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ORIGINAL ARTICLE

A comparison of strategies used by lecturers to improve students' perceived feelings toward statistics—A study that is Stat-tastic!

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Abstract

One way of addressing anxiety in students studying statistics as a non-specialist is dedicated statistics anxiety workshops, but some students are too anxious to attend such sessions. In this multi-university study, lecturers presented content from such a workshop in one slide per session throughout their statistics teaching. This "Stat-tastic thoughts" approach was compared with other strategies, typically used in statistics teaching to address statistics anxiety, by students scoring each strategy for how it affected their feelings toward statistics. While all strategies had a positive effect on feelings, staff approachability, the lecturer's attitude toward the subject, and attempts at humor or fun, consistently scored highest. Our findings suggest that it is these elements of a statistics course that students think statistics educators should concentrate their limited time and energy on to increase their students' positive feelings toward statistics.

KEYWORDS

anxiety, lecturer qualities, teaching statistics

1 | INTRODUCTION

Statistics anxiety, defined by Zeidner[49] as the "extensive worry, intrusive thoughts, mental disorganization, tension, and physiological arousal when encountering statistical situations," is reported to be one of the most prevalent forms of situational anxiety among students in Higher Education (HE),[36] especially for students engaged in "non-mathematical" disciplines.[10] Students often have misconceptions about statistics—such as its difficulty or relevance[38]—and negative thoughts about their own ability, which contributes to their anxiety. Importantly, students may not recognize that their struggles often stem from their anxiety rather than a lack of ability, or that many of their peers share similar feelings.

Statistics anxiety is a related but distinct construct from maths anxiety (but see Ref. [40]), though many students transfer their anxiety about mathematics to learning statistics.[30, 49] Being statistics- or maths-anxious is detrimental to learning, with students showing higher levels of intrusive thoughts and being less able to regulate their emotions.[17] Moreover, anxiety is linked to motivation, metacognition, and performance[12, 22]; anxious students are therefore more likely to practice avoidance

behaviors,[2, 32] procrastinate,[35] postpone work,[22] lack persistence, and are less likely to use deep learning strategies or self-regulate their learning.[12, 35] These behaviors can contribute to a negative feedback loop of adverse learning, leading to poor performance, which increases anxiety further. When preoccupied by worry, working memory capacity is reduced,[2, 48] making learning more challenging. Reducing statistics anxiety is therefore essential to empowering students to self-regulate their emotions and improve their own learning, ultimately improving both student experience and attainment.

Mitigating statistics anxiety is a multifaceted challenge that requires addressing both the physiological and emotional responses that interfere with cognitive processes. Encouragingly, interventions that focus on emotional regulation, cognitive reappraisal, and tackling negative beliefs about statistical abilities have shown promise in reducing the impact of anxiety.[33, 44] For example, cognitive reappraisal training—such as tackling the negative belief that you need to have "a mathematical brain" or previous maths qualifications to study statistics[2, 38]—has been linked to improved emotional control and a more accurate perception of statistical challenges, which can lead to long-term reductions in anxiety.[23, 33, 44]

Beyond cognitive reappraisal training, statistics lecturers have a multitude of tangible strategies that they can use to mitigate statistics anxiety,[4] each addressing a different facet of the student experience. These include breaking complex material into smaller, more manageable segments; using practical-based assessments; and fostering cooperative learning environments between staff and students.[28, 47] Other strategies, like incorporating real-world examples and offering regular low-stakes quizzes, aim to engage students while also alleviating their fears.[19, 20, 29, 37] Likewise, methods such as reflective journaling, utilizing virtual discussion boards, and providing platforms to ask questions and receive immediate feedback have been employed to give students the opportunity to express and process their anxieties.[7]

An effective, holistic strategy to reduce anxiety is fostering a positive and supportive learning environment. Students are more likely to attempt learning statistics when the classroom atmosphere is engaging, enjoyable, and collaborative.[45] Instructors who use both verbal and non-verbal immediacy behaviors—such as providing positive feedback and being approachable—can further reduce student apprehension, promote a sense of belonging, and improve students' perceived quality of learning.[6, 15, 43, 46] Indeed, simply smiling in class, engaging in conversation, and praising students have been shown to be effective in promoting student outcomes.[46]

The use of humor or fun is commonly used strategies to make statistics feel more accessible (reviewed by [20, 45]). While these have been shown to engage most audiences, they pose the risk of being seen as a distraction by students who are not negatively predisposed toward statistics and who may prefer a more formal focus on the content.[27] Another approach that has returned mixed results is encouraging students to work with peers,[1] which has been shown to promote self-efficacy in some, but not all, learners, and especially not for students working within groups where peers are not perceived to be contributing equally.[5]

Workshops that directly address statistics anxiety have been used in an attempt to reduce anxiety,[24] and have been found to improve student self-efficacy and increase the value that students attribute to statistics.[16] However, research also highlights that students are often too anxious to attend ad-hoc statistics anxiety workshops.[24] One approach to overcoming this is to deliver such workshops as a compulsory element of a timetabled course or module. This increases the potential to reach all students who may be anxious about statistics, yet suffers from the limitation that students who may already feel positive about statistics may consider the workshops unnecessary. A compromise is to integrate content from statistics anxiety workshops more seamlessly throughout an otherwise compulsory statistics training course; something that to our knowledge has not previously been attempted.

Several studies have recognized the importance of implementing multiple techniques to reduce statistics anxiety,[28, 31] but few have evaluated the effectiveness of different teaching strategies employed simultaneously.[28, 47] To our knowledge, no research has yet examined a range of teaching strategies simultaneously and in multiple universities. In this study, we hence address two outstanding research gaps by (i) implementing several statistics-anxiety reducing interventions simultaneously in a multi-cohort study and by (ii) including a novel intervention that integrates content from a statistics anxiety workshop one slide per lecture in a compulsory course. This study offers unique insights into the comparative effectiveness of different strategies, and whether their efficacy is consistent across student cohorts. Our results provide guidance for statistics educators to decide what teaching interventions to implement, or what general approaches to take, to most effectively mitigate statistics anxiety.

