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Fear of the unknown: Relationship between statistics anxiety and attitudes toward statistics of university students in three countries

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Abstract

In an increasingly data-driven world, statistical literacy is a necessity yet statistical learning is often inhibited by statistics anxiety. Using the Auzmendi Scale to Measure Attitude toward Statistics (ASMAS), this study examines how statistics anxiety in university students is related to other dimensions of their attitudes toward statistics and how statistics anxiety and other dimensions change following introductory statistics instruction. Based on data collected from Spain, Canada, and Australia, this study finds that anxiety is negatively related to security–confidence, pleasantness, and motivation. The structure of these relationships is consistent across countries and disciplines and remains in place after statistics instruction. Further, by the end of an introductory statistics course, students report higher security–confidence and pleasantness but lower anxiety. Results thus suggest where efforts to improve students' experience with statistics might need to be directed, and the paper concludes with a discussion of the implications of these results for statistics instruction.

KEYWORDS

attitudes toward statistics, statistics anxiety, statistics instruction, teaching statistics

1 | INTRODUCTION

Statistics underpins many tools and processes used for data analysis across a broad range of disciplines, from science and technology to policy and business. Given the growing role of artificial intelligence (AI) in many areas of life, including education, statistics has an important role to play in the development of AI systems, specifically study design, assessment of data quality, distinction between causality and association, and quantifying certainty of results.[1] However, it is well documented that many people who need and use statistics experience statistics anxiety,[2] which is characterized by feelings of fear, tension, and nervousness toward statistics, and has been shown to be a barrier to learning statistics and engaging with the subject.[3,4]

The widespread need for statistical literacy is reflected in the incorporation of statistics courses across many academic disciplines, including those that are stereotypically perceived by students as not quantitative such as management, education, or sociology. For these disciplines, as well as psychology, health, and other areas of business, learning statistics is seen as essential for developing into skilled professionals or future researchers, yet students tend to be surprised by the inclusion of statistics in the curriculum.[5] As mentioned in Ref. 6 regarding psychology students, and based on our own teaching experiences in health and business, statistics often evokes memories of school-level mathematics that students believed they had left behind for good. It can feel disproportionately quantitative compared to how they perceive the subject they have chosen (e.g., psychology) or markedly distinct from their recollection of mathematics from their school days. To underscore its significance and establish connections with the discipline, statistical concepts are usually integrated within a disciplinary context. The emphasis is on interpreting data and drawing conclusions to enhance comprehension. Despite the importance and efforts to put statistics in context, it is well documented that students have negative attitudes toward statistics; in fact, they fear it.[7–9] Moreover, first year of a university degree is typically when students encounter statistics as a discipline for the first time and research has shown that students perceive statistics as challenging and irrelevant.[10] The mandatory inclusion of statistics in their degree program often triggers statistics anxiety among students, which is recognized for its detrimental impact on both engagement and academic performance.[4,5,11–17] While related to mathematics anxiety, statistics anxiety has been confirmed as a distinct construct reflecting differences in cognitive processes involved in learning statistics, such as thinking about probabilities and learning a new language for working with data to understand social phenomena, behavior, and insights.[8,16,18] However, compared to mathematics anxiety, statistics anxiety has received much less attention, and the underlying mechanisms are yet to be fully understood.[19]

Perkun's control-value theory[20] offers a framework for understanding why students might grapple with anxiety when confronted with statistics in their university curriculum. According to this theory, academic emotions can be separated into two types of appraisals in achievement settings; those linked to self-confidence and expectations for success (control) and those linked to value (level of importance ascribed to the task). These emotions influence learners' motivation to learn and their learning strategies, which in turn influences their learning outcomes. Based on this theory, anxiety is experienced in learning settings when students perceive that they have low control and highly value the subject. In particular, the control-value theory proposes that lower control leads to higher anxiety and higher anxiety can reinforce a belief in lower control. Supporting evidence for these propositions in the context of classroom-related mathematics anxiety can be found in Ref. 21. Additionally, Bandura's social cognitive theory[22] underscores the significance of self-efficacy—the belief in one's capability to perform tasks. Research indicates that students with high levels of mathematics anxiety often exhibit low self-efficacy.[23–25] Furthermore, students lacking prior exposure to statistics, particularly those with weaker quantitative backgrounds, may lack confidence in their ability to undertake statistical analyses.[3,26] Yet, they might feel pressured to excel, especially if statistics courses are mandatory for program completion. This scenario mirrors the low control/high-value dynamic described by Pekrun's theory, thus fostering anxiety.

Building upon previous research on mathematics anxiety,[27] statistics anxiety can be viewed as just one facet within the broader spectrum of students' attitudes toward statistics. This perspective aligns with the notion of a multidimensional construct, encapsulating individuals' "disposition to respond favourably or unfavourably to objects, situations, or people related to statistics learning."[28] Numerous studies and instruments have attempted to address the complex nature and the underlying dimensions that form students' attitudes toward statistics. A systematic review of proposed survey instruments can be found in Ref. 29 and a further discussion of the need to distinguish between statistics anxiety and attitude toward statistics in Ref. 8. One of the proposed scales is the Auzmendi Scale to Measure Attitude toward Statistics (ASMAS[11,30–32]), which considers five dimensions: (1) pleasantness (perception of enjoyment with statistics problem solving); (2) anxiety (fear experienced facing statistics); (3) value–utility (value and usefulness perceived of statistics); (4) security–confidence (self-security and self-confidence when dealing with statistics); and (5) motivation (desire to study and use statistics). This scale, originally designed in Spanish and subsequently translated and adapted to English,[32,33] forms the basis for the work herein of exploring the relationship between statistics instruction and students' attitudes toward statistics. A better understanding of that relationship could provide valuable insights into the conditions that promote or inhibit statistics anxiety. In turn, this has direct implications for creating more positive attitudes toward statistics and encouraging more effective statistical learning.

