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Overcoming the Bottlenecks in Teaching Psychological Statistics

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Abstract

Teaching and learning undergraduate statistics has been a most challenging task for undergraduate psychology majors (Salkind, 2017). A seasoned statistics instructor consulted with a seasoned instructional designer on a method to improve a particularly demanding course using a performance improvement approach to address learning difficulties she had noted in previous semesters. The Decoding the Disciplines methodology identified the most challenging concepts and provided a methodology to improve student learning performance. The methodology focused on five core concepts in psychological statistics: probability, variability, central limit theorem, independent/ dependent variables, and degrees of freedom. The Decoding the Disciplines curriculum was used for three semesters. In these three semesters, performance was compared pre and post on these concepts within the semester. Repeated measures t-tests found a significant change in the percentage of correct answers between the pretest and the final exam on the five core concepts.

Keywords

Decoding the Disciplines, Bottlenecks, Teaching of statistics, Teaching of psychology

Overcoming the Bottlenecks in Teaching Psychological Statistics

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Teaching and learning undergraduate statistics has been a most challenging task for undergraduate psychology majors (Salkind, 2017). A seasoned statistics instructor consulted with a seasoned instructional designer on a method to improve a particularly demanding course using a performance improvement approach to address learning difficulties she had noted in previous semesters. The Decoding the Disciplines methodology identified the most challenging concepts and provided a methodology to improve student learning performance. The methodology focused on five core concepts in psychological statistics: probability, variability, central limit theorem, independent/dependent variables, and degrees of freedom. The Decoding the Disciplines curriculum was used for three semesters. In these three semesters, performance was compared pre and post on these concepts within the semester. Repeated measures t-tests found a significant change in the percentage of correct answers between the pretest and the final exam on the five core concepts.

An educator and a psychology statistics instructor collaborated to focus on recurring difficulties in a psychological statistics course. Through the instructor's experience in teaching psychological statistics, she learned that there were a few key concepts that determined a student's long-term success (Stoa et al., 2022). These concepts are some of the central concepts in psychological research, and usually they are first introduced in the introduction to psychological statistics course. According to Chew and Dillon, "empirical evidence suggests that students in nonmathematical disciplines (e.g., social sciences) regard statistics courses as the most anxiety-inducing course in their degree programs" (2014, p. 196). Salkind further explains the trepidation students express about the class, "Statistics is difficult; the math involved is impossible, what do I need this stuff for? Students who study introductory statistics find themselves…thinking at least one [of these thoughts]" (2017, p. 5). We also found that students report a "stigma surrounding stats being so difficult." Instructors may balk at the idea of teaching this course as many instructors report anecdotally that they believe that the course leads to low student ratings which can impact instructors' careers. Yet, because this is a foundational course in the field of psychology, it cannot be avoided, and hence must be taught well with the core concepts understood.

In addition to addressing difficult concepts in the course, student attitudes toward the course needed to be addressed. Many psychology students aspire to help people and even become therapists, not statisticians (Harton & Lyons, 2003; Marrs, Barb, & Ruggiero, 2007). They enter the course uncomfortable with the abstract thinking of statistics, which forms the basis for answering scientific questions that guide therapy. The novice/expert difference in attitude between the students and the instructor creates a gulf of communication (Elliott & Janney, 2022). The expert instructor may have lost touch with how they learned statistics (Hsu, 2006). Instructors who recognize this challenge adopt different strategies to breach the novice/expert challenge such as peer teaching assistants, peer tutors, and group work. However, these approaches fail when students neglect to ask questions, because as novices, they do not know what questions to ask about something they truly know next to nothing about.

SoTL (Scholarship of Teaching and Learning) uses structured, research-based approaches to improving student learning. One of these approaches is Decoding the Disciplines, a methodology for getting students through learning difficulties, known as "bottlenecks." Decoding the Disciplines helps the instructor become aware of bottlenecks and provides a methodology for leading students through the bottleneck. "In decoding theory, the bottleneck is the result of miscommunication between teacher and student. It is the instructor who needs to figure out where he or she is speaking in tongues to students, decrypt the code in which he or she speaks, teach students what the code is, and help them navigate through the narrows," (pp. 40-41, Shopkow & Middendorf, 2019).