2 | METHODS

2.1 | Respondents

Students from four HE institutions took part in the study: two universities from the United Kingdom and two from

TABLE 1 Characteristics of the student cohorts that the respondents were part of and details of the survey and intervention approach used.

Institution	Year of study	Degrees	Statistical software taught	When were students surveyed	How interventions were used
Macquarie University	First year undergraduate and some Masters	Wide spectrum of around 60 different non-statistical BSc Science majors	Excel	After the last assessment	During live-lectures
La Trobe University (module ran twice giving data from two groups)	First year undergraduate	Science, Life Science, Health science, Computing	Mostly Jamovi and some R	Four weeks before the final assessment	During a statistics subject called *Making Sense of Data*
Cardiff University	First year undergraduate	Biosciences degree; Biological Sciences, Zoology, Biomedical Science, Neuroscience, or Biochemistry	R	After the final taught session (5 weeks before assessment deadline)	During the statistics part of a *Skills for Science* module
University of Leeds	First year undergraduate	Biology, Genetics, Zoology, Ecology and Conservation or Natural Sciences	SPSS	Five weeks before assessment deadline	During the statistics part of a *Practical Skills and Data Analysis* module

Australia, with two different cohorts in one of the Australian universities (La Trobe). Students were mostly first-year undergraduates on a broad range of degrees (Table 1).

2.2 | Stat-tastic slides and other interventions

Slides featuring "Stat-tastic Thoughts" (Supporting Information A) were shown to students during lectures (1 per lecture) as part of a typical statistics course or module. To make data collection across different institutions possible, the Stat-tastic slide intervention was flexible in terms of exactly which slides and the number of slides that were included in each course. Lecturers used between 7 and 10 of a possible 10 slides with their cohort, enabling them to use their professional judgment to tailor the use of slides appropriately for their specific cohort and their own personal teaching style. This also accommodated the varying number of lectures taught. We viewed this slight variation among cohorts as a justified trade-off in being able to collect data from multiple cohorts.

The content of the "Stat-tastic Thoughts" slides, in brief, included an anonymous poll on how students felt about statistics to demonstrate that individuals were not alone in their feelings or perceptions; a challenge to the myth that someone needs a "maths brain" to do statistics; a description of statistics anxiety and how it encourages students to avoid classes; highlighting that lacking a maths qualification does not prevent you from being good at statistics; the importance of statistics; challenging negative thoughts; encouraging students to ask for help; reference to the growth zone model[13]; how anxiety makes it harder for you to engage your brain in learning; and a 2-min video explaining statistics anxiety.

How effective the slides were in reducing perceptions of statistics anxiety was compared with other interventions or aspects of teaching. As is typical in teaching, the number and specific details of these aspects varied among our universities. However, in using four different settings we hoped to observe a variety of statistics teaching, therefore improving the relevance of our findings. One aspect was how approachable the lecturers or PhD demonstrators were perceived to be. In all universities apart from Macquarie, the attitude that lecturers and demonstrators had toward the subject of statistics was also examined. Other aspects included how fun or humorous the lecturers were during lectures. Since there were varying ways that humor could be included and due to humor being subjective, the questionnaire asked students about "attempts" of the lecturers to be humorous or fun, without referring to specific humorous actions or events. Active learning elements such as the use of interactive polls or quizzes via platforms like Kahoot or Mentimeter were also evaluated. Quizzes in one university (La Trobe) referred to the use of low-stakes, assessed quizzes.

The use of discipline-specific examples or datasets to teach statistics—such as examining the prevalence of

Alzheimer's disease for neuroscientists or biomedical sciences students—was another intervention considered. Where cohorts were composed of students from varying disciplines, more general examples were chosen to be relatable to all students. A related strategy was using data that students had collected themselves, implemented by La Trobe and Leeds. This question was adapted for Macquarie students to evaluate using data in practicals that had been first encountered in the lectures. This strategy was not assessed at Cardiff. Providing students with opportunities to ask questions either during lectures, practicals, or via online forums such as through padlet was evaluated in all universities; in Cardiff, this question was split to evaluate both asking questions in person and asking questions via Slack.

Teaching statistics typically involves practical training using computer software. Hence, in contrast to lectures, we evaluated how students perceived the use of statistical software (Excel, Jamovi, R, or SPSS) to affect their statistics anxiety. In practical classes, students could work with peers if they wanted to, and this was also evaluated through the questionnaire. At all institutions, additional statistics support outside of taught sessions was offered and promoted to students. These comprised additional drop-in sessions provided by the same lecturer who taught the statistics classes or a separate university-level service. All students except those at Cardiff were asked about this support in the questionnaire.

Alongside the interventions presented herein, Macquarie ran another intervention, a mixture of peer instruction with active learning, to boost students' engagement and participation in the live lectures.[3] Since it was run alongside this project, it may have had some effect on students' responses; thus, it was also considered.

Finally, students at Cardiff only were asked to evaluate the perceived effects of a few additional strategies, namely the inclusion of the lecturer's pets in examples of statistics; anecdotes of the lecturer's own personal journey from loathing to loving statistics; the use of real or simulated data in examples; providing recommendations for directed reading; including relevant statistics-related quotes from famous statisticians, mathematicians, or other scientists; and including references to how statistics has been used historically.

2.3 | Questionnaires

Questionnaires assessing students' perceptions toward statistics were distributed to students during a lecture or practical class toward the end of the teaching period. Distribution of questionnaires was undertaken by a third party (i.e., blind) to mitigate the potential effects of students responding more positively in the presence of their lecturer(s).