In this study, we investigate the dimensions of students' attitudes toward statistics and their relationship with anxiety, as well as the broader impact of exposure to statistics instruction. To ascertain the generalizability or cultural specificity of our findings, our study draws upon university students from three distinct countries. We investigate shifts in these relationships subsequent to introductory statistics training, and we discuss pedagogical implications for classroom instruction in light of our findings. Thus, our study has two primary objectives: first, to elucidate the interplay between anxiety and other dimensions of attitudes toward statistics, and second, to examine how (and whether) these relationships evolve following statistics instruction, aiming to provide insights to potentially mitigate statistics anxiety more effectively.

2 | STUDY DESIGN

2.1 | Participants

Two hundred and eighty students across Spain, Australia, and Canada participated voluntarily in this study by completing an online questionnaire during the first week of the course and then again during the final week. Study participants were recruited from students enrolled in statistics courses as part of the requirements of their chosen degree of study: business (e.g., accounting, business law, and management) and clinical health disciplines (e.g., pharmacy) in Australia, sociology in Canada, and psychology in Spain. Students were mostly in their first (Australia) or second (Canada and Spain) year of study and like others before them, brought some mixed feelings and a degree of apprehension about studying statistics, making them ideal candidates to study attitudes toward statistics. Students were thanked for their participation and in the case of Australia and Canada, received additional nominal course credit for completing the surveys. The study was approved by local ethics committees and abided by the principles stated in the American Psychological Association code of ethics.[34]

Key demographics of the sample are shown in Table 1. The majority of study participants were female (76%), which is representative of the student population in the university courses selected for the study in Spain (psychology) and Canada (sociology). In the health course in Australia, approximately two-thirds of students enrolled are female while in the business course, the majority of students are typically male (approximately two-thirds), so the self-selected survey participants in those disciplines do not adequately represent the student populations. Despite wide range of ages in the study sample, participants were very similar in age, with the majority (92%) under 23 years old.

2.2 | Curriculum variation across disciplines

For all students participating in the study, completing a statistics or more broadly quantitative methods course was a requirement in recognition of the importance of data literacy and knowledge of fundamental data analysis tools for their chosen disciplines (business, health, psychology, and sociology). Students in the business course in Australia learned some business mathematics concepts (e.g., time value of money) plus statistics concepts such as collecting, summarizing and displaying data, correlation and simple linear regression, elementary probability concepts, normal distribution, elementary statistical estimation, and hypothesis testing (up to a one-sample z-test). Sociology students in Canada were further introduced to one- and two-sample t-tests, measures of association for categorical data, tables, and chi-square. For health and psychology students, the statistics curriculum also included analysis of variance and for health students only, nonparametric techniques, types of experimental design, internal and external validity, and study power. The teaching and learning arrangements included lectures and workshops where statistical concepts, theory, and examples were presented, complemented by either tutorials (business) or practical sessions (health, psychology, and sociology) to give students an opportunity to apply statistical concepts to real data problems and to use statistical analysis software: Excel in business, Minitab in health, SPSS in sociology, and R in psychology. There was a single course and primary instructor per discipline, with the primary instructor having full responsibility for the course structure and design, resulting in data from four courses and four instructors consisting of one course and instructor in Canada, one course and instructor in

TABLE 1 Demographic information about the participants in the study: discipline (psychology, sociology, business, and health) and country (Australia, Canada, or Spain), in which an introductory statistics course was undertaken, gender (male or female), age (years).

	Gender count ($Mdn_{age} \pm$ MAD) [$range_{age}$]			Age	
Discipline (Country)	**Males**	**Females**	**Total**	**Range**	**Mdn ± MAD**
Psychology (Spain)	8 (19 ± 1) [18–26]	29 (20 ± 1) [18–26]	*37*	18–26	19.5 ± 0.5
Sociology (Canada)	32 (20 ± 1) [18–27]	128 (20 ± 1) [18–28]	*160*	18–28	20 ± 1
Business (Australia)	14 (20 ± 1) [18–28]	14 (19.5 ± 0.5) [18–44]	*28*	18–44	20 ± 1
Health (Australia)	13 (20 ± 2) [18–28]	42 (19 ± 1) [17–52]	*55*	17–52	19 ± 1
Total			280		
Total (gender)	Males = 67	Females = 213			
Total age range				17–52	
Total $Mdn_{age} \pm$ MAD					20 ± 1

Abbreviations: MAD, median absolute deviation; Mdn, median.

Spain, and two courses and two instructors in Australia. All four courses had at least one timed exam-type component contributing from 50% (health and business) to 70% (psychology) toward the final grade, which consisted of multiple-choice and related question types in sociology and psychology and scenario analysis questions in business and health. In addition to an exam, psychology students were assessed on their practical work and class attendance, while in business and health, students were given weekly quizzes and completed two report-style data analysis tasks. In sociology, in addition to exam-type assessments, students were graded on weekly assignments focused on reviewing key concepts and practicing data analysis, in-class exercises, and discretionary "learning point" activities.

2.3 | Survey instrument

The ASMAS introduced in Ref. 11 is composed of 25 items grouped into five dimensions: value–utility (val), pleasantness (ple), anxiety (anx), motivation (mot), and security–confidence (sec). Items are scored using a 5-point Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree"; see Appendix A). For the purposes of the current study, participants completed the ASMAS questionnaire twice, during the first week (first time point) of the course and then again during the final week (second time point).