The Decoding the Disciplines approach to improving student learning and implementing change has been successful in other fields such as statistics (Norton, 2015), business statistics (Lemieux & Quiring, 2021), history (Shopkow, 2017), and law (Quintanilla, et al., 2019). In these examples, the research methodology included survey research (Quintanilla, et al., 2019) and case studies (Norton, 2015; Lemieux & Quiring, 2021; and Shopkow, 2017). Pinnow (2016) conducted a psychology study, and Lee-Post (2019) conducted a business study, both with a statistically significant difference when the Decoding the Disciplines approach was applied

There are many different study designs available to SoTL researchers. Some readers may prefer a controlled study methodology to show the usefulness of Decoding the Disciplines. Pinnow (2016) took this approach and found support for the usefulness of Decoding the Disciplines.

We chose a pre-post-test paradigm to capture quantitative data with the least amount of error due to individual differences. In agreement with this perspective, Nilson (2013) argues that the least flawed, and currently the gold standard in measuring classroom learning, is direct, pre- and post-tests. The complexities of learners and classroom learning make it difficult to consider hypotheses and practices when there are thousands of interactions going on while teaching (Weimer, 2018). We included open ended classroom assessment techniques to capture qualitative

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data for a richer explanation of results. We believe, as Hutchings found in her Carnegie Foundation Case Studies, "A mix of methods will tell you more than a single approach" (p. 2, Hutchings, 2000).

This study can be viewed from Pat Hutchings (2000) overall taxonomy of four questions that characterizes SoTL: Does it (the approach) work? What is it? What might happen if I tried something different? What might be a new conceptual framework for shaping thought about teaching and learning practice? While not all SoTL studies answer all of these questions, this study does have something to say about each of them. It uses quantitative and qualitative pre-and post-test items to answer, "Is it working? To answer the more descriptive question, "What is this/What does it look like?" question, we provide step by step details of the Decoding the Disciplines approach and the bottleneck lesson on variability for the introduction to psychological statistics course in this study. For the question, "What might be if I tried something different?" question we compared previous semesters where the first four weeks of class consisted of lectures on history, terminology, and guiding concepts prior to adopting the Decoding the Disciplines bottleneck lessons. Finally, and importantly because SoTL still is often more pragmatic than theoretical, this study considers Decoding the Disciplines theory as a conceptual framework to show how Decoding the Disciplines theory is being used to drive lesson design.

Decoding the Disciplines is a method for guiding students to learn unfamiliar ideas and difficult concepts. The theory explains how expert tacit knowledge of statistics (or any field) can be made into explicit mental moves that are more accessible for students. The theory uses a seven-step framework for identifying bottlenecks and suggesting the most effective way to enable students to overcome them [See Figure 1] (Middendorf & Shopkow, 2018). The first part of the theory identifies a learning difficulty, and the second part applies instructional strategies to help students overcome the difficulty (Shopkow & Middendorf, 2019). The Decoding the Disciplines methodology includes collecting