While pre- and post-statistics anxiety scales such as STARs[8] are the standard approach to measuring statistics anxiety, we had previously experienced substantial limitations in sample size when using these lengthy questionnaires. In addition, we did not want to bias our study toward students who are often willing or incentivized to complete such surveys. Therefore, we used a short, novel questionnaire (Supporting Information B) that captured students' perceptions of statistics as a proxy for statistics anxiety in exchange for larger sample sizes and increased statistical power. Similarly, when using pre- and post-intervention surveys, we have experienced low numbers of students completing both especially a drop in the number of students completing the latter. Hence, we surveyed students only once toward the end of their teaching period to prevent survey fatigue. Two questions asked students to indicate their feelings toward statistics at the beginning and the end of the teaching period. To mitigate this limitation of relying on student's memory of how they felt about statistics at the beginning of their teaching, the first "Stat-tastic Thought" slide was an anonymous poll of how students felt about statistics using the same wording as the questionnaire. Students were asked to make a note of how they answered this poll on their phone or on paper, so that they could refer back to this when completing the questionnaire at the end of the taught period.

Questionnaires were distributed either on paper (Cardiff and Leeds) or online (Macquarie and La Trobe) via Microsoft Forms or REDCap. The first two questions asked students to rate, using a five-point Likert scale, how they remembered feeling about statistics at the start of the module and how they felt now. Respondents were then asked to score each teaching aspect or intervention on how much they thought it had affected their feelings toward statistics, ranging from -5 (negative) to $+5$ (positive). An open text question captured qualitative data on any thoughts that the respondents had on their feelings toward statistics and how any of the strategies employed by the lecturers may have affected them.

It is unclear if gender is a mediator of students' perceptions of statistics[41] but since some studies find a clear effect, we decided to collect this demographic data via an open text question that allowed students to self-describe their gender. Age has been found to interact with gender to affect statistics anxiety,[34] we did not collect age data as the vast majority of students were of similar age (<25 years) and thus both the resolution of the age predictor and the sample size for mature students would have been insufficient to draw reliable statistical inferences.

2.4 | Quantitative analysis

We undertook statistical analyses in-line with our pre-registration (osf.io/zbmw2) with some minor adaptations noted below. All analyses were undertaken using R statistical software (Version 4.4.1; R Core Team, 2024) using the RStudio interface (Version 2024.4.2.764; Posit team, 2024).

To evaluate any overall shift in the perception of statistics, we first investigated the association between the proportion of respondents' Likert scores (1 = hate statistics, 2 = dislike statistics, 3 = neutral, 4 = like statistics, 5 = love statistics) and time point (start and end of the course) using Fisher's exact tests. We applied these tests for all cohorts together and for each cohort separately, using a starting significance threshold of 0.05. We further tested for any change in Likert score using one-sample Wilcoxon tests, where a median difference of 0 would indicate no change. We assessed how the change in pre- versus post-course Likert score was associated with gender and cohort using a General Linear Model (GLM). Only two genders, "man" and "woman," had sufficient sample size to be considered for this analysis. This reduced the overall sample size from 387 to 340 (i.e., by 12%).

For each teaching intervention, collectively and for each cohort, one-sample Wilcoxon rank-sum tests were used to test if the scores given (−5 to 5) were significantly different from 0, which would represent no effect on a student's feelings toward statistics. Following the same analytical approach outlined above, we used data from Cardiff to do further exploratory analyses on nine additional questions that evaluated strategies used only in Cardiff. These strategies were not listed in the pre-registration.

There were no effects of respondent and therefore the inclusion of respondent as a random effect in repeated measures ANOVAs to control for variation among students was not necessary. The assumptions of ANOVAs outlined in the pre-registration were not strictly met due to the ordinal nature of the data. In addition, the effect of cohort was significant. Therefore, sensitivity analyses were undertaken to check the ANOVAs and post hoc Tukey test results. This involved ordinal Cumulative Link Models (CLMs) with cohort included as a random effect when modeling all cohorts together. The vast majority of results agreed, but the ANOVAs and post hoc Tukey test results were more conservative in that they determined a small number of comparisons (six of the 55 comparisons among the 11 strategies) to be not significant when an ordinal model found them to be significant. In light of the ANOVAs being planned in the pre-registration and those results being more conservative, we present the ANOVA and Tukey results here.

2.5 | Qualitative analysis

Inductive thematic analysis was undertaken to understand why students perceived certain strategies to affect their feelings toward statistics. The analysis was data driven to capture ideas outside of the authors' perceptions. After becoming familiar with the text, codes were assigned to sections of the data that represented key themes. Each of the cohorts were analyzed by two authors independently, who then agreed on themes by comparing codes.

3 | RESULTS

The number of respondents in the different cohorts ranged from 56 to 135 (Table 2). As expected, the response rate was low given ethically motivated efforts to ensure students did not feel obliged to complete the questionnaire.

3.1 | Perceived feelings toward statistics

Students' reported feelings showed a shift toward more positive feelings at the end of their statistics teaching.

TABLE 2 The number of respondents that filled in a questionnaire on their feelings toward statistics and what teaching strategies they thought had affected their feelings toward the subject while learning statistics in their university course.

Cohort	Man	Woman	Non-binary or gender not given	Total	Number taught statistics	Response rate (%)
Macquarie	30	26	17	73	1135	6
La Trobe 1	20	36	10	66	508	13
La Trobe 2	16	35	6	57	647	9
Cardiff	30	93	12	135	475	28
Leeds	20	34	2	56	129	43
Total	116	224	47	387	2894	13