A principal component analysis[35] with varimax rotation was conducted at each time point. The analysis indicated a five-factor structure, capturing 63.2% (first time point) and 66.5% (second time point) of the variance in the 25 items. Extracted factors largely corresponded to the original Auzmendi scale,[11] with some redistribution of items and items mapping onto more than one factor, also reported in Ref. 36. The overall internal consistency (Cronbach's alpha) observed for the scale was 0.92 (first time point) and 0.94 (second time point). The component internal consistency for the original scale (five questions per dimension) ranged from 0.64 (first time point) and 0.66 (second time point) for motivation to 0.89 (first time point) and 0.92 (second time point) for anxiety. Similar internal consistency indices ranging from 0.66 to 0.88, with an overall internal consistency of 0.90 are reported in Ref. 36.

Following survey administration at the beginning of the course and then at the end, dimension scores for anxiety (anx), motivation (mot), security–confidence (sec), value–utility (val), and pleasantness (ple), together with the overall ASMAS score, were obtained for each student using the original Auzmendi[11] groupings of survey items.

2.4 | Analysis methods

The methods utilized to conduct the analyses in this study include visual exploration of the distributions and relationships using boxplots, bar plots, mosaic plots, correlograms, and regression line plots, and general linear modeling to investigate the statistical significance of observed relationships. Data visualizations were created in RStudio and SAS Studio, and general linear modeling was performed using PROC GLM in SAS Studio.

Since participants for the study were recruited from four disciplines across three countries, there is a natural hierarchy in the data so multilevel modeling approach would normally be considered for assessing the statistical significance of relationships observed in the data. However, given that our study includes only three countries, the scope for multilevel modeling is limited. Consequently, general linear modeling was performed with disciplines as fixed effects.[35,37,38]

3 | RESULTS

3.1 | Correlation structure of relationships among ASMAS dimensions

The relationships among the ASMAS dimensions for the four disciplines: business (Australia), health (Australia), sociology (Canada), and psychology (Spain) are shown in Figures 1–4. The anxiety dimension was negatively related to motivation, value-utility, security–confidence, and pleasantness. In all disciplines and countries, the strongest negative correlation (and largest effect size) was recorded between anxiety and security–confidence. This is what we would expect, namely that students with less confidence in their ability to do well when it comes to learning statistics would feel more anxious about having

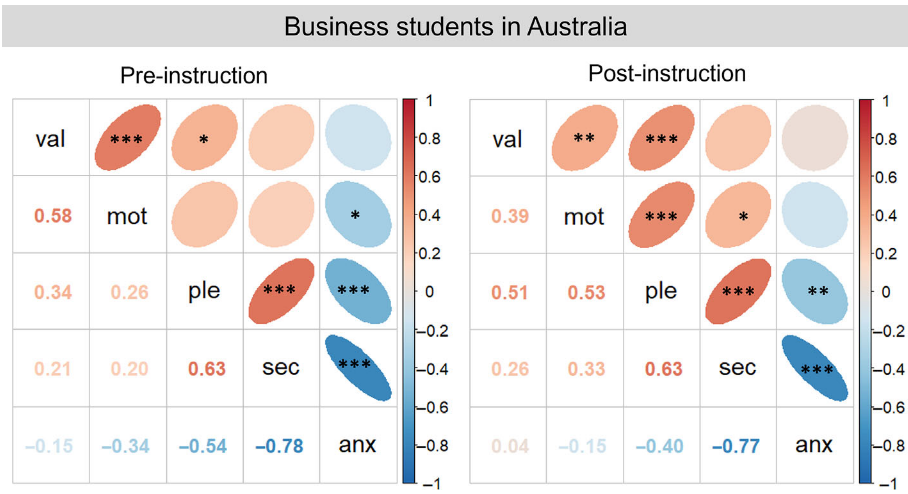


FIGURE 1 Pearson correlation structure among pre-instruction ASMAS dimension scores (i.e., first time point) among post-instruction ASMAS dimension scores (i.e., second time point) for business students in Australia. Asterisks indicate the statistical significance of the corresponding correlation coefficients (***$p < 0.01$; **$0.01 < p < 0.05$, *$0.05 < p < 0.10$). Correlations were calculated using individual participants' scores on each of the five ASMAS dimensions: anxiety (anx), motivation (mot), pleasantness (ple), security–confidence (sec), and value–utility (val). ASMA, Auzmendi Scale to Measure Attitude toward Statistics. [Color figure can be viewed at wileyonlinelibrary.com]

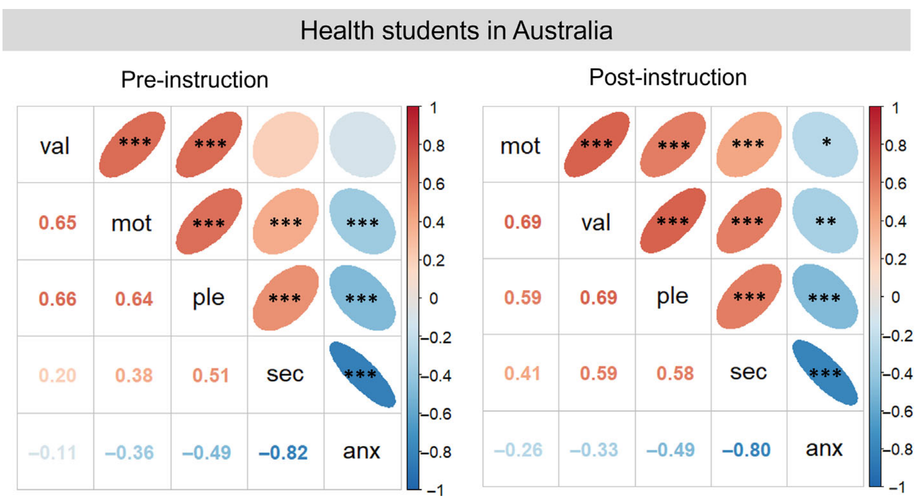


FIGURE 2 Pearson correlation structure among pre-instruction ASMAS dimension scores (i.e., first time point) and post-instruction ASMAS dimension scores (i.e., second time-point) for health students in Australia. Asterisks indicate the statistical significance of the corresponding correlation coefficients (***$p < 0.01$; **$0.01 < p < 0.05$; *$0.05 < p < 0.10$). Correlations were calculated using individual participants' scores on each of the five ASMAS dimensions: anxiety (anx), motivation (mot), pleasantness (ple), security–confidence (sec), and value–utility (val). ASMAS, Auzmendi Scale to Measure Attitude toward Statistics. [Color figure can be viewed at wileyonlinelibrary.com]

