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Patricia J. Brooks, C. Donnan Gravelle, Nicole M. Zapparrata, Elizabeth S. Che, Arshia K. Lodhi, Raoul Roberts, and Jessica E. Brodsky

Department of Psychology, The College of Staten Island, City University of New York

Psychology and Educational Psychology Programs, City University of New York Graduate Center

The American Psychological Association Guidelines for the Psychology Major emphasize the development of scientific inquiry and critical thinking skills. We present findings from a department-wide effort to promote statistical literacy in introductory psychology at a nonselective public college. We examined course outcomes across 10 course sections taught in person or online with varying enrollments (total $N = 485$ students). Instructors administered online assignments about psychological research via Qualtrics, featuring statistics exercises and Excel worksheet activities. As a low-stakes introduction to statistical reasoning, instructors graded work based on completion rather than accuracy. Students completed the majority of Qualtrics assignments and about half of the Excel worksheets. As potential factors related to student outcomes, we considered external factors, internal factors, and student skills, and included demographic factors as control variables. Students with greater work obligations and those who completed work on smartphones or tablets (external factors) completed fewer assignments than their peers. Students with higher self-efficacy and greater anxiety about statistics (internal factors) completed more Qualtrics assignments, and those with higher statistics knowledge and reading comprehension (student skills) completed more Excel worksheets. Course section characteristics (modality, enrollment) were unrelated to student outcomes. The results demonstrate the feasibility of using low-stakes assignments to promote statistical literacy while emphasizing psychology as an empirical science. Future studies should assess learning gains associated with the curriculum and identify specific pedagogical features (e.g., feedback, active learning) that increase student engagement.

Keywords: statistical literacy, introductory psychology, low-stakes assignments, active learning, data analysis

Patricia J. Brooks https://orcid.org/0000-0001-8030-8811

C. Donnan Gravelle https://orcid.org/0000-0003-2419-894X

Nicole M. Zapparrata https://orcid.org/0000-0002-0319-0431

Elizabeth S. Che https://orcid.org/0000-0003-3242-7458

Arshia K. Lodhi https://orcid.org/0000-0002-5068-8603

Raoul Roberts https://orcid.org/0000-0003-1884-7958

Jessica E. Brodsky https://orcid.org/0000-0001-9654-6806

Jessica E. Brodsky is now at the Department of Academic Affairs, American Association of Veterinary Medical Colleges.

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Correspondence concerning this article should be addressed to Patricia J. Brooks, Department of Psychology, The College of Staten Island, City University of New York, 2800 Victory Boulevard, Staten Island, NY 10314, United States. Email: Patricia.Brooks@csi.cuny.edu

The American Psychological Association (APA) emphasizes scientific inquiry and critical thinking as the second broad goal for the undergraduate major (American Psychological Association, 2023). This broad goal encompasses statistical literacy (also called quantitative reasoning), defined as the ability to understand and draw inferences from statistics and data. Quantitative reasoning has long been recognized as critical for general education and seems to fit naturally within the introductory psychology curriculum (Lutsky, 2006). Yet, in a recent national survey (Richmond et al., 2021), introductory psychology instructors reported that "getting students to think critically" was moderately to very challenging and rated it third highest in a list of teaching challenges. Further, when asked about the frequency of incorporating career skills into introductory psychology, only 36.8% of instructors reported that they directly taught analytical thinking skills, and only 3.1% reported direct teaching of hardware/software skills advantageous for data analysis and manipulation. Recognizing the need to support introductory psychology instructors in teaching quantitative reasoning, the Society for the Teaching of Psychology (STP) organized a Presidential Task Force on Introductory Psychology Statistical Literacy and published guidelines for the introductory psychology course (Neufeld et al., 2022).

Given the sheer volume of material taught in introductory psychology (Richmond et al., 2021), why add statistics instruction into the mix? Let us first consider the nonmajors taking the course. Hundreds of thousands of students take introductory psychology for general education credit every year (Gurung et al., 2016), and many do not take any additional psychology courses in their college careers (Frantz, 2020). For these students, the introductory course may be their only exposure to psychology as an academic discipline. Moreover, students enrolled in psychology coursework may lack awareness of the role of statistics in psychology (Ruggeri et al., 2008). Teaching statistical literacy in introductory psychology serves to reinforce the key idea or "integrative theme" that psychological science relies on empirical evidence and adapts as new findings emerge (American Psychological Association Introductory Psychology Initiative, n.d.; Gurung et al., 2016).

For undergraduates majoring in psychology, the APA guidelines list foundational and baccalaureate indicators for each broad goal (APA, 2023), with the recognition that students need practice to develop these competencies. For scientific literacy and critical thinking (Goal 2), the foundational indicators appropriate for introductory psychology include, for example, "Describe the value of and/or calculate basic descriptive and inferential statistics" and "Explain findings presented in data visualizations" (APA, 2023). The skills provide the requisite starting point for success in upper-level courses like psychological statistics and experimental psychology. Many students enter college with weak conceptual knowledge and skills in mathematics (Carpenter & Kirk, 2017) and high anxiety toward the subject (Foley et al., 2017), which places them at risk of failing required statistics courses (Ferrandino, 2016; Rabin et al., 2021). Exposing students to basic statistical concepts and data analytic procedures via low-stakes assignments in introductory psychology may help to prepare them for subsequent high-stakes statistics coursework.