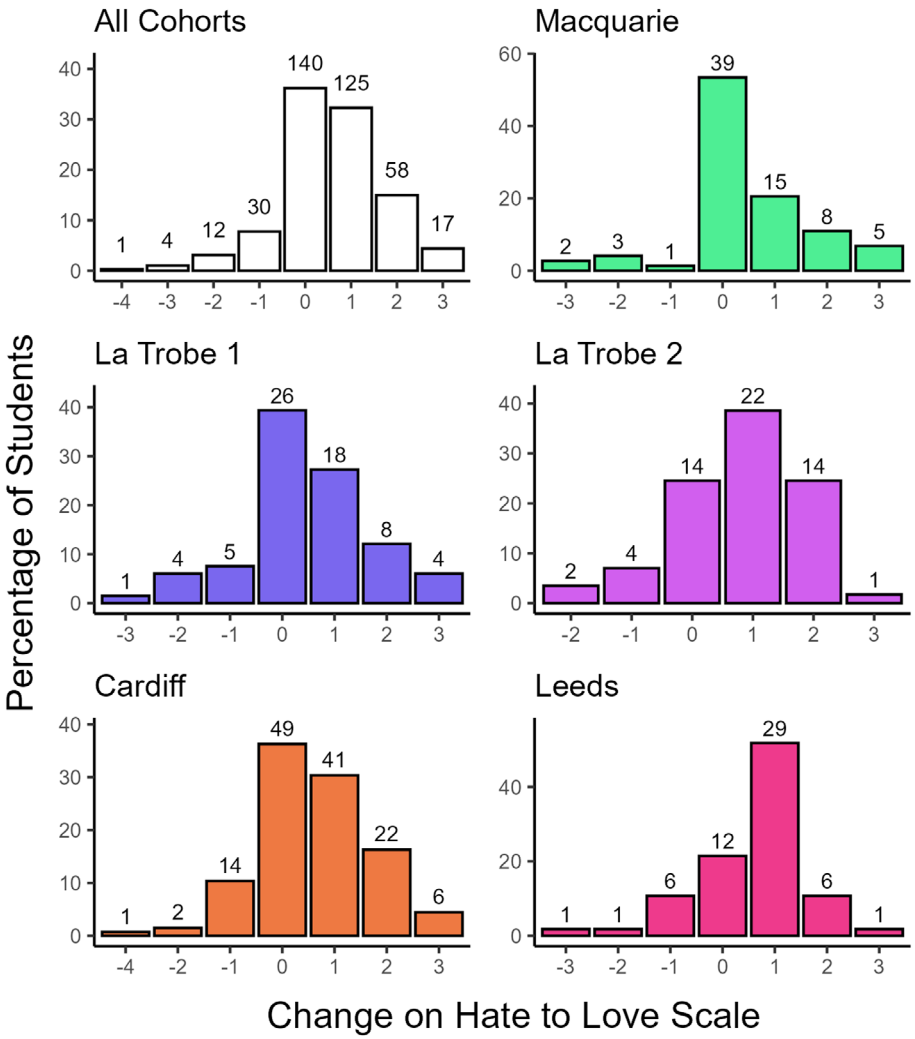

FIGURE 1 The change in student perception of statistics between the start and end of a students' statistics teaching. Number of students shown above each bar. A positive number indicates that they felt more positive about statistics at the end compared with the start of their teaching. Students were asked at four universities with two cohorts asked at La Trobe. [Colour figure can be viewed at wileyonlinelibrary.com]

The changes in individual students' feelings were significantly different from 0 for all cohorts (Wilcoxon one-sample test, all five cohorts: $p < 0.01$; Figure 1). These changes were consistent across cohorts (regression, $p = 0.46$). There were no students who reported that their feelings had changed from hating (1) to loving (5) statistics (i.e., scoring a change of +4) and only one that changed from loving to hating (scoring −4).

The degree to which women and men reported that their feelings toward statistics had changed was not significantly different in three of the universities. However, Leeds men changed significantly less than women (cohort × gender interaction, $p < 0.01$; Supporting Information C). This meant Leeds were different from the other three universities in how women and men differed in their feelings toward statistics; however, there were no other differences among the other cohorts.

The distribution of the number of students in each feeling toward statistics category (hate, dislike, neutral, like, and love) changed significantly between the start and end of the statistics teaching for all cohorts (Fisher's exact tests, all five cohorts $p < 0.05$). All cohorts, except Macquarie, reflected a pattern where there were more students reporting a dislike toward statistics than a like at the start of the statistics teaching. However, at the end of the teaching, this had shifted to more liking than disliking statistics. Macquarie students had relatively fewer negative feelings toward statistics to begin with. The proportion that liked statistics increased at the end for Macquarie students (Figure 2).

3.2 | Scores for different teaching strategies

Across the cohorts, students scored teaching strategies as having a positive effect on their feelings toward statistics (scores were significantly higher than 0 on the −5 to 5 scale). This indicated that, as a group, students reported that all strategies the lecturers used helped them feel