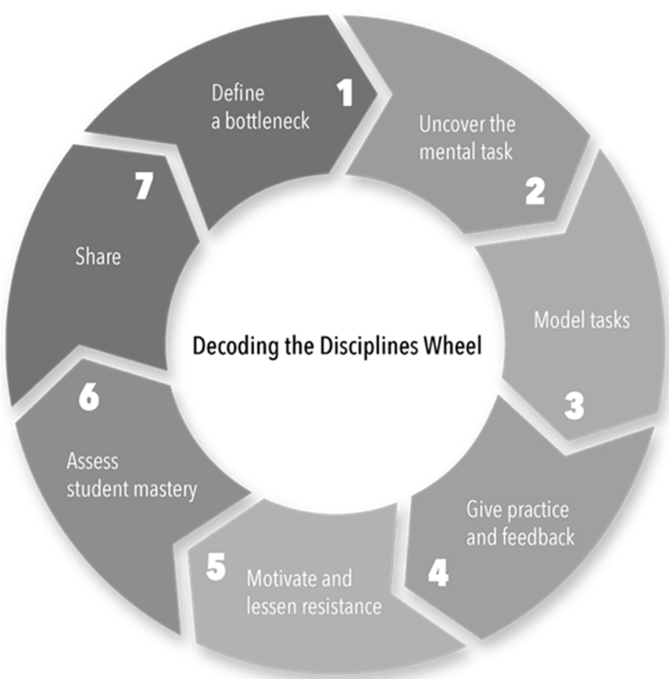

Figure 1. The Decoding the Disciplines process wheel

data to see if, in fact, learning improves. Decoding the Disciplines can be undertaken with an outside colleague individually or in a workshop setting. As the "black boxes" of the field are opened, striking differences in our ways of conducting our professional work will emerge, as will surprising similarities across radically different areas of academia.

Step 1 Identify Bottlenecks

Bottlenecks are the places where students, or novices, repeatedly struggle to learn. Examples of bottlenecks that many students struggle with are how to generate hypotheses in biology, when to realize their own biases in health, or how to visualize evolutionary processes across vast timescales in the geo-sciences. The bottleneck can be a small concept that might take 15 minutes to learn, or it might be a recurring difficulty that comes up again and again in the course. To identify a bottleneck, instructors are asked to notice at which points in the course students tend to struggle the most. Bottlenecks show the instructor where to focus their efforts in the course.

Step 2 Decode

Decoding the Disciplines uses an interdisciplinary approach to help the expert/instructor uncover their tacit knowledge, the critical reasoning that the expert uses to get through the bottleneck. The uncovering of expert tacit knowledge is called decoding. The uncovering takes place through an explicit interview or using mind maps, analogies, rubrics or other decoding processes (see Middendorf & Shopkow, 2018). The methodology involves a dialogue between a colleague from outside-the-discipline and the expert (instructor) from within-the-discipline. Once a bottleneck where students repeatedly struggle to learn has been identified, the question is, what does the expert do to get through the bottleneck? In dialogue, the outside colleague pursues the expert's mental process or "mental moves." The expert must be willing to break things down for the outside colleague for the methodology to be effective. The outside colleague must dig into what they do not understand and ask the expert to explain it, breaking down the expert's mental process in finer and finer detail, repeatedly asking, "How do you do that?" until the outside colleague can explain the mental move. The methodology is a rare chance to play in the sandbox of another colleague's discipline and discover hidden aspects of one's own disciplinary expertise. In the present study, we used analogies to uncover the implicit mental moves the expert uses in statistical analysis so that we could make them available to students. Analogies have been an effective way to bridge the gap between expert and novice (Elliott & Foltz, 2005). The mental move decoded in Step 2 drives further pedagogical choices for instructional strategies in Steps 3-6.

Step 3 Model

To show students the mental move, start with an analogy or metaphor to show exactly which "mental muscles" to use. Hofstadter (2007) describes analogy as the "interstate freeway" of the mind. Some fields (e.g., history, philosophy) prefer narratives as a way to introduce the mental moves. After introducing the mental move through analogy or narrative, the instructor presents an example of the mental move being used on the current disciplinary content, with examples being the typical way of teaching. As the instructor uses these examples, they focus on highlighting exactly where the mental move takes place so students can see the mental move in action/location.

Step 4 Practice

Students need to practice using new mental moves on disciplinary content. After all, with difficult bottlenecks they will not be able to just absorb the idea from watching a lecture but will require additional practice and strengthen new neural connections that make up the mental moves. This may take repeated practice at first, often broken into smaller steps, which is called "scaffolding," (Wood, Bruner, & Ross, 1976).

Step 5 Motivate

To encourage student persistence in the mental moves, the instructor decides which are the most difficult bottlenecks, or those with extra barriers and then consider how to build in motivation to keep students going by breaking down the difficulty into further parts, making it fun, making it social, lessening any threat, building in success, etc.

