprehension, the exercise offers students a first step toward literacy with an important quantitative method.

CONCLUSION

Improving quantitative literacy is essential to both the employee and the citizen of the future. As the ASA has long recognized, sociology as a discipline is uniquely positioned to train students to be able to interpret the kind of statistical information necessary for many desirable occupations and increasingly common in mass media reports and public documents. The ability to be critical of statistical analysis depends on one's ability to interpret it independently.

As sociology instructors strive to improve students' quantitative literacy, it is essential that they be educated in current statistical methods. For nearly 30 years, regression analysis has been the basic method of analysis in quantitative sociology, and yet, it is typically introduced very late in students' college careers if at all. The exercise presented here offers one small way of introducing regression analysis early in the course sequence in a manner that is highly relevant to students' own lives. Like the acquisition of any foreign language, the key to helping students develop fluency in quantitative analysis is to plan many small but frequent opportunities to encounter and interpret data.

APPENDIX

Table A1. Descriptive Statistics from Introductory Sociology Assignments

	Mean	Median	Standard Deviation	Minimum	Maximum
Quiz average	80.1	81.3	10.6	30.5	100
Exam 1	84.8	86.5	10.7	50	100
Exam 2	84.7	86	11.7	0	100

Notes: n = 339, 10 sections, all scores presented as percentages.

(continued)

APPENDIX (continued)

Table A2. Regression of Exam 1 Performance on Quiz Score

	Unstandardized Coefficient	Standardized Beta
Constant	47.038	
Quiz	.472***	.468

Notes: On regressions: Models using clustering to adjust the standard errors for the nonindependence of students within the 10 sections produced no differences in significance levels.
R^2 = .219. *** $p < .001$.

Table A3. Regression of Exam 2 Performance on Quiz and Exam 1 Scores

	Model 1	Model 2
Constant	32.791***	15.54***
Quiz	.648 (.588)***	.475 (.431)***
Exam 1		.367 (.335)***
R^2	.346	.434

Notes: Standardized beta in parentheses. On regressions: Models using clustering to adjust the standard errors for the nonindependence of students within the 10 sections produced no differences in significance levels.
***$p < .001$.

NOTES

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1. The PowerPoint slides in Figures 1 through 4 were produced for a recent section of my introductory sociology course. Though great variability in exam performance is typical in introductory courses, this section's first exam scores were lower and more variable than most sections (mean of 80.3 and standard deviation of 11.7 as compared to 84.8 and 10.7 in all sections). With such a small number of cases, most course sections do not fall into a perfectly normal distribution.
2. In fact, given that the exam scores constitute a population rather than just a sample, the significance level has little meaning since the coefficients are not estimates. For the purposes of this exercise, I treat the data set as a sample from the larger population of all sociology exam scores in order to introduce the concept of statistical significance.

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BIO

Andrew M. Lindner is an assistant professor at Concordia College (Moorhead, MN). He teaches Introductory Sociology, Media & Society, Political Sociology, and a course on attitudinal survey research. His research interests include mass media, political sociology, and sociology of culture.