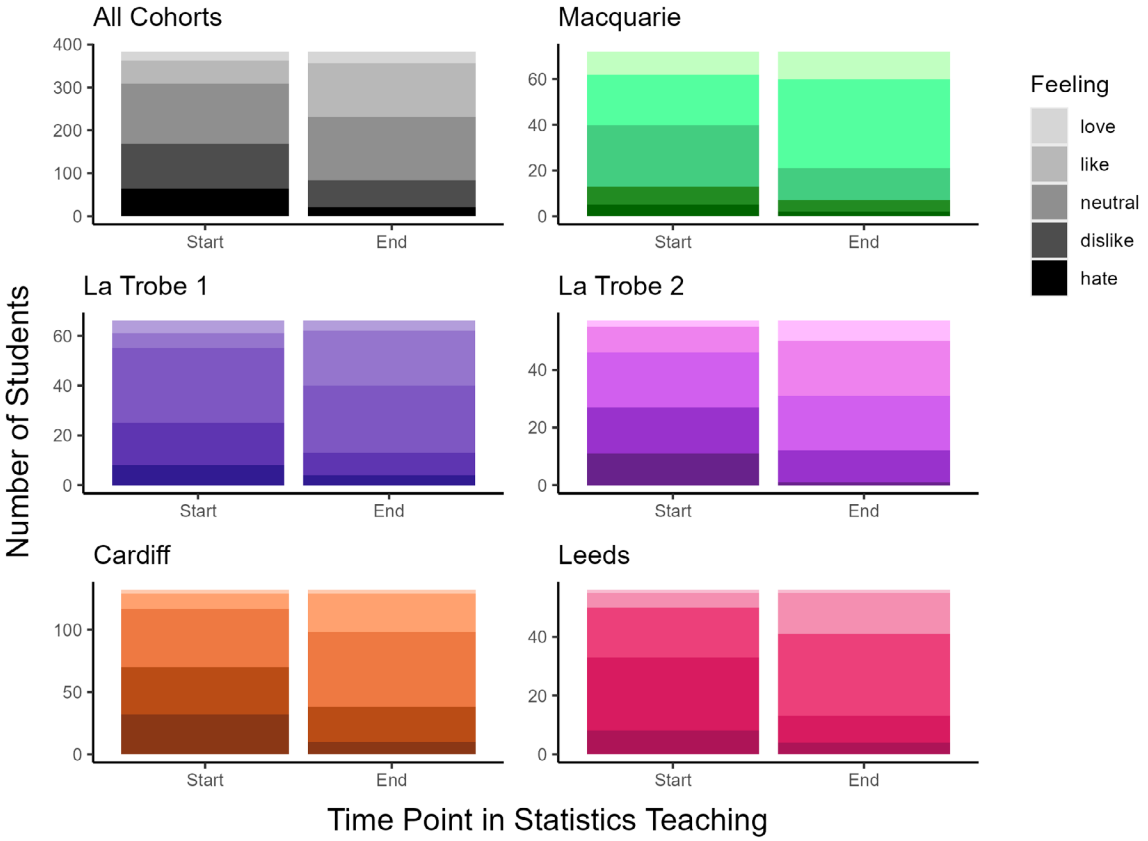

FIGURE 2 Student responses to the question: how did they feel about statistics at the start of their statistics teaching and how do they feel at the end? In general, there is a shift toward more students liking statistics at the end. For all cohorts, the darkest color is hate and the lightest is love. [Colour figure can be viewed at wileyonlinelibrary.com]

more positive about statistics (one-sample Wilcoxon rank-sum tests with Benjamini–Hochberg corrections, all <0.01). The one exception to this was Leeds statistics support, which had no effect ($p = 0.42$).

Some strategies were scored by students as having a more positive effect on their feelings toward statistics than others (data from all cohorts, ANOVA, $F = 39.08$, $p < 0.001$; Figure 3). All analyses (all data together and for each cohort separately) found no significant differences between measures of how approachable the staff were or were not ("Approach," Figure 3), the staff's attitude toward statistics ("Attitude") and attempts by the lecturer to include humor or make it fun ("Humor"); letters above boxes in Figure 3 indicate where there were no significant differences between strategies.

However, there was variation among the cohorts in what strategies worked as well as attitude, approach, and humor (Figure 3). For Macquarie and both La Trobe cohorts, the students rated quizzes ("Quizzes"), using data that were relevant to the students' discipline ("Relevant"), having opportunities to ask questions ("Questions") and using software for themselves ("Software") as being just as effective at improving their feelings toward statistics (see letters "a" on Figure 3). In addition, Macquarie and La Trobe cohort 1 rated using their own data ("OwnData") as being just as effective as other top strategies. Similarly, Leeds students found quizzes to be effective. A notable contrast for the students using the software for themselves strategy was observed among the cohorts. Cardiff and Leeds students gave more variable scores for this strategy, ranging from −5 to 5 (software on Figure 3).

Working with peers in computer practicals ("Peers") was found to be as effective as other top strategies in Leeds only. Whereas in La Trobe 1 working with peers was one of the least effective strategies. The "Stat-tastic thoughts" slides ("Slides") consistently scored lower compared with other strategies. Similarly, the use of some form of statistics drop-in or service ("Support") also tended to score lower. However, there was variation, with many La Trobe students scoring support highly and few Leeds students using support and therefore most scoring it as affecting their feelings neither positively nor negatively (Figure 3).