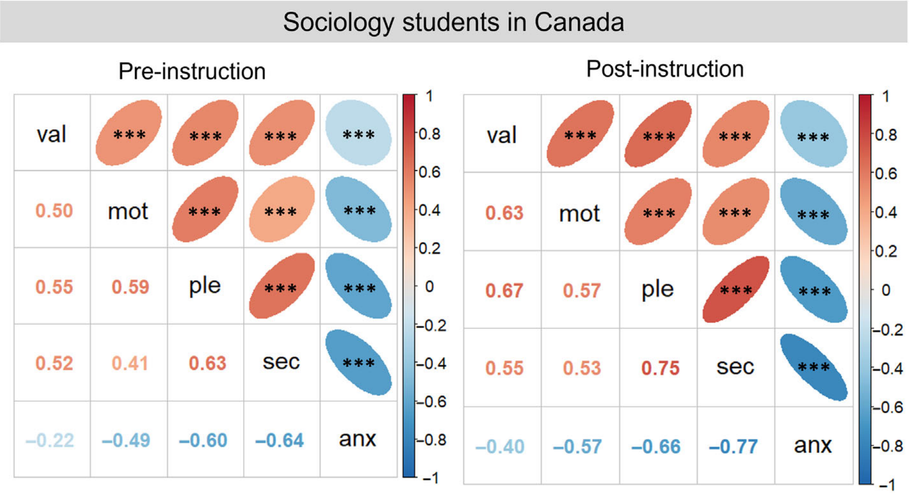


FIGURE 3 Pearson correlation structure among pre-instruction ASMAS dimension scores (i.e., first time point) and post-instruction ASMAS dimension scores (i.e., second time-point) for sociology students in Canada. Asterisks indicate the statistical significance of the corresponding correlation coefficients (***$p < 0.01$; **$0.01 < p < 0.05$; *$0.05 < p < 0.10$). Correlations were calculated using individual participants' scores on each of the five ASMAS dimensions: anxiety (anx), motivation (mot), pleasantness (ple), security–confidence (sec), and value–utility (val). ASMAS, Auzmendi Scale to Measure Attitude toward Statistics. [Color figure can be viewed at wileyonlinelibrary.com]

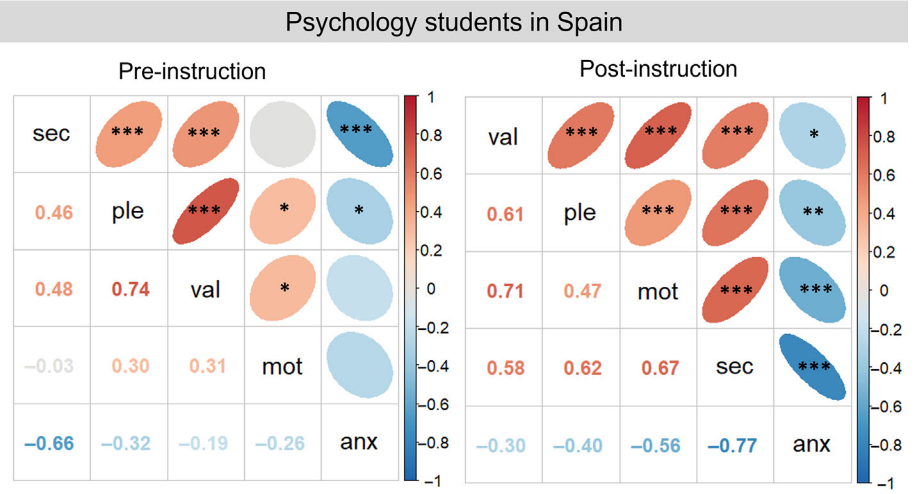


FIGURE 4 Pearson correlation structure among pre-instruction ASMAS dimension scores (i.e., first time point) and post-instruction ASMAS dimension scores (i.e., second time point) for psychology students in Spain. Asterisks indicate the statistical significance of the corresponding correlation coefficients (***$p < 0.01$; **$0.01 < p < 0.05$; *$0.05 < p < 0.10$). Correlations were calculated using individual participants' scores on each of the five ASMAS dimensions: anxiety (anx), motivation (mot), pleasantness (ple), security–confidence (sec), and value–utility (val). ASMAS, Auzmendi Scale to Measure Attitude toward Statistics. [Color figure can be viewed at wileyonlinelibrary.com]

to take a statistics course. Relationships among pleasantness, security–confidence, value-utility, and motivation were all positive with the strongest positive correlations involving pleasantness and security–confidence, which is also in line with expectations.