In this article, we describe efforts to embed statistical literacy in introductory psychology at a nonselective public college and the results of outcomes assessment of student engagement with the curriculum. As part of a departmental endeavor to revamp the introductory psychology course in accordance with the APA guidelines, a team of instructors used Qualtrics survey software to construct online assignments about psychological research. The Qualtrics assignments included statistics exercises from the *STP Statistical Literacy, Reasoning, and Thinking: Guidelines 2.0* for introductory psychology (Neufeld et al., 2022), content acquisition podcasts (CAPs; Kennedy et al., 2016) explaining statistical concepts (e.g., correlations), scientific abstracts, technology, entertainment, and design talks, and other features to engage students with psychological research. Building on prior work using video tutorials to teach students how to use statistical software (Breneiser et al., 2018; Lloyd & Robertson, 2012), over half of the assignments included Excel worksheet activities, with step-by-step instructions (provided via CAPs) on how to use Microsoft Excel to manipulate, analyze, and visualize data sets. We chose Excel for our curriculum because students had access to a university subscription (paid with student technology fees) and could download Microsoft 365 free of charge to any of their devices.

We graded the low-stakes assignments on the basis of completion rather than correct answers,

with feedback provided through Qualtrics. Our goal was to familiarize students with statistical concepts and data analytic procedures while minimizing potential math anxiety. Student completion of low-stakes assignments has been linked to reduced anxiety, increased engagement with material, and higher performance on tests and other assessments (e.g., Malespina & Singh, 2022; Modiano & Bonanome, 2019; Sotola & Crede, 2021). In the present study, students completed the online assignments asynchronously (i.e., outside of class time) on computers or other internet-enabled devices. Instructors administered the same assignments across sections taught in person or synchronously online via Zoom.

Variability in Student Learning Outcomes

In assessing the course curriculum, we utilized the composite persistence model (Rovai, 2003) as a framework for understanding factors associated with variation in learning outcomes. Rovai's model builds on prior work (e.g., Bean & Metzner, 1985; Cabrera et al., 1992) aimed at understanding why some students show higher persistence (i.e., lower attrition) in completing higher education programs than others. While Rovai (2003) developed the composite persistence model in the context of online distance learning programs, its relevance extends to blended (i.e., web-enhanced) courses with online course components (e.g., asynchronous assignments), like our introductory psychology course. Under the composite persistence model, myriad factors associated with student persistence in college-level coursework include student characteristics (i.e., demographics), external factors (e.g., work and family obligations, access to computers and software), internal factors (e.g., self-efficacy, anxiety), and student skills (e.g., academic abilities, time-management skills).

With regard to demographics, in a recent report assessing learning outcomes across multiple semesters of an undergraduate psychology statistics course ($N = 460$), non-White students exhibited lower exam grades when compared to their White peers (Rabin et al., 2021). This finding held after controlling for basic mathematics skills, which also predicted statistics exam grades. Such findings resonate with wider concerns about the quality of math education at minority-serving public high schools (Hemphill et al., 2015) and a New York State report that White high school students enroll in advanced mathematics courses at much higher rates than non-White students (New York Equity Coalition, 2018). In the United States and elsewhere, race/ethnicity and socioeconomic status are interrelated variables (Williams, 1996). Socioeconomic status is an external factor encompassing family income, parental education, food and housing security, and the like. Members of marginalized and minoritized race/ethnicity groups face increased risk of experiencing poverty, food and housing insecurity, low educational attainment, inadequate health care, and psychological distress (American Psychological Association, 2017).

Given associations between demographics and external factors like socioeconomic status, we included race/ethnicity and other demographic variables as control variables in our analysis of course outcomes, even though these variables were not the main focus of this report. Based on prior work, other demographic variables considered were age (traditional vs. nontraditional; Gravelle et al., 2023), gender (male vs. nonmale; Gravelle et al., 2022), parental education (first-generation status vs. not; Stephens et al., 2012), and native language (English vs. non-English; Soria & Stebleton, 2013).

With regard to external factors, we focused on work obligations and the use of mobile devices for coursework as factors contributing to learning outcomes. The majority of students attending community colleges and other nonselective schools work part-time or full-time while attending classes (Perna, 2010). Extensive work obligations may place these students at academic risk (Porchea et al., 2010). In addition, students at community colleges often rely on mobile devices, as opposed to computers, for coursework but may struggle to complete assignments on these devices (Rockey et al., 2023). In a previous study, students who reported using a smartphone or tablet to complete their first assignment in an online introductory psychology course submitted fewer assignments overall than those using computers (Gravelle et al., 2022).