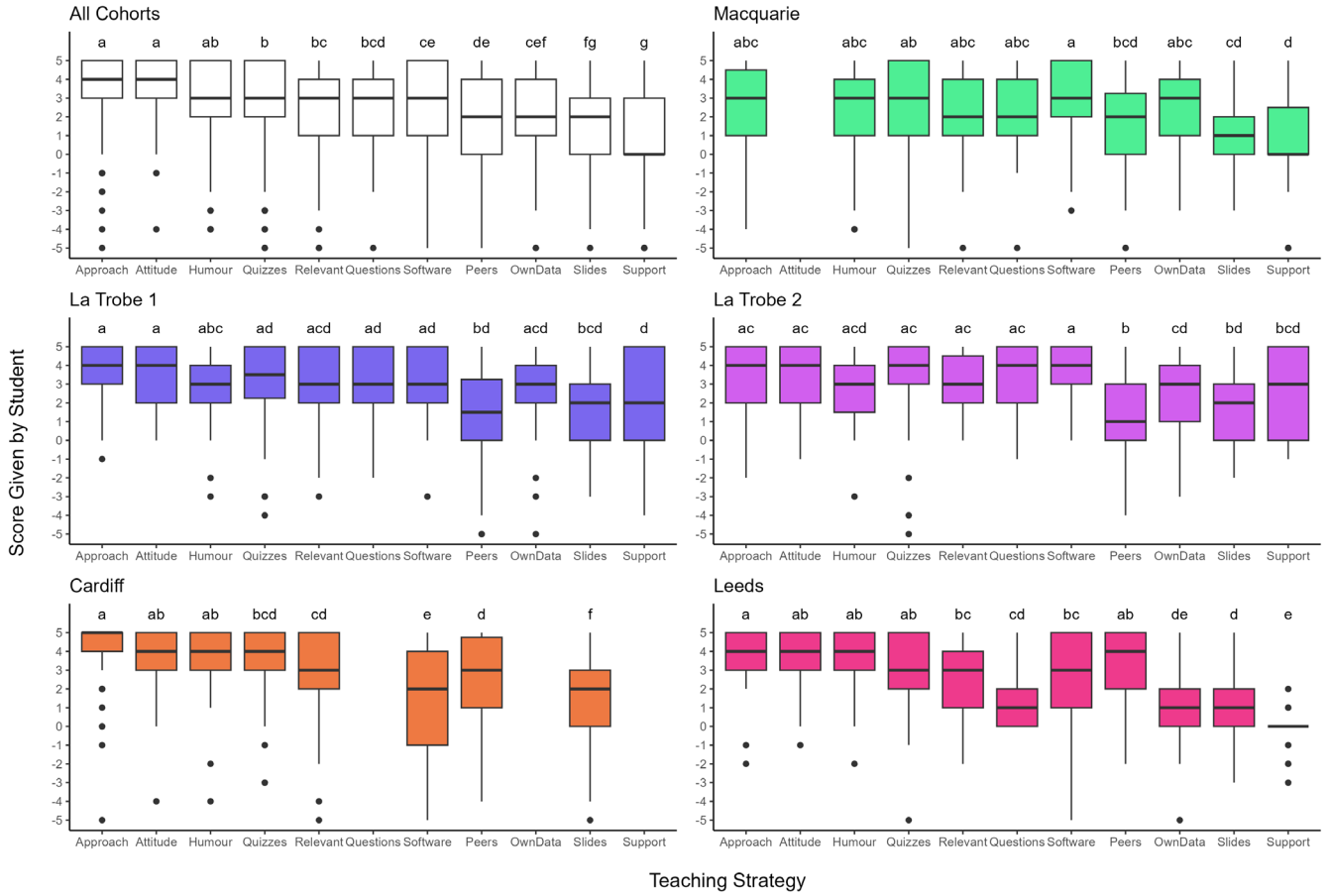

FIGURE 3 Scores given by students for the perceived effect of different teaching strategies on their feelings toward statistics. Strategies were scored on a scale of −5 (a large negative effect) to 5 (a large positive effect) with 0 being no effect on feelings toward statistics. Within each graph, boxplots with the same letter above them are not significantly different from one another (Tukey post hoc tests, p values adjusted for multiple comparisons). Strategies are ordered on all boxplots according to their mean score for all the data from the five cohorts together (white boxplots). [Colour figure can be viewed at wileyonlinelibrary.com]

Data was analyzed to investigate if students' ratings of strategies were affected by both the specific strategy and their overall change in attitude toward statistics (positive, negative, or neutral). Only when data from all cohorts were combined together was this strategy-change interaction significant (ANOVA, all cohorts $p < 0.05$; MQ $p = 0.97$, LTU1 $p = 0.95$, LTU2 $p = 0.63$, Cardiff $p = 0.22$, Leeds $p = 0.55$), suggesting a small interaction effect which may only be detected with more statistical power. Furthermore, students whose feelings toward statistics became more negative (e.g., liking at the start to hating it by the end of teaching) tended to give lower scores to some strategies compared with those whose feelings had become more positive. However, importantly, this "negative" group of students still gave strategies scores that were overwhelmingly from 0 to 5, that is, in the neutral-positive range of the scale (data not shown). In other words, our results do not indicate that any particular strategy worked for one type of student; for example, no single strategy worked most effectively for those who experienced feeling more positive nor worked least effectively for students who become more negative toward statistics by the end of the taught period. Our results hence suggest that lecturers employing any of these strategies in an attempt to improve students' feelings toward statistics need not worry that a strategy will have an overtly negative effect on a student.

3.3 | Exploratory analyses on other useful teaching strategies

All the extra strategies that Cardiff students had been asked to evaluate were significantly different from 0 (Figure 4). This suggests students thought all these additional strategies affected their feelings toward statistics in a positive way. In particular, the lecturer incorporating their pets in the teaching content ("Pets") was scored as highly as attitude, approach, humor and quizzes. Having the opportunity to ask questions in person ("Qs In Person")

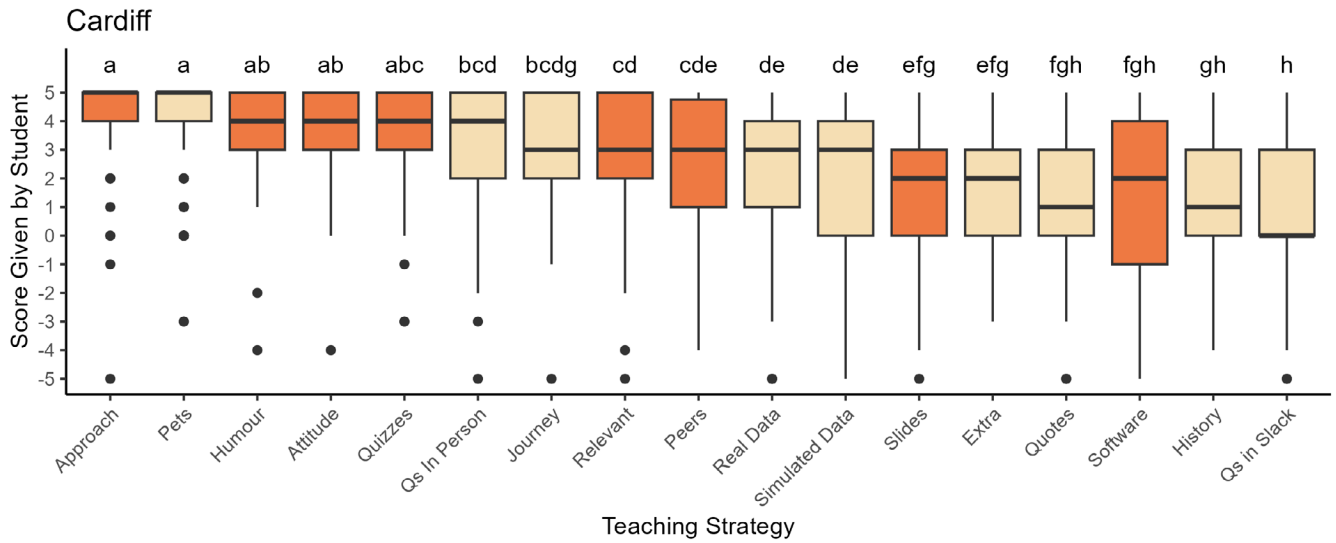

FIGURE 4 Students' scores of how much they thought different teaching strategies at Cardiff had affected their feelings toward statistics. Strategies already presented are in orange and the extra strategies are in cream. Boxplots with the same letter indicate no significant difference ($p > 0.05$) according to Tukey's HSD post hoc tests. Strategies are ordered according to the mean scores. [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 3 The percentage (and number) of comments from each cohort that related to each theme.