Step 6 Assess

Instructors check early and often that students can perform the mental move sufficiently, so that if they cannot, there can be remediation. An additional benefit of frequent learning assessments is the metacognition that prompts students to review what they have learned, providing further practice. Learning assessments often provide feedback to the instructor about where unaddressed bottlenecks remain and additional practice is needed.

Step 7 Share

Sharing involves going public with what we have learned from the study of these bottlenecks and decoding them to learn from each other and so that other instructors of psychological statistics do not have to reinvent the wheel. This article is an example of Step 7.

METHOD

The current study involved implementation of the Decoding the Disciplines methodology within an introductory psychological statistics undergraduate course. The authors hypothesized that applying the Decoding the Disciplines methodology would create a needed change in this course by improving student understanding of key concepts and changing students' attitude towards the course. They used Decoding the Disciplines to identify the most challenging concepts or bottlenecks because up to this point, they have not found these specific bottlenecks addressed in the literature.

Participants

The author/instructor teaches a required 200 level undergraduate introductory psychological statistics course. In a typical semester, there are about 20 students in their sophomore year (3rd or 4th semester) with a small portion of the students (approximately 10%) having unsuccessfully taken the course in a previous semester. The course is the first of four courses that students take to learn about psychological research methods and is required for their degree in psychology. The classes that contributed to the project had an average of 20 students. On average, two students late-drop the course each semester. Most of the students were psychology majors with a grade point average above a 3.0. The classes discussed in this article were taught in person. The prerequisite for this course is a 100-level introduction to psychology course, a college algebra course, and several 200 level psychology content courses such as introduction to developmental psychology, psychology of gender, or similar courses. Students must earn a C or better in these courses to take this course. Institutional review board approval was obtained.

Materials and Procedure

Students took a 41-item multiple choice pre-test during the first week of the class. These were the same questions that were on the final exam given each year. The questions focused on data analysis, analysis results, and the five bottleneck concepts: probability, variability, central limit theorem, independent/dependent variables, and degrees of freedom. Most students finished the untimed exam in 18 minutes.

In previous semesters, the instructor had introduced statistics in general to the students through the history, terminology and guiding concept lectures for the first four weeks. The decoding lessons replaced these lessons. Throughout the course, the instructor maintains the pattern of concept introduction, practice with the instructor, with a team, self/solo practice, and assessment. Previously, the instructor had used the first four weeks to discuss terminology and statistical reasoning. Then, the standard psychological statistics curriculum was taught: z-scores, t-tests, ANOVA, correlation, regression and chi-square. Students learn the assumptions of each test, when each test should be used, key formulas, and how to execute the test using the software program SPSS (IBM Corp., 2020). At the course's end, students take a cumulative final exam.

Implementing the Decoding the Disciplines process

To create the decoding exercises, the author/instructor of the psychological statistics course identified the concepts that students repeatedly struggled with throughout a psychological statistics course: probability, variability, central limit theorem, independent and dependent variables, and degrees of freedom. We developed five lessons with each focused on the instructor's mental moves, student practice, motivation, and assessment. This pedagogical approach follows Decoding the Disciplines theory and organizes the teaching and learning process for success. In the following paragraphs, we will provide the procedure for the variability lesson, as an example.

Step one: Identify the bottleneck

In the variability bottleneck, students struggle to see statistical significance in the data. This bottleneck includes other smaller bottlenecks such as; a) learning how variability can change the outcome, b) the numbers that represent variability within and between the scores of experimental treatments, and c) the numbers that represent them on different levels of the experiment. Understanding variability helps students learn how a test functions (i. e., t-test or ANOVA). This lesson focused on visualizing the variability patterns in the data.

Step two: Decode the mental move

The mental move is known as subitizing: An expert can instantly judge variability by visualizing the spaces between the numbers in the data sets. Are the spaces consistent? Close together? Far apart?