Regarding internal factors, students' perceptions of their academic capabilities and self-efficacy have been linked with success in online coursework (Gravelle et al., 2023; Gurung & Stone, 2023). However, several studies suggest

that self-efficacy may not be predictive of performance in psychology statistics courses (Rabin et al., 2021; E. R. Walker & Brakke, 2017). A more relevant factor may be students' math anxiety and negative feelings about doing math or statistics, both of which may decrease students' motivation to complete assignments involving statistical concepts and data analysis (Chang & Beilock, 2016; Foley et al., 2017). Shifting to student skills, prior work suggests that reading comprehension plays a critical role in coursework (Altman et al., 2022; Brodsky et al., 2021), yet many students enter community colleges and other nonselective institutions with weak literacy skills (Perin, 2013). Additionally, many students enter college with a weak understanding of statistical concepts (Cook & Fukawa-Connelly, 2016); this may also contribute to lower performance in psychology statistics courses (Rabin et al., 2021).

Research Aims and Hypotheses

As part of a departmental effort to promote statistical literacy in introductory psychology, we conducted course outcomes assessment to identify factors associated with rates of completion of (a) Qualtrics assignments and (b) Excel worksheet activities on data visualization and analysis. Due to the need to follow step-by-step instructions and manipulate data, we anticipated that the Excel worksheet activities would be more demanding of students' time and effort than other aspects of the Qualtrics assignments (i.e., multiple-choice and short-answer prompts). Uncovering factors associated with student engagement with statistics instruction in introductory psychology may help instructors implement the curriculum at their institution. We based our hypotheses on Rovai's (2003) model of persistence in online coursework and hypothesized that external factors (i.e., work obligations, use of computers for completing assignments), internal factors (i.e., self-efficacy, statistics anxiety), and student skills (i.e., reading comprehension, statistical knowledge) would predict student outcomes. Based on prior research (Gravelle et al., 2022, 2023), we also expected to find associations between student outcomes and demographic factors (e.g., gender, age, race/ethnicity) and included relevant demographic factors in analyses.

Method

Data Source and Online Repository

We collected outcomes assessment data from Fall 2022 and Spring 2023 course sections of introductory psychology taught at a nonselective minority-serving public college in the Northeastern United States (Institutional Review Board classification: exempt). The college has an open-admissions policy and accepts 100% of applicants with a high school degree or its equivalent. Undergraduates may enroll in associate or bachelor's degree programs. Although there are some dormitories on campus, most students commute to college and hold jobs off-campus. About half of the student body consists of first-generation college students (i.e., neither parent attended college).

Following best practices for replicability, the course syllabus, Qualtrics assignments, and Excel worksheet activities are publicly available in an Open Science Framework (OSF) online repository (Brooks et al., 2024). For purposes of reproducing the analyses, the deidentified data file, *R markdown* files supporting the statistical analyses, and additional online material tables associated with this project are also available in the OSF repository.

Course Section and Student Characteristics

Data came from 10 course sections of introductory psychology that utilized statistics exercises from the *STP Statistical Literacy, Reasoning, and Thinking: Guidelines 2.0* (Neufeld et al., 2022). (Other course sections did not follow the revised curriculum and are not included.) Eight course sections had regular enrollments ($\leq$50 students, $M = 44.4$, $SD = 8.3$, range = 29–50), and two had large enrollments ($\leq$135 students, $M = 134.0$, $SD = 1.0$, range = 133–135). Seven course sections met in person (one large enrollment), and three sections met online via Zoom (one large enrollment).

Of the 608 students enrolled in the 10 sections, 75 students (12.3%) did not complete the first assignment containing the measures used in this report, and 48 other students (7.9%) withdrew from the course. We did not include the students who skipped the first assignment in the analytic

sample to avoid problems of missing data, though some of these students may have completed other assignments. Table 1 provides a demographic breakdown of the 485 students who comprised the analytic sample for this report (i.e., students who submitted the first assignment and completed the course). Given the diversity of the sample in terms of age ($M_{age} = 19.5$ years, $SD = 3.9$, range = 17–57), we dummy-coded the variable into two categories (traditional vs. nontraditional age) using guidelines from the National Center for Education Statistics (n.d.): 0 = traditional age (<25 years, $n = 456$), 1 = nontraditional age (≥25 years, $n = 29$). Students self-reported their race/ethnicity using nonmutually exclusive categories (see Table 1). We dummy-coded race/ethnicity variables as follows: 0 = nonmembership, 1 = membership.

Course Materials

All course sections followed a uniform syllabus with links to course materials posted to a learning management system. Given the broad survey of content in introductory psychology, not all materials and assignments focused on statistical literacy. Other materials and assignments included textbook modules from the Noba Project (Diener Education Foundation, 2020), multiple-choice quizzes and tests based on the Noba modules, a role-play activity on research misconduct at Tuskegee and at Willowbrook State School (Rose et al., 2022), and instructions, PowerPoint template, rubric, and worked example for student presentations on psychological disorders (Schwartz et al., 2017). We will not discuss these materials and assignments further in this report.