Theme	Mac (38)	LaT 1 (36)	LaT 2 (35)	Card (104)	Leeds (32)
Great staff	11 (4)	17 (6)	29 (10)	35 (36)	31 (10)
Staff attitude	5 (2)	3 (1)	6 (2)	18 (19)	31 (10)
Negative staff	3 (1)	3 (1)	14 (5)	8 (8)	
Fun/humor	3 (1)			1 (1)	9 (3)
Difficulty level	8 (3)	11 (4)	3 (1)	24 (25)	19 (6)
Help sufficient	5 (2)	8 (3)	9 (3)	4 (4)	
Needed more help		6 (2)	3 (1)	33 (34)	3 (1)
Organization of teaching	3 (1)	31 (11)	40 (14)	8 (8)	25 (8)
Importance of statistics	5 (2)	14 (5)	11 (4)	2 (2)	
Quizzes	8 (3)	8 (3)	11 (4)	1 (1)	
Relevant data			6 (2)		3 (1)
Statistics support			9 (3)		

Note: Percentages are rounded to whole numbers. Comments could contain none to multiple themes. The numbers after the cohort names are the total number of students that left a comment of any kind. Empty boxes indicate that the theme was not evident in the comments from that cohort. Themes are in the same order as presented in the text in Section 3.4.
Abbreviations: Card, Cardiff; LaT, La Trobe; Mac, Macquarie.

was scored significantly higher than being able to ask questions online via Slack ("Qs In Slack"). The lecturer sharing their journey of going from hating to loving statistics ("Journey") was also scored relatively highly. Other notable strategies were the inclusion of quotes ("Quotes"), examples of extra reading ("Extra"), and anecdotes of how statistics had been used in history ("History") which all scored relatively low (Figure 4). There was no significant difference between the use of "Real Data" and "Simulated Data."

3.4 | Qualitative analysis of students written comments

The dominant theme across all four universities was how much students valued "*great*" staff. Many students described specific behaviors of the lecturers, tutors and demonstrators mentioning "*the approachability, helpfulness, and patience of lecturers*" (Cardiff) or "*approachable teaching team*" (La Trobe) and describing the "*kind and caring nature*" (La Trobe) of lecturers (Table 3).

The other main category of staff personality that students talked about in the comments was the "*positive attitude toward statistics*" (Leeds) or how "*positive, and enthusiastic*" (Cardiff) staff were about the subject. Such qualities were often described along with the effect they had on students' feelings toward statistics. This could be in terms of their capabilities "*much more confident in my ability*" (La Trobe) or their fears of statistics "*made it less overwhelming*" (Macquarie) or their motivation to study it:

> "He inspires me to actually care about statistics when he seems so interested and curious about it" (Cardiff).

In addition, many students suggested that the qualities or behavior of the lecturer and staff had mitigated a subject that would otherwise be "*dry and a struggle*" (Macquarie) and that staff had "*made statistics more bearable*" (Cardiff). There were comparatively few negative comments about staff behavior (Table 3). In contrast to the many comments about the lecturer's approachability and attitude that supported the high scores given to those strategies, there were very few comments on the staff's attempts at humor or when they "*made it fun*" (Leeds).

Given the reputation of statistics as a hard subject, it was perhaps not surprising to find that the difficulty level was another theme that was common across universities. This was particularly prominent in Cardiff where all students were taught the software R:

> "R affected my experience and feelings towards statistics negatively" (Cardiff).

The theme of getting help varied among and within cohorts with some students feeling like they had plenty of opportunities and could ask for help and others requesting more help, especially with coding. The small group teaching in Macquarie was appreciated by many students.

The organization of the teaching affecting students' feelings toward statistics emerged as a theme that we had not asked about in the list of strategies the students had quantitatively scored. One student commented "well run subject" (La Trobe).

Macquarie and La Trobe had themes emerge around students seeing the importance of statistics, which lecturers consciously communicated, for example:

> "This unit has opened my eyes in terms of how useful statistics can be" (Macquarie).

However, this message did not come through to all students:

> "I think the content we learned wasn't beneficial towards my learning or course" (La Trobe).

Similarly, comments on quizzes were common in only the Australian cohorts.

Comments from La Trobe students revealed that collecting data from their peers in the classroom, for example, type of phone or number of times they have visited a certain shop in the last month, was not as interesting as the datasets that were subject specific (referred to as relevant data in the quantitative questions):

> "much of the data collected in class seemed to be irrelevant" (La Trobe).

> "the Health Sciences side with regards to research questions was much more interesting" (La Trobe).

Finally, there were comments that demonstrated that the statistics support service was important for some individuals:

> "Without math hub I would not have understood as much as I did" (La Trobe).

4 | DISCUSSION

Our research suggests that students think we can positively affect their feelings toward statistics through the various teaching strategies we employed. Furthermore, there are some strategies that have a greater impact than others when it comes to making students feel better about statistics. While our results agree with other evidence that strategies such as students collecting their own data and analyzing it for themselves using software[39] or working with peers[5] are useful, they also suggest that these are not as effective as other strategies that are related to the staff. The lecturer, demonstrator, or tutor being approachable; their attitude toward statistics; and their attempts at humor and making it fun are valued particularly highly by students (Figure 3).

Our Stat-tastic slides, though not as effective as other strategies, had the desired positive effect on students' feelings toward statistics and are shared here for others to adapt (Supporting Information A). This emphasizes why our study design, which compared these interventions

against other strategies, was essential in demonstrating that there are other aspects, such as the personal qualities of the lecturer, to focus on that could be more lucrative in improving students' feelings toward statistics.