Correlation plots in Figures 1–4 also show that while directions of relationships among ASMAS dimensions were generally the same across the two time points, the strength of relationships differed across time and disciplines. Correlation coefficient estimates corresponding to the end of statistics instruction were larger in absolute value and statistically significant. In terms of differences among the four disciplines, at the beginning of instruction, only some relationships among ASMAS dimensions

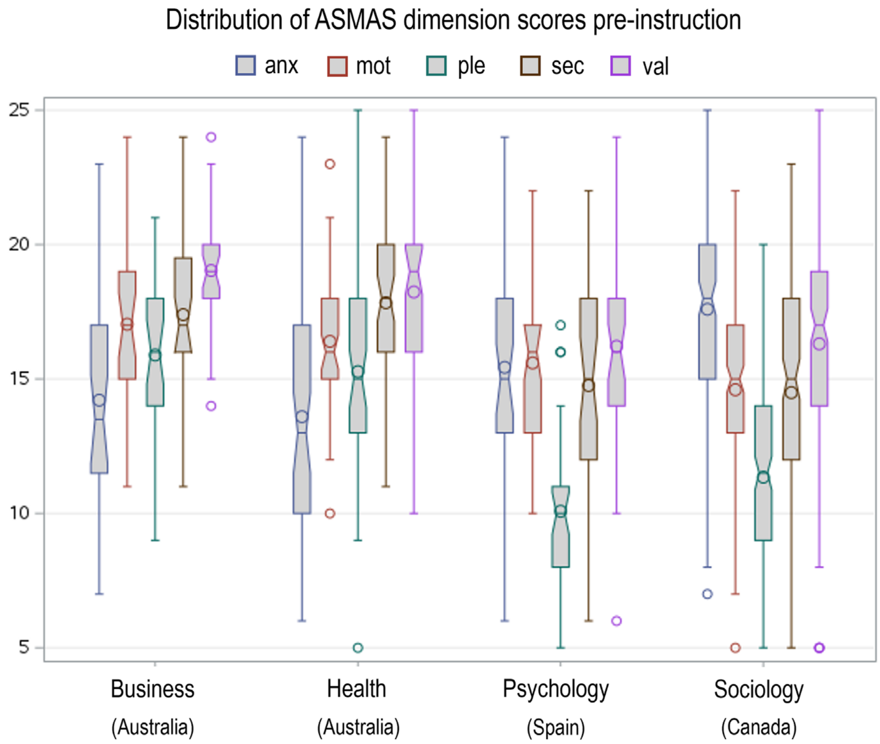


FIGURE 5 Distribution of ASMAS dimension scores at the beginning of instruction, by discipline. ASMAS, Auzmendi Scale to Measure Attitude toward Statistics. [Color figure can be viewed at wileyonlinelibrary.com]

were statistically significant, particularly for business students in Australia (see Figure 1) and psychology students in Spain (Figure 4). Note, however, that business has only 28 respondents and psychology only 37, so differences in results for those two groups of participants might just reflect the greater uncertainty of the estimates. Correlation coefficients at the end of statistics instruction were generally much more similar across the four disciplines.

Relationships that stand out the most by being the strongest for all four disciplines are the negative association between anxiety and security–confidence and the positive association between security–confidence and pleasantness. This suggests that together with anxiety, pleasantness, and security–confidence may be the most important dimensions of students' attitudes toward statistics.

3.2 | Distribution of ASMAS dimension scores before and after statistics instruction

It is also interesting, and instructive, to examine the distributions of scores for the five dimensions comprising the overall ASMAS score, namely anxiety (anx), motivation (mot), pleasantness (ple), security–confidence (sec), and value–utility (val), all measured on the scale from Min = 5 to Max = 25.

3.2.1 | Distribution of ASMAS dimension scores by discipline

Distributions of dimension scores across the four disciplines (business and health in Australia, psychology in Spain, and sociology in Canada) before and after statistics instruction are shown in Figures 5 and 6.

Both figures show a high degree of spread in dimension scores, particularly in sociology. There are also two distinct patterns in the positioning of the distributions. In business and health at the beginning of statistics instruction, anxiety scores were quite variable but relatively lower than scores on other dimensions, particularly security–confidence and value-utility. Also lower were pleasantness scores suggesting that overall, business and health students in Australia were not particularly worried about having to take a statistics course as part of their degree, saw value in learning statistics, and were quite motivated and reasonably confident in their ability to master the subject but unsure if they were going to enjoy the experience. The pattern was largely unchanged at the end of instruction, with pleasantness scores moving up in both business and health, plus anxiety scores becoming less variable in health. In contrast, for students in psychology and sociology, anxiety scores at the beginning of instruction (Figure 5) were higher and on par with value-utility, with pleasantness scores distinctly lower than other dimension scores, and much lower than pleasantness scores

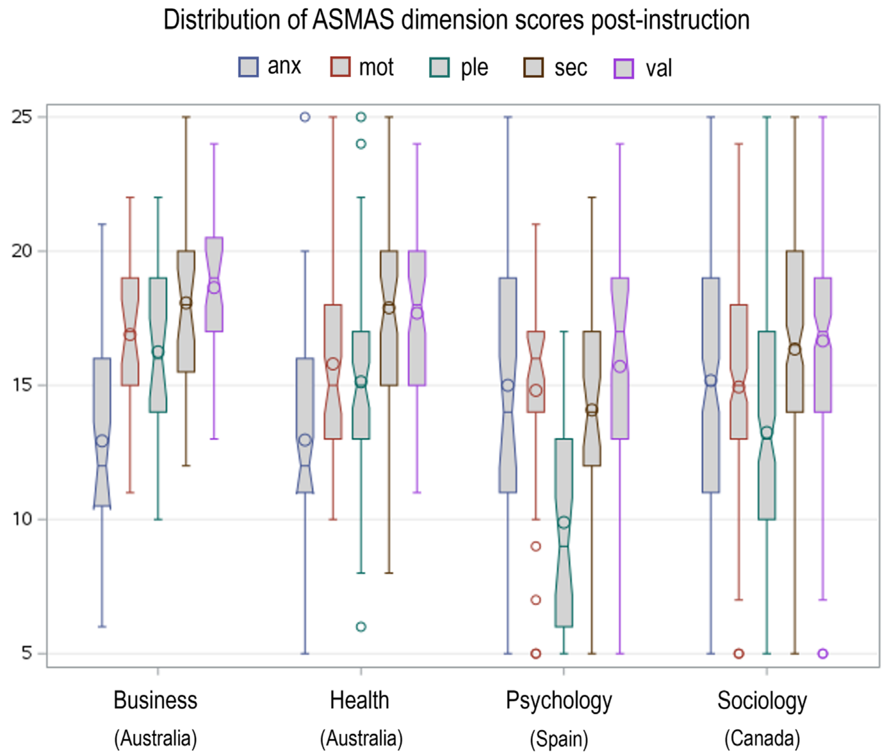


FIGURE 6 Distribution of ASMAS dimension scores at the end of instruction, by discipline. ASMAS, Auzmendi Scale to Measure Attitude toward Statistics. [Color figure can be viewed at wileyonlinelibrary.com]