Qualtrics Assignments

The instructional team used Qualtrics survey software to create eight online assignments introducing students to psychology as an empirical science; see the OSF online repository for PDFs of each assignment and Qualtrics Survey Files for implementation (Brooks et al., 2024). Instructors administered the Qualtrics assignments biweekly over the course of the 15-week semester. Each assignment had content related to research methods and statistics. The first assignment contained a demographic questionnaire and additional measures described in the following sections.

The Qualtrics assignments featured Technology, Entertainment, and Design talks on psychological topics (e.g., M. Walker, 2019, on sleep, Alvoid, 2019, on microaggressions), instructions on how to locate research articles using the campus library website and Google Scholar, exercises in reading

Table 1
Student Demographics (N = 485)

Characteristic	Frequency (%)
Age	
Nontraditional ≥25 years	29 (6.0%)
Traditional <25 years	456 (94.0%)
Gender	
Female	293 (60.4%)
Male	183 (37.7%)
Another gender identity/prefer to self-describe	4 (0.8%)
Prefer not to respond	5 (1.0%)
Race/ethnicity (not mutually exclusive)	
White	207 (42.7%)
Latinx, Chicanx, Hispanic, or Spanish origin	111 (22.9%)
Black/African American	79 (16.3%)
Asian/Asian American	61 (12.6%)
Middle Eastern/North African	41 (8.5%)
American Indian/Alaska Native	4 (0.8%)
Native Hawaiian/other Pacific Islander	2 (0.4%)
Some other race	13 (2.7%)
Prefer not to say/unknown	18 (3.7%)
Either parent attended college (yes = 1)	257 (53.0%)
Native language (English = 1)	363 (74.8%)

and interpreting results from scientific abstracts and evaluating knowledge claims, and CAPs on statistical concepts (e.g., correlations, *t* tests). Five of the Qualtrics assignments included statistics story problems adapted from the *STP Statistical Literacy, Reasoning, and Thinking: Guidelines 2.0* (Neufeld et al., 2022). We converted the statistics story problems from open response to multiple choice to allow scalability; see Table 2 for an example in its original and adapted formats. Each statistics story problem linked to an article introducing the topic, followed by questions that required students to evaluate research claims and methodologies. Additional multiple-choice and short-answer questions probed aspects of statistical reasoning, such as different types of research claims, experimental and correlational design, independent and dependent variables, correlation coefficients, and limitations and generalizability of findings. After responding to a given prompt, students received the correct answer and explanation. Students received full or partial credit for completing each of the eight Qualtrics assignments, with no penalty for answering questions incorrectly. Students completed most of the Qualtrics assignments ($M = 6.6$, $SD = 2.0$, range = 1–8).

Excel Worksheet Activities

Five of the Qualtrics assignments provided links to Excel worksheet activities that required students to manipulate, analyze, and visualize psychology-related data sets. (Note that all students had university subscriptions to Microsoft Office 365 for completing these activities.) Each Excel worksheet activity featured one or more CAPs providing step-by-step video tutorials (e.g., how to generate graphs, create pivot tables to compare groups, and compute summary statistics using the data provided in the worksheet). Table 3 provides an example activity utilizing a data set adapted from the Emerging Adulthood Measured at Multiple Institutions–2 study (Grahe et al., 2018) and screenshots of completed work. In addition to embedding links within the Qualtrics assignments, we provided direct links to the Excel worksheets and CAPs on the learning management system so that students could complete the worksheet activities at a different time. Hence, it was possible for students to complete the Excel worksheets without completing the Qualtrics assignment and vice versa. Students uploaded their completed Excel worksheets to the learning

Table 2
Example of Statistics Story Problem for Sexuality and Gender Unit

Original STP open-response problem	Adapted multiple-choice problem
News article link: https://www.insidehighered.com/news/2021/10/26/lgbtq-students-face-sizable-mental-health-disparities *Prompt:* Do you think the claim the authors are making is fair based on the data you see? Explain your answer. Criteria (what constitutes success): 1. Students can identify that the data do suggest some large differences, but that the correlational design does not confirm causation by simply being in the LGBTQ+ community. 2. Students identify the importance of replication in confirming the findings. *Example response:* The study provides correlational data from one sample of students. While this provides some support for their claims, as the difference in percentages between LGBTQ+ and non-LGBTQ+ students appears to be large for some mental health-related concerns, the design was correlation. Other variables, besides just being a member of the LGBTQ+ community, may be driving the higher rates of mental health concerns. Replication would allow us to determine how reliable this difference is among other samples of high school and college students.	*Prompt:* Which of the following statements best describes the appropriateness of the claim the authors are making based on the data reported in the study? If you need to look at the article, here is the link: https://www.insidehighered.com/news/2021/10/26/lgbtq-students-face-sizable-mental-health-disparities 1. The study provided experimental data that support a statistically significant difference between LGBTQ+ and non-LGBTQ+ students. This strongly supports the author's claim. 2. The study provided correlational data from one sample of students. This supports some of their claims, as the difference in percentages between LGBTQ+ and non-LGBTQ+ students appears to be large for some mental health-related concerns. 3. There are no data presented to support the claim the author is making. *Feedback:* (correct answer is 2) Other variables, besides just being a member of the LGBTQ+ community, may be driving the higher rates of mental health concerns. Replication would allow us to determine how reliable this difference is among other samples of high school and college students.