The high staff approachability scores were mirrored in the students' comments. The comments illustrate examples of mostly positive but also some negative interpersonal qualities or perceived personality traits of the staff that the students thought had affected their feelings toward statistics and their success in learning statistics. This is recorded in Higher Education outside of statistics teaching, where positive interactions between staff and students promote academic performance because students feel they are supported and can ask questions. In contrast, negative traits prevent these good learning behaviors.[18] Specifically, in statistics teaching, a connection has been made between lecturers who show more immediacy behaviors and lower levels of statistics anxiety.[43, 45] In our results, the high scores for the lecturer's pets featuring in the teaching material at Cardiff may be an example of how a lecturer could seem more approachable and relatable. It has previously been noted that there is a lack of recognition of the teacher–student relationship despite its importance to student success.[14] This may explain our initial surprise in approachability being scored highest.

Similarly, the lecturer's attitude toward statistics as a subject was scored high in this study and commented on by the students. Positive attitudes manifesting as enthusiasm and a passion toward statistics inspire students.[47] Both of these results serve as a reminder to managers in HE of the importance of recruiting approachable and passionate people into statistics teaching roles and avoiding offloading the subject onto an unwilling staff member. In addition, where there are large teaching teams, including multiple tutors and demonstrators on a statistics course, ensuring everyone is trained to understand the importance of their behavior in the classroom should reap the rewards in promoting positive student feelings toward statistics.

Compared with approachability and attitude, the third strategy that consistently scored high—attempts at humor or fun—was referred to very little in students' written comments. Using humor to teach statistics has precedent,[20] and specific examples of statistics teachers incorporating fun in the classroom include cartoons, songs, and jokes.[11, 21, 47] In this study, we suspect students had difficulty recalling specific funny or enjoyable events because different lecturers used rapport-building humor in various ways that aligned with their individual personalities to create a lighthearted atmosphere. This may have made the sense of fun less easily identifiable and less tangible than a planned joke.

Regular interactive activities such as Mentimeter or Kahoot quizzes, which yielded varied results in how much students reported they affected their feelings toward statistics, are one way we injected fun into our statistics classrooms. Other studies suggest that this is especially successful if the quiz uses engaging polling software[3] with bright colors, exciting names, and upbeat music (e.g., Kahoot.com).[37]

While collecting data for themselves is reported to be more engaging for students,[39] based on the comments we received, we would recommend that such data collection should also be relevant to the discipline of study. For many subjects, this may require more teaching time to be taken up doing this task, which may not be feasible. Related to the choices the lecturer makes about the data used, scores from Cardiff students indicated that whether the data was simulated or real did not affect how students felt about statistics.

The different software used in the universities explains the higher scores in Macquarie and La Trobe for the strategy of using statistical software on students' feelings. Comparatively, the scores were notably lower for Cardiff and Leeds. Macquarie used what is likely a more familiar software to students: Microsoft Excel. Most La Trobe students were taught Jamovi, an interface for R, while Leeds students used SPSS, both of which use "point-and-click" user interfaces. Unsurprisingly, Cardiff students gave low scores for using the software for themselves. They wrote about how the use of R was difficult, demonstrating that this can be challenging for students, especially if they are unfamiliar with programming languages.[42] Teaching R can be the right choice as it gives students sought-after skills in coding.[9] Being aware of the effects of that choice on how it makes students feel toward statistics is helpful, so lecturers can try to mitigate this. This mitigation could include following best practices for teaching R, for example, delivering participatory code-along sessions where the students see the lecturer making mistakes[26] and providing adequate time and scaffolding to learn coding skills.[19]

It has been previously found that following attendance at support services, students have reduced statistics anxiety.[25] While in this study attending drop-in support services was perceived as having a positive effect on students' feelings, it was scored lower than other strategies. However, this is because of the lack of students, especially at Leeds, engaging with such services. Where students reported that they did engage, most commonly in La Trobe, they commented that it was essential to their understanding of the subject.

4.1 | Limitations and strengths of the study

We acknowledge that students' reported feelings toward statistics is not measured accurately because we relied on them remembering how they felt at the start of their teaching. Furthermore, we are aware that students' answers to these questions may have been biased by a desire to fulfill the researchers' or even the students' own expectations that they would feel more positive about statistics at the end of teaching. Most of our respondents were in their first year of university study, limiting the applicability of the results.

With evidence from a previous study where students reported that the statistics anxiety workshop helped them (unpublished), an experimental design where some students did not receive this information in a control group was considered unethical and rejected. Furthermore, this would not have allowed us to compare the slides to other strategies which we hope will help other statistics teachers decide where to put their resources for maximum benefit. The strength of our study also lies in the number of universities that took part, which increases the generalizability of the results. The varying order of highest scores among the universities demonstrates that the same interventions will vary in their rankings, perhaps due to specific lecture style or institutional differences. The comparison between the two La Trobe cohorts shows that even when strategies are implemented in the same way, they can be received differently depending on the cohort.

5 | CONCLUSION

Our results show that overall, students appreciate our attempts to improve their perception of statistics and find various different interventions useful. Furthermore, given our results represent students from multiple institutions, we hope other statistics lecturers are more convinced that having a positive attitude toward statistics and being both approachable and enthusiastic are universally the best ways to improve students' perceptions of statistics.

AUTHOR CONTRIBUTIONS

ACR, AJS, and EM conceived and designed the analysis; ACR, AJS, WPK, and KPB collected the data; ACR, AJS, WPK, and KPB performed the analysis; ACR, AJS, EM, WPK, and KPB wrote and edited the manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data for three of the four universities https://osf.io/6fdnu and R code https://osf.io/ax8du used in the study is available online.

ETHICS STATEMENT

The study was ethically approved in each of the four universities by their respective ethics boards under the following numbers: Macquarie HREA-16687; La Trobe HEC23021; Cardiff SREC 23 10-01; Leeds BIOSCI 13-001.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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