Step three: Model the mental move

We introduce the mental move with an analogy to music: The spaces between each number within and between the groups in a data set reveal the pattern like the combination of notes and spaces in music. There are two considerations: the distance between the numbers and the regularity, in other words, is it consistent or irregular? Is it like the steady beat of a marching band's drum, or is it improvisational like jazz? Is it a quarter note, or is it a sixteenth note? Is the former held longer and the latter held shorter? So too can the spaces between numbers in a data set can be visualized, such as between two sets of numbers: 5, 10, 15, 20, 25 and 3, 10, 11, 20, 34. Which group has greater variability? The first set of numbers is very predictable with the same variability throughout the group; the second set of numbers is not as predictable and has a wider range of variability. We can calculate a standard deviation of about 8 for the first set and 12 for the second set. By visualizing the spaces between and across the numbers in data sets, we can observe where the most variability occurs.

Next, we model the mental move by presenting a typical example: Students consider the amount of time per month spent on Facebook among different age groups. Looking at the data; 1 hr., 2 hrs., 6 hrs. for college students and 20 hrs., 22 hrs., 36 hrs. for their parents, is there variation in time spent on Facebook within each age group? Across the two age groups? We can calculate a standard deviation of about 3 hrs. for the first set and 9 hrs. for the second set and that tells us that the second set, the parents, are less alike each other when they view Facebook while the college students are more like each other, more uniform. Across the groups, there is more variability in how much time the parents spend on Facebook compared to the college students. If we add in the mean for both groups of 3 hrs. for the college students and 26 hrs. for the parents, we see that the college students don't use Facebook as much and as a group they are unified in this behavior. The parents seem to like Facebook much more than the college students, but some parents like to use Facebook much more than other parents. This example modeled how to visualize variability and compare the spacing within and between the sets; it was used in the instructor presentation part of the lesson.

Step four: Provide students practice

We provide number sets that students act out, making a human graph to emphasize the spacing in between numbers, holding up numbers and spreading out. How many spaces are in between? What do the spaces reveal about variability? After this in-class group work, students individually complete homework from simple data sets to more complicated ones, to actual experiments with results for which they must determine the variance.

Step five: Motivate students to persist

To motivate students and lessen math phobia, numbers over 100, formulas, fractions, and decimals were avoided in the lessons for the first six weeks of the course, so students could focus on the concepts instead of the math. Another motivation tactic: Students get to practice in class together to solidify their understanding before tackling problems individually.

Step six: Assess the mental move

Questions check to see if the student understood variability. These pretest and the posttest multiple choice questions could be graded easily, otherwise it would have been overwhelming as this was one of five bottlenecks we were working on in the course. These questions came from previous semesters or were from test banks provided by book publishers.

RESULTS

To establish empirically that Decoding the Disciplines improved student understanding of the five key bottleneck concepts and changing students' attitude towards the course we collected both quantitative and qualitative data. For the quantitative data, students selected the correct answer in two multiple choice exams before and after the lessons. To establish a change in students' attitude toward the course and inform additional information on student understanding, students responded to several classroom assessments. This is the qualitative data. First, we will discuss the quantitative exam results.

Table 1. **Comparing the change in the percentage of questions answered correctly between the pretest and the post test**

Semester	Bottleneck Category	t-test	Degrees of Freedom	Significance	Effect Size
Fall21	Central Limit	N/A	N/A	N/A	NA
Fall22	Central Limit	1.651	13	0.0613	.17
Spring23	Central Limit	3.441*	24	0.0011	.33
Fall21	Degrees of Freedom	4.136*	12	0.0007	.59
Fall22	Degrees of Freedom	1.555	16	0.0698	.13
Spring23	Degrees of Freedom	4.136*	20	0.0003	.46
Fall21	Independent/ Dependent Variables	4.347*	21	0.0001	.47
Fall22	Independent/ Dependent Variables	3.815*	39	0.0002	.27
Spring23	Independent/ Dependent Variables	6.347*	60	0.0000	.40
Fall21	Probability	4.291*	26	0.0001	.41
Fall22	Probability	4.682*	60	0.0000	.27
Spring23	Probability	6.668*	75	0.0000	.37
Fall21	Variability	5.308*	14	0.0001	.67
Fall22	Variability	4.652*	37	0.0000	.37
Spring23	Variability	9.562*	61	0.0000	.60