Note. STP = Society for the Teaching of Psychology.

Table 3

Example of Excel Assignment for Developmental Psychology Unit

Component of the assignment
Statistical concepts and CAP links
Using independent samples *t* tests to compare groups on their attitudes toward risk avoidance behaviors as a marker of emerging adulthood, using a data set adapted from the EAMMI-2 (Grahe et al., 2018).
Part 1: Comparing male and female respondents using a *t* test (https://www.youtube.com/watch?v=iCG1li-6e3A)
Part 2: Comparing conservative and liberal respondents using a *t* test (https://www.youtube.com/watch?v=7HI_a_JMR8Q)
Screenshot of Excel worksheet with raw data and mean calculations

participantID	sex	political_view	risk_1	risk_2	risk_3	risk_4	average_risk avoidance
p3	female	conservative	4	4	1	4	3.25
p4	female	conservative	4	4	4	4	4
p5	female	conservative	4	4	3	4	3.75
p9	female	liberal	3	4	4	4	3.75
p11	female	liberal	3	1	4	4	3
p13	female	conservative	4	4	4	4	4
p14	female	liberal	4	4	4	4	4
p16	female	conservative	4	4	4	4	4
p17	female	conservative	4	4	4	4	4
p18	female	liberal	1	3	4	4	3
p19	female	conservative	4	4	1	4	3.25
p20	female	liberal	2	3	4	2	2.75
p21	female	liberal	2	4	4	4	3.5
p22	female	conservative	2	3	2	4	2.75
p25	female	conservative	4	4	4	NA	4

(*table continues*)

Table 3 (*continued*)

Component of the assignment
Screenshot of independent samples *t* test results

t-Test: Two-Sample Assuming Equal Variances

	Females	*Males*
Mean	3.197727273	3.086028192
Variance	0.405206897	0.42987288
Observations	1210	402
Pooled Variance	0.411350412	
Hypothesized Mean Difference	0	
df	1610	
t Stat	3.025288677	
P(T<=t) one-tail	0.001261649	
t Critical one-tail	1.645800616	
P(T<=t) two-tail	0.002523297	
t Critical two-tail	1.961438534	

t-Test: Two-Sample Assuming Equal Variances

	Conservatives	*Liberals*
Mean	3.28215513	3.088156484
Variance	0.381052363	0.421561119
Observations	679	933
Pooled Variance	0.404502152	
Hypothesized Mean Difference	0	
df	1610	
t Stat	6.046881671	
P(T<=t) one-tail	9.16055E-10	
t Critical one-tail	1.645800616	
P(T<=t) two-tail	1.83211E-09	
t Critical two-tail	1.961438534	

Note. CAP content acquisition podcast; EAMMI-2 Emerging Adulthood Measured at Multiple Institutions–2.

management system to receive credit. Grading was based on completion, with partial credit given for incomplete work. Students completed more than half of the Excel worksheets ($M = 2.8$, $SD = 2.0$, range = 0–5).

Additional Measures

Work Obligations

As part of the demographic questionnaire, we asked students to indicate their work obligations from a list of options. The students reported their work obligations as follows: 30.1% ($n = 146$) not working; 11.6% ($n = 57$) working <15 hr per week; 32.8% ($n = 159$) working 15–30 hr per week; 12.2% ($n = 59$) working more than 30 hr per week; 13.2% ($n = 64$) declined to respond. We dummy-coded the data to reflect reported work obligations of 15 or more hours per week (1 ≥ 15 hr per week, 44.9%, $n = 218$; 0 < 15 hr or declined to respond, 55.1%, $n = 267$).

Device Used

Students reported the device they used to complete the first Qualtrics assignment. The majority (89.3%, $n = 433$) reported using a desktop or laptop computer, while 10.7% ($n = 52$) reported using a tablet or smartphone.

Self-Efficacy Scale

We administered an adapted version of Shen et al.'s (2013) self-efficacy scale for online learning. In adapting the scale, we made minor changes in wording to ensure that the items were appropriate for students in both in-person and online course sections. The scale consisted of 15 items assessing students' confidence in their ability to complete coursework (e.g., *successfully complete all of the required activities*), use online technology relevant to the course (e.g., *submit assignments through Blackboard*), and interact with their instructor or peers (e.g., *inform my instructor when unexpected situations arise*). Students responded to each item using a 5-point Likert scale (1 = *not confident at all,* 5 = *completely confident*). We created composite scores by averaging across the 15 items ($M = 4.12$, $SD = 0.93$, $\alpha = .93$); see additional online material in Table S1 for item-level statistics.