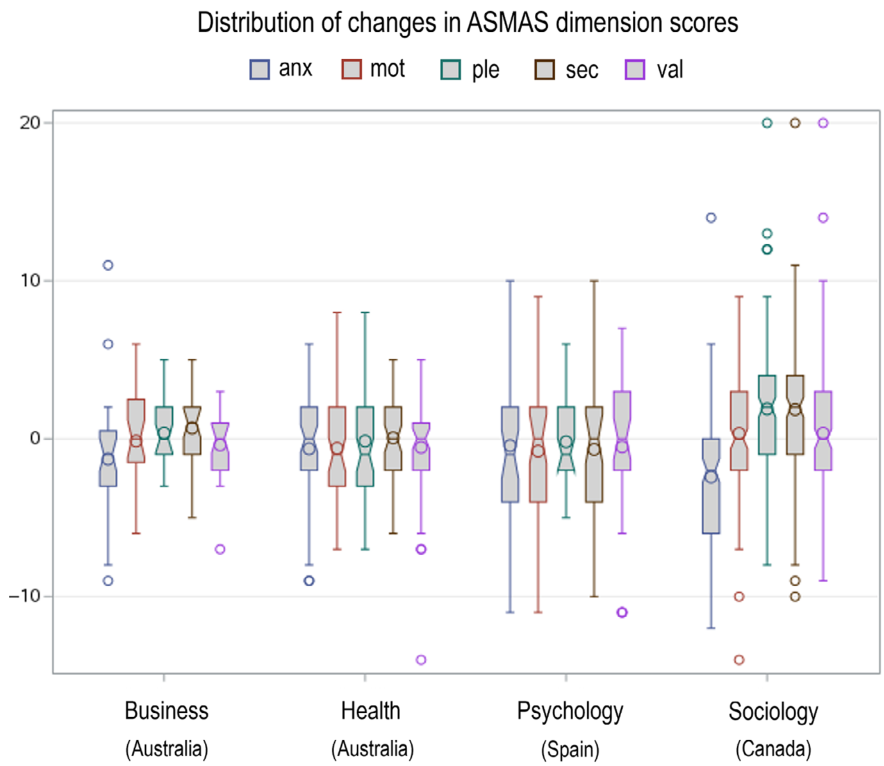


FIGURE 7 Distribution of change ASMAS dimension scores (end-of-course values minus beginning-of-course values), by discipline. Values below zero indicate a negative effect of statistics instruction and values above zero indicate a positive negative effect of statistics instruction. ASMAS, Auzmendi Scale to Measure Attitude toward Statistics. [Color figure can be viewed at wileyonlinelibrary.com]

in business or health. Pleasantness scores in psychology were particularly low while anxiety scores were particularly high in sociology. For psychology students, patterns of dimension scores at the end of instruction (Figure 6) were similar for anxiety and pleasantness showing more variability. For students in sociology, however, the pattern has changed somewhat showing more variability across all dimensions, plus a decrease in anxiety scores and an increase in pleasantness scores.

Further insights can be gained by examining the distributions of the change in dimension scores shown in Figure 7. There are again two distinct patterns, one for

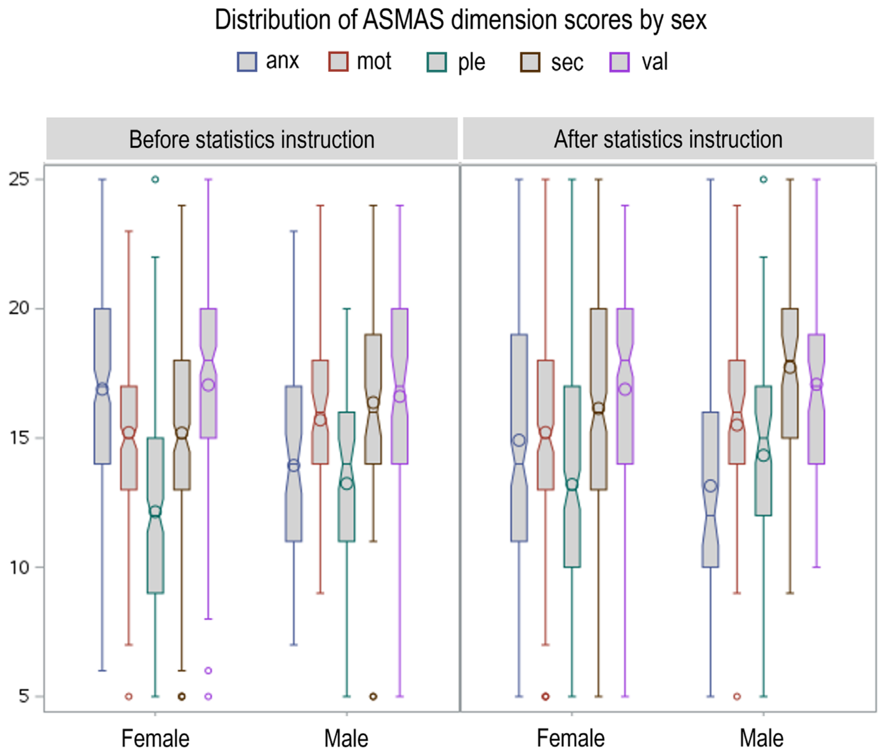


FIGURE 8 Distribution of ASMAS dimension scores at the beginning and end of instruction, by sex. The five ASMAS dimensions are as follows: anxiety (anx), motivation (mot), pleasantness (ple), secure–confidence (sec), and value–utility (val), each with the range from 5 to 25. ASMAS, Auzmendi Scale to Measure Attitude toward Statistics. [Color figure can be viewed at wileyonlinelibrary.com]