* denotes a significant finding

Quantitative Results

We segregated the number of correct answers on the pretest and post test questions by category on five core concepts (i. e., central limit, degrees of freedom, probability, variability and independent/dependent variables) and calculated the change in the percent of correct answers for each concept. We wanted to see the change by bottlenecks and semester to identify which bottlenecks were strongest and weakest. Keeping track of the data in this way, we could make adjustments semester by semester, for example in Fall 2022 and Spring 2023 for Degrees of Freedom, more practice was added to improve the learning. Table 1 shows the repeated measures t-tests between the pretest and the final exam for each category by semester. In this analysis note that only the Fall 2021 and 2022 Central Limit category and the Fall 2022 Degrees of Freedom category did not produce a significant change. In Fall 2021, the questions on the Central Limit category were not in the pretest, only in the final exam. The results signal that there was a marked increase in understanding.

Qualitative Results

The classroom assessments checked to see how students' attitude toward the course was changing and if there were any additional details that we were missing from the quantitative data. The results of the formative classroom assessments supported the quantitative results with more detail on how the students experienced the class and brought in more of the students' voices. In the Spring 2023 class, students agreed to share their responses to three formative classroom assessments (adapted from Angelo & Cross, 1993): HAYD (How are you doing?); Advice to the Future; Two Questions. Table 2 describes each assessment, the frequency, the purpose and prompts used in class.

In the "HAYD" classroom assessment we gathered data on how confident students had become with conducting an analysis on their own. At the end of the course, 60% of the students reported a mode of 3 (I think that I understand it) with 30% reporting 4 or 5 (I understand it and have no doubt that I could do it on my own). This shows that the students in the class were confident that the class had helped them to acquire the skills needed to go on to the next research course. In the "Advice to Future Students" assessment a word cloud analysis as shown in Figure 2 which revealed the most common words were: time, notes, work, learn, questions, easier, and recommend.

As we examined the "Advice to the Future" assessment further, students revealed their attitude toward the course. Students advised future students about study methods and behaviors; to make friends in class; to come to class; and to be on time because the instructions are given at the beginning of class for that day's work. Students also recommended that you ask your partners for help, mistakes were part of learning so do not be afraid to redo assignments, and take good notes. Students stated that future students should focus on keeping up with the assignments and redoing assignments in class when they can ask questions of other students and the instructor. One student put it very succinctly, "As long as you come to class, ask questions when you are confused, and stay up with your assignments this class is decently easy." Another student stated:

> *I am sure everyone has heard that 'statistics is so hard,' I would know because I used to say that despite not having any knowledge of the concepts of stats. That statement would only be deemed true if you don't show up to class, take notes and ALWAYS ask questions when you don't understand. Don't allow the stigma around stats being so difficult influence you from succeeding in this course. The more you immerse yourself in the course by showing up to class, taking notes every chance you get and reading the book which is also another helpful tool. Even if it's still confusing, asking questions and getting extra help from classmates will definitely help you get a grasp of- if not all, most of the concepts of stats. It may seem like a lot, but the more you engage, the easier it gets.*

In the "Advice to the Future" assessment, students could have answered in several directions such as addressing particular content or negative feelings about the class, but instead students uniformly encouraged their fellow students to follow good study habits and they were ensuring future students that this would have good results. This statement indicated that the students still perceived the class as rigorous, but their attitude toward the course showed an updated confidence in statistics as contributing to the training in research they would need.

In the "Two Questions" classroom assessment, students pointed out topics where they needed more understanding. This classroom assessment was aimed at checking if there were any big remaining misunderstandings about the bottlenecks. These comments helped the instructor to understand if further work needs to be done on the bottlenecks. While there were some misunderstandings, most were not related to the bottlenecks as shown in Table 3.