Statistics Anxiety Scale

We assessed students' statistics anxiety using a six-item scale adapted from the Statistical Anxiety Rating Scale (Teman, 2013). The first three items asked students to rate their anxiety about completing statistics-related tasks (e.g., *interpreting the meaning of a table in a journal article*) using a 5-point Likert scale (1 = *not at all anxious*, 5 = *extremely anxious*). The second three items asked students to rate their agreement with stated attitudes toward statistics (e.g., *since I have never enjoyed math I do not see how I can enjoy statistics*) using a 5-point Likert scale (1 = *strongly disagree*, 5 = *strongly agree*). We created composite scores for statistics anxiety by averaging across the six items ($M = 2.52$, $SD = 0.82$, $\alpha = .84$); see additional online material in Table S2 for item-level statistics.

Reading Comprehension Test

Students read a passage from the New York State Regents High School Examination in English Language Arts (New York State Education Department, 2019) and answered six multiple-choice questions about the passage ($M = 70.5\%$ correct, $SD = 26.5$, range = 0%–100%; $\alpha = .63$; $\omega = .71$).

Statistical Knowledge Test

We constructed a 12-item formative statistical knowledge test using items adapted from practice tests for the Advanced Placement (AP) Statistics Exam (College Board, n.d.) and from the New York Times "What's Going On in This Graph" column (The Learning Network, 2021). Questions covered a wide range of basic statistical concepts, for example, calculating the mean and standard deviation of a data set, features of a normal distribution, and different types of *t* tests. We calculated scores by computing the percentage of questions answered correctly ($M = 56.5\%$ correct, $SD = 17.8$, range = 0%–100%; $\alpha = .48$; $\omega = .54$); see additional online material in Table S3 for item-level statistics.

Results

We used *RStudio* software for statistical analysis (RStudio Team, 2022). We conducted hierarchical linear modeling to examine external factors, internal factors, and student skills associated with rates of completing the Qualtrics assignments and Excel

worksheet activities (*lme4* package in R; Bates et al., 2014). We included a random intercept for course section in the models to account for the nesting of students within course sections (i.e., different groups of students taught by different instructors). We conducted preliminary analyses to determine which course-level and demographic variables to retain as control variables in the final models; see additional online material in Tables S4 and S5. Regarding course-level factors, neither enrollment (regular, large) nor format (in person, online) were related to rates of completion of Qualtrics assignments or Excel worksheets; we removed these variables from the final models. Regarding demographic factors, the following variables were unrelated to course outcomes and dropped from the final models: gender (1 = male), parental education (1 = either parent attended college), and native language (1 = English).

Additionally, as a check on collinearity, we examined correlations between the variables used to assess external factors, internal factors, and student skills. Additional online material Table S6 presents the correlation matrix (Bonferroni-adjusted $\alpha = .0033$). Reading comprehension had significant positive associations with self-efficacy, $r(483) = .16$, $p < .001$, and statistical knowledge, $r(483) = .41$, $p < .001$. Statistics anxiety had significant negative associations with self-efficacy, reading comprehension, and statistical knowledge, rs(483) ranged from −.19 to −.37, all ps < .001. No other correlations were significant.

The final models included external factors, internal factors, student skills, and demographic (control) variables as predictors of course outcomes. We present the results for the Qualtrics assignments in Table 4; note that the full model explained 17.4% of the variance in the number of Qualtrics assignments completed. Students who reported working 15 or more hours per week completed fewer assignments than their peers who worked less or not at all. Students who reported their race/ethnicity as Black/African American or Latinx also completed fewer assignments than their peers who did not identify as members of these race/ethnicity groups. Nontraditional college students (ages ≥25 years) completed more of the Qualtrics assignments than students of traditional age. In terms of internal factors, higher self-efficacy and higher statistics anxiety were associated with students completing more of the Qualtrics assignments. (We will aim to interpret the latter, unexpected finding in the discussion.) Neither of the student skills variables (reading comprehension, statistical knowledge) predicted rates of completing Qualtrics assignments. Using a desktop or laptop computer to complete the first assignment was marginally associated with completing more assignments.

We present the results for the Excel worksheet activities in Table 5; the full model explained 34.5% of the variance in the number of Excel worksheets completed. Students with greater work obligations completed fewer Excel worksheets than their peers, as did students who

Table 4
Hierarchical Linear Model Predicting Rates of Completion of Qualtrics Assignments (N = 485)

Variable	β	*SE*	*t*	*p*
Intercept	3.52	0.84	4.20	<.001
Student demographics (control)				
Age (≥25 years = 1)	0.79	0.35	2.26	.024
Race/ethnicity (African American/Black = 1)	–0.76	0.23	–3.35	<.001
Race/ethnicity (Latinx = 1)	–0.69	0.20	–3.54	<.001
External factors				
Work obligations (≥15 hr per week = 1)	–0.54	0.17	–3.21	.001
Device used (computer = 1)	0.51	0.26	1.94	.053
Internal factors				
Self-Efficacy Scale	0.49	0.14	3.41	<.001
Statistics Anxiety Scale	0.24	0.11	2.15	.032
Student skills				
Reading comprehension test	0.51	0.34	1.50	.135
Statistical knowledge test	0.36	0.51	0.72	.474

Note. Intraclass correlation = .116; Conditional $R^2 = .174$. *SE* = standard error.