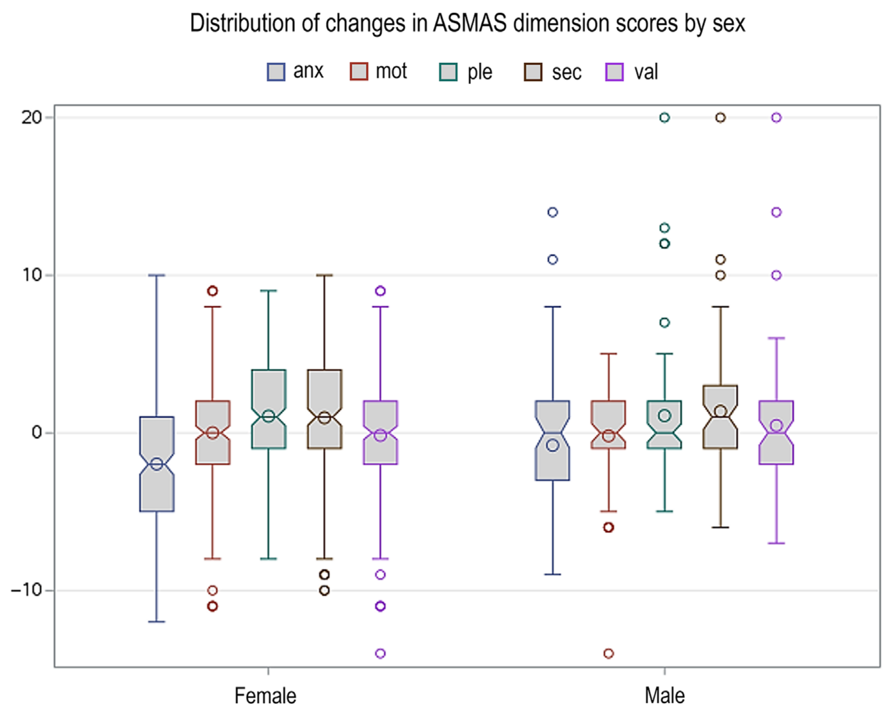


FIGURE 9 Distribution of differences in ASMAS dimension scores (end-of-course values minus beginning-of-course values), by sex. Values below zero indicate a negative effect of statistics instruction and values above zero indicate a positive negative effect of statistics instruction. ASMAS, Auzmendi Scale to Measure Attitude toward Statistics. [Color figure can be viewed at wileyonlinelibrary.com]

students in health and psychology and another for students in business and sociology. Changes in dimension scores for health and psychology are either centered at zero or slightly below zero, indicating no or a slightly negative effect of statistics instruction on average for all dimensions. For sociology students and to a lesser extent for business students, the distribution of changes in anxiety scores is centered below zero suggesting a decrease in anxiety following instruction. For pleasantness and security–confidence, distributions of the changes suggest an improvement following instruction and for motivation and value-security, there appears to be no change on average. It should be noted, however, that there is a lot of variability in the distributions of the

TABLE 2 Results for a model with fixed effects of discipline (business, health, psychology, and sociology), sex (female and male), age, ASMAS dimension (anxiety, motivation, value-utility, security–confidence, and pleasantness), time (time of survey), and an interaction term between dimension and time of survey (score ~ discipline + sex + age + dimension*time).

Variable	Degrees of freedom	*F*-value	*p*-value	Partial eta-squared	Effect size
Discipline	3	29.03	<0.0001	0.031	Small
Sex	1	1.00	0.32	0.000	
Age	1	0.22	0.64	0.000	
Dimension	4	75.60	<0.0001	0.099	Medium
Time	1	0.18	0.67	0.000	
Time × dimension	4	10.98	<0.0001	0.016	Small
Total degrees of freedom	2778		*R*-squared	0.1361	
			Cohen's f^2	0.1576	Medium

Note: The response variable is the dimension score (Min = 5, Max = 25). Partial eta-squared is the proportion of variance explained by a given variable after accounting for variance explained by other variables in the model.[39] Cohen's f^2 measures the size of the effects for the model overall and is defined as the proportion of variance explained by the model (R^2) over the proportion of variance not explained by the model ($1 - R^2$).[40]
Abbreviation: ASMAS, Auzmendi Scale to Measure Attitude toward Statistics.

changes, including some extreme values in sociology, so the experience of individual students with statistics instruction was quite varied.

3.2.2 | Distribution of ASMAS dimension scores by sex

We now turn our attention to differences, if any, in attitudes toward learning statistics of female and male students. Distributions of ASMAS dimension scores for anxiety (anx), motivation (mot), pleasantness (ple), security–confidence (sec), and value–utility (val) by sex are shown in Figure 8 and the distributions of the change in dimension scores by sex in Figure 9.

There is a different pattern for females and males before statistics instruction, most notably higher anxiety scores and lower pleasantness scores for females compared to males. Following statistics instruction, differences between females and males are much less pronounced, although there is more spread in dimension scores for females, particularly in anxiety scores. Being exposed to statistics instruction appears to have generally lowered anxiety scores and improved pleasantness as well as security–confidence scores for female students. For male students, there does not appear to be much change in the distributions of dimension scores following statistics instruction.