Another source for qualitative consideration was the student ratings of the instructor provided by the institution at the end of the course for all instructors' courses. Before the full implementation of the Decoding the Disciplines lessons, the students' ratings of the instructor questions were typical. Students rated the quality of the instructor and the quality of the class on a scale of 1-7 with 1= poor and 7 = excellent. For the quality of the instructor rating, the question was, "Rate how well the instructor promoted

Table 2. **Formative Assessments. The formative assessments used in Spring 2023.**

Assignment name	Frequency	Purpose	Questions/description
HAYD (How are you doing in class?)	After each major module in the class	To gauge understanding through words and a numerical rating as the class progresses	What parts are muddy? What would you like to know more about? I feel like I could do this analysis and interpret it. On the scale below, how well do you understand this week's topic? How are you feeling about this class? Is it going too fast or too slow?
Advice to the Future	At the end of the semester	What stood out to them as important things that they needed to do to succeed	What advice would you give students who are starting this course? What do they need to know to do well in the course? What are the main things that they have to do?
Two Questions	At the end of the semester	To understand what they remembered from the bottleneck lessons after they applied them in the analysis section of the course (weeks 6-13).	From the topics that we covered below, list two topics that you don't understand well and one question that you have about the topic: probability, degrees of freedom, variability, hypotheses; central limit theorem; significance; sample or population; operationalizing; falsifiability; dependent and independent variables

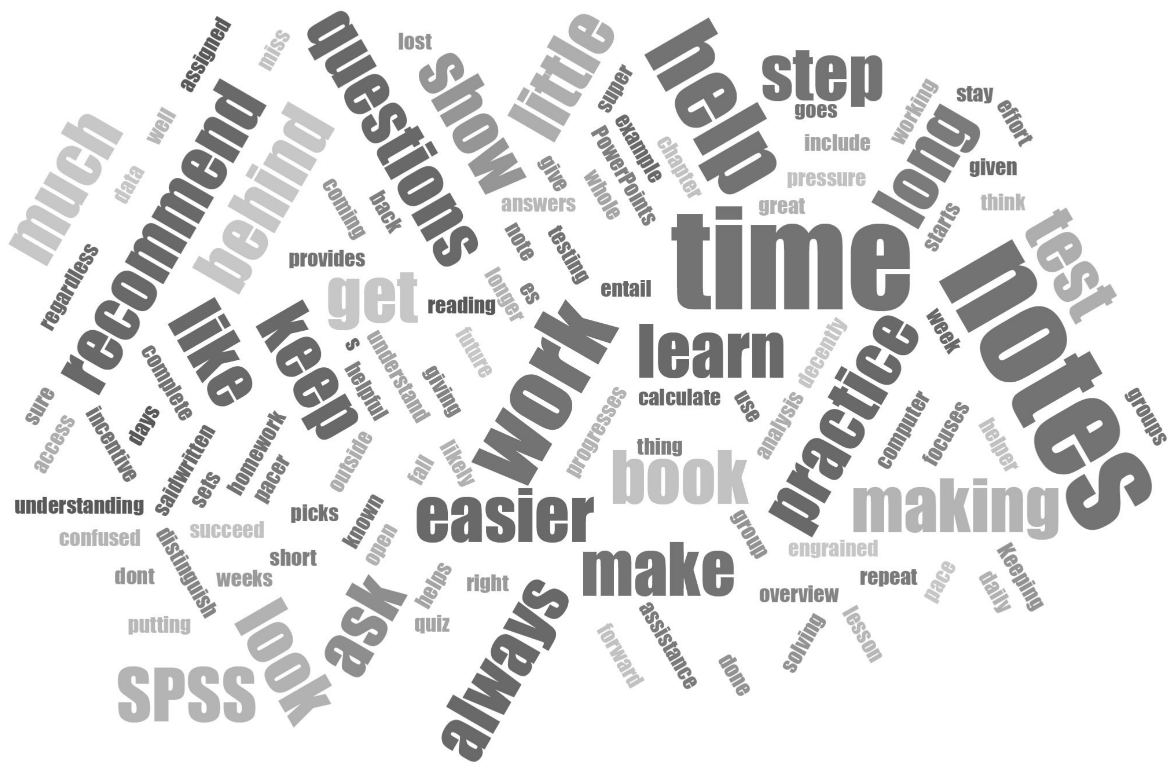

Figure 2. The word cloud from "Advice to the Future" generated at https://www.jasondavies.com/wordcloud/