Table 5
Hierarchical Linear Model Predicting Rates of Completion of Excel Worksheets (N = 485)

Variable	β	*SE*	*t*	*p*
Intercept	0.13	0.87	0.15	.883
Student demographics (control variables)				
Age (≥25 years = 1)	1.08	0.34	3.16	.002
Race/ethnicity (African American/Black = 1)	–0.36	0.22	–1.60	.110
Race/ethnicity (Latinx = 1)	–0.54	0.19	–2.83	.005
External factors				
Work obligations (≥15 hr per week = 1)	–0.36	0.16	–2.20	.028
Device used (computer = 1)	0.73	0.26	2.84	.005
Internal factors				
Self-Efficacy Scale	0.16	0.14	1.14	.256
Statistics Anxiety Scale	0.05	0.11	0.49	.624
Student skills				
Reading comprehension test	1.21	0.33	3.61	<.001
Statistical knowledge test	1.03	0.50	2.08	.038

Note. Intraclass correlation = .301; Conditional R^2 = .345. *SE* = standard error.

reported their ethnicity as Latinx. Nontraditionally aged students completed more Excel worksheets than their younger counterparts. Students who reported using a computer (laptop or desktop) on the first assignment completed more Excel worksheets than students who reported using other devices (tablets or smartphones). In terms of student skills, both reading comprehension and statistical knowledge were associated with higher rates of Excel worksheet completion. In contrast, neither of the internal factors (self-efficacy and statistics anxiety) predicted rates of completing the Excel worksheets.

Discussion

This article reports findings from a departmental effort to promote statistical literacy in introductory psychology via low-stakes online assignments, developed by a team of instructors using Qualtrics survey software. The Qualtrics assignments introduced students to empirical research related to psychology topics covered in textbook modules (Diener Education Foundation, 2020), including mental health, microaggressions, sleep habits, and emerging adulthood. Students completed the majority of the Qualtrics assignments (M = 83.1%) and over half of the Excel worksheet activities (56.5%) requiring manipulation, visualization, and analysis of data sets.

Factors Associated With Coursework Completion

In accordance with the composite persistence framework (Rovai, 2003), we examined potential factors associated with completing the Qualtrics assignments and Excel worksheet activities. External (work obligations) and internal factors (self-efficacy, statistics anxiety), but not student skills (reading comprehension, statistical knowledge), were associated with rates of completing the Qualtrics assignments containing multiple-choice and short-answer questions about psychological research. For the more demanding Excel worksheet activities that required hands-on manipulation of data sets, external factors (work obligations, device used) and student skills (reading comprehension, statistical knowledge), but not internal factors, were associated with work completion. We discuss these findings in turn.

With regard to work obligations, 45% of the students reported working 15 or more hours per week, which is in line with national trends for college student employment (National Center for Education Statistics, 2022), with the highest rates of employment observed among low-income community college students (Perna, 2010). College students with extensive work obligations face competing priorities (e.g., wages vs. grades) and may make do by skipping assignments, as we observed here. Having to juggle college coursework

with work responsibilities increases students' risk of dropping out and extends their time to degree (Behr & Theune, 2016; Bound et al., 2012). Considering tuition costs, efforts to increase access to scholarships and grants may help students to reduce their work commitments and devote more time and energy to their coursework (Broton et al., 2016).

With regard to the type of device used, 11% of students submitted the first Qualtrics assignment on a mobile device (tablet or smartphone). While the mobile interface was sufficiently flexible for completing the Qualtrics assignments, the Excel work was likely too demanding to complete on a small screen using the mobile app (Microsoft Excel Mobile). Indeed, the CAPs providing step-by-step instructions for the Excel worksheets were made for computers and may not have aligned well with the features of the mobile app. Thus, despite the potential for mobile devices to increase available spaces and times for students to complete college coursework, students who rely on these devices over computers may find it challenging to complete some assignments (Rockey et al., 2023).

The internal factors of self-efficacy and statistics anxiety had positive associations with rates of completing the Qualtrics assignments. The positive effect of self-efficacy is in keeping with other work linking self-efficacy with academic motivation and engagement (Azila-Gbettor et al., 2021; C. O. Walker et al., 2006). That is, students who are more confident about their academic abilities tend to show higher levels of engagement with their coursework. Counter to the hypothesis that math anxiety would interfere with learning (Skagerlund et al., 2019), students with higher statistics anxiety submitted more Qualtrics assignments than their peers with lower anxiety. However, given that most students gave low-to-mid-level ratings of statistics anxiety (M = 2.52; scale midpoint = 3), our findings fit with other work suggesting that midrange levels of statistics anxiety may benefit learning (Keeley et al., 2008). Additionally, one might argue that our use of low-stakes assignments graded on the basis of completion (rather than correctness) might mitigate negative effects of high statistics anxiety by providing students with a sense of control over their learning (Pekrun et al., 2017). This is in keeping with other research indicating benefits of low-stakes assignments in teaching statistics (Herman & Kerby-Helm, 2022; Modiano & Bonanome, 2019).