3.2.3 | Statistical significance of changes in ASMAS dimension scores

Exploratory analysis of survey results presented thus far suggested some differences in the effect of statistics instruction on ASMAS dimension scores, in particular anxiety, pleasantness, and security–confidence. Results of statistical significance testing of the effects of age, sex, discipline, and time of survey on ASMAS dimension scores using a general linear model are shown in Table 2. Main effects of sex, age, and time of survey were not statistically significant. There was, however, a statistically significant main effect of discipline, explaining 3% of total variance after accounting for other effects included in the model. Another statistically significant effect was due to ASMAS dimensions (10% of total variance explained) and the interaction between the time of survey and ASMAS dimensions (3% of total variance explained), suggesting significant differences in the effect of statistics instruction on at least one of dimensions of students' attitudes toward statistics. The estimated effect size for the model overall was 0.1576 (medium effect).

The mean changes in ASMAS scores across the dimensions are illustrated in Figure 10. On average, there was an increase (one point on average) in pleasantness and security–confidence following statistics instruction and a decrease on average in anxiety scores (a decrease of 1.7 points on average). There was effectively no change in motivation or value–utility scores on average.

3.3 | Relationship between ASMAS dimension scores before and after statistics instruction

The analysis thus far assumed that there was a simple shift in survey scores following statistics instruction and there was a one-to-one relationship between pre- and post-instruction scores for all dimensions. However,

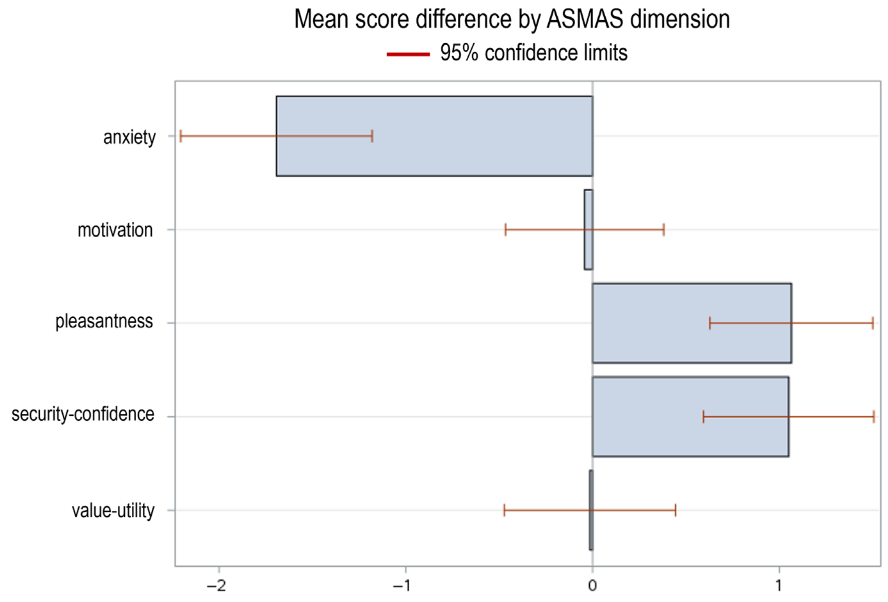


FIGURE 10 Mean change in score (end-of-course values minus beginning-of-course values) by ASMAS dimension. ASMAS, Auzmendi Scale to Measure Attitude toward Statistics. [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 3 Results for a model relating scores at the end of statistics instruction and the beginning of statistics instruction with additional predictors of discipline (business, health, psychology, and sociology), sex (female and male), age, ASMAS dimension (anxiety, motivation, value-utility, security–confidence, and pleasantness), and an interaction term between scores at the beginning of instruction and ASMAS dimension (score_post ∼ score_pre*dimension + sex + age + discipline).

Variable	Degrees of freedom	*F*-value	*p*-value	Partial eta-squared	Effect size
Dimension	4	5.41	0.00	0.016	Small
Discipline	3	5.40	0.00	0.012	Small
Sex	1	1.33	0.25	0.001	
Age	1	1.88	0.17	0.001	
Score_pre	1	471.31	<0.0001	0.255	Large
Score_pre × dimension	4	3.10	0.01	0.009	Negligible
Total degrees of freedom	1387		*R*-squared	0.3678	
			Cohen's f^2	0.5818	Large

Note: Partial eta-squared is the proportion of variance explained by a given variable after accounting for variance explained by other variables in the model.[39] Cohen's f^2 measures the effect size for the model overall and is defined as the proportion of variance explained by the model (R^2) over the proportion of variance not explained by the model ($1 - R^2$).[40]
Abbreviation: ASMAS, Auzmendi Scale to Measure Attitude toward Statistics.

the relationship between the survey scores before and after statistics instruction may be more complex. A general linear model (fixed effects only) was fitted again with the ASMAS dimension score at the end of the course as the response variable and the ASMAS dimension score at the beginning of the course plus age, sex, discipline, and ASMAS dimension (categorical variable) as predictors. Results are shown in Table 3.

Scores from the beginning of the course significantly predicted scores at the end of the course (25.5% of total variance explained after accounting for other variables in the model; large effect). There was a significant effect of discipline (small effect), ASMAS dimension categories (small effect), and a significant interaction between ASMAS dimension and scores from the beginning of the course (negligible effect). Age and sex were not statistically significant. The effect size for the model overall was 0.5818 making it a large effect overall. In practical terms, these results suggest that prior attitudes toward statistics are an important factor in explaining how students feel about it at the end of a course. The students' experience in a statistics course is, unsurprisingly, a reflection of their prior beliefs and experience.

Relationships between pre- and post-instruction scores across the five ASMAS dimensions are shown in Figure 11. Since all slopes are less than one, our results indicate that at least on average, statistics instruction has the effect on narrowing differences in scores for all