***Table 3*. The Two Questions assessment by topic with the bottleneck topics indicated by ***

Topic	Frequency
Operationalize	27%
Falsifiability	14%
Which analysis to use?	14%
Central Limit*	9%
APA style	9%
Degrees of Freedom*	9%
Researchers Opinion	4%
Significance	4%
Sample or Population	4%

a meaningful learning experience for you." Before the Decoding lessons were implemented the instructor's median rating was a 6, after the lessons were implemented the instructor's median rating was a 7. For the quality of the course rating, the question was, "Rate how well this course increased your understanding of the course topics." Before the Decoding lessons were implemented, the course's median rating was a 4, which is typical for this course. After the lessons were implemented, the course's median rating rose to a 7 for the course.

DISCUSSION

We found that the Decoding the Disciplines technique did result in better understanding of the five core concepts in psychological statistics: probability, variability, central limit theorem, independent and dependent variables, and degrees of freedom. Qualitative feedback from the students suggests that most students' attitude toward statistics as a difficult and anxiety inducing course was updated to one of perseverance (Chew & Dillon, 2014; Salkind, 2017). The students reported that the course was enjoyable and that they were confident in their ability to perform these analyses. For a course that is universally feared and hated, the students had more confidence and a better attitude.

In all five concepts students showed that they understood them better on the post test. This difference was significant. For example, when probability was discussed in relation to percentile ranks in z-scores, students grasped that being in the 85th percentile on a standardized exam was better than being in the 15th percentile. When we came to the application part in the second half of the course then, translating the idea of probability to an ANOVA result was simpler. The instructor rarely had to revisit these bottleneck concepts when teaching the analyses section of the course. Students had a solid understanding about what degrees of freedom were and why the degrees of freedom were different for different tests.

In semesters before the Decoding the Discipline lessons, subsequent course instructors complained that students were under-prepared and not able to apply the skills they learned in this class. Since the Decoding the Discipline lessons were implemented, this changed, and instructors of the subsequent research courses have reported anecdotally that the students were well prepared for the statistical analyses part of their course. The course will keep the Decoding the Discipline lessons in future semesters.

There were a few limitations to the study. First, there was only a single instructor and at a single institution which presented the typical challenges of a single group, pre-posttest design. The institution is a selective public university. Instructors teaching at other types of institutions such as community colleges, open enrollment or small private liberal arts colleges may also find different results. While the authors are willing to share the lessons, other instructors who create other lessons using Decoding the Disciplines may find different results. While the authors did not know each other prior to this project, the collaboration within the project fostered a deep trust and openness which helped the instructor as expert reveal as much as possible to the non-expert. We imagine that without the openness that both the expert and non-expert had committed to the project, the lessons would not have been as effective. Indeed, the non-expert has witnessed this phenomenon in other expert/non-expert pairs attempting to use this approach.

Instructors might fear trying a new method knowing there might be no difference in student learning or enjoyment of the course. For the instructor to put in the effort of redesigning a course, there must be a promise of significant learning for students without a drop in student ratings, which was the result here. However, this is no guarantee that the same thing will happen for every instructor. However, instructors teaching from a theoretical basis, such as Decoding the Disciplines, are more likely to obtain better outcomes.

As universities face retraction, psychology needs to retain many students to flourish. There is no way to get around the fact that the introduction to psychological statistics course must be rigorous. The Decoding the Disciplines approach helped this instructor keep the rigor of the course while making it accessible for increasingly under-prepared students.

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