Both internal factors (self-efficacy and statistics anxiety) failed to predict student engagement with the more demanding Excel worksheet activities. Instead, student skills (reading comprehension and prior statistical knowledge) were associated with completion of the Excel worksheets. These positive associations align with other work linking reading and math abilities with college learning outcomes (Altman et al., 2022; Brodsky et al., 2021; Rabin et al., 2021). Given concerns about postpandemic declines in academic skills (Toness & Lurye, 2022), instructors may need to increase the level of student support provided for these activities. Additional support might include demonstrating Excel functions in class and troubleshooting difficulties, holding designated office hours to assist students with Excel work, or engaging teaching assistants (or peers) as tutors. Future research should examine whether different forms of support improve rates of completion of the Excel worksheet activities and students' grasp of the underlying statistical concepts (e.g., correlations, normal distribution).

Notably, the predictive effects of the external and internal factors and student skills held after controlling for demographic factors related to course outcomes. Moreover, the group-level differences in coursework completed remained statistically significant with external factors, internal factors, and student skills included in the model. Nontraditional students (≥25 years) completed more of the assignments than traditional-aged students. This finding aligns with a prior report indicating higher final grades and lower rates of course withdrawal for nontraditional students (Gravelle et al., 2023). Students who identified as Latinx and/or Black/African American completed fewer assignments than their peers who did not identify as members of these groups, also matching prior findings (Gravelle et al., 2022). Our analyses rule out a number of factors, from work obligations to self-efficacy to statistics knowledge, as explanations of the observed group differences and suggest that other factors are at play. Additional factors to be examined in future research include health and/or mental health concerns (Lopez et al., 2021; Saltzman et al., 2021), housing and food insecurity (Ilieva et al., 2019; Olfert et al., 2023), and family obligations (Nelson et al., 2013). Accounting for educational disparities is fraught with difficulties and may require a shift in perspective from individual-level to systemic factors (Chater & Loewenstein, 2023; Zengilowski et al., 2023).

Limitations and Future Directions

A major limitation of the present study is its focus on coursework completed. That is, we did not assess learning of specific statistical concepts and data analytic procedures. Therefore, we do not know the extent to which students gained new skills and understanding. In future iterations, researchers might ask students to report their prior experience using Excel and other spreadsheet software (e.g., Google Sheets) to gain a sense of students' existing knowledge and use performance-based assessments as pretest/posttest measures of learning.

We also do not know which specific pedagogical features (e.g., feedback, active learning) promoted student engagement with the curriculum in support of learning. As instructors of a general education course, our goal was to familiarize students with statistical concepts and data analysis as the foundation for psychological science without expecting students to demonstrate mastery. We implemented the curriculum following best practices, using self-paced exercises with feedback provided after each statistics problem, scientific abstract, and so forth (Wisniewski et al., 2020). For introducing statistical concepts and the Excel worksheet activities, we provided direct instruction via CAPs alongside hands-on active-learning exercises (Kennedy et al., 2016). In doing so, we extended prior work using CAPs to teach statistics in upper-level courses (Breneiser et al., 2018; Lloyd & Robertson, 2012) to introductory psychology, using software that students had personal access to via the university subscription. However, even with the step-by-step instructions provided by the CAPs, some students failed to complete any of the Excel worksheets, indicating the need for additional support.

Future research is also needed to determine whether curricular efforts to develop statistical literacy in introductory psychology improve learning outcomes in upper-level psychology courses (e.g., experimental psychology and psychology statistics) that rely heavily on data analysis and exhibit high failure rates (Carpenter & Kirk, 2017). Students' performance in statistics in upper-level courses may be more strongly associated with their beliefs at the time of the assessment than those held initially (Dempster & McCorry, 2009). Therefore, pedagogical efforts should focus on modifying students' initially negative attitudes about statistics (e.g., in courses like introductory psychology) while boosting their acquired competencies in statistics (Milic et al., 2016).

Conclusions

The revised APA Guidelines for the Psychology Major (APA, 2023) emphasize psychology as a science, technology, engineering, and mathematics field, with scientific inquiry, statistical reasoning, and data analysis at its foundation. Along these lines, we set out to foster statistical literacy in introductory psychology by engaging students in statistical reasoning and data manipulation, visualization, and analysis. Across online and in-person course sections taught at a nonselective college serving a diverse student body and varying in enrollment, students completed the Qualtrics assignments at similarly high rates and the Excel worksheets at similar, albeit lower, rates. In the present implementation, the Qualtrics assignments and accompanying Excel worksheets spanned diverse topics within psychology and dovetailed with the assigned textbook modules and quizzes. Thus, as a proof of concept, we demonstrated that it is feasible to foster statistical literacy in introductory psychology without sacrificing content coverage. Due to the asynchronous online format of the assignments, students completed the work largely outside of class time, leaving room for the instructors to focus on other aspects of the course during class hours. However, given students' lower rates of completing the more demanding Excel worksheets, in future semesters, instructors should devote more time to acclimating students to the software and providing instructional support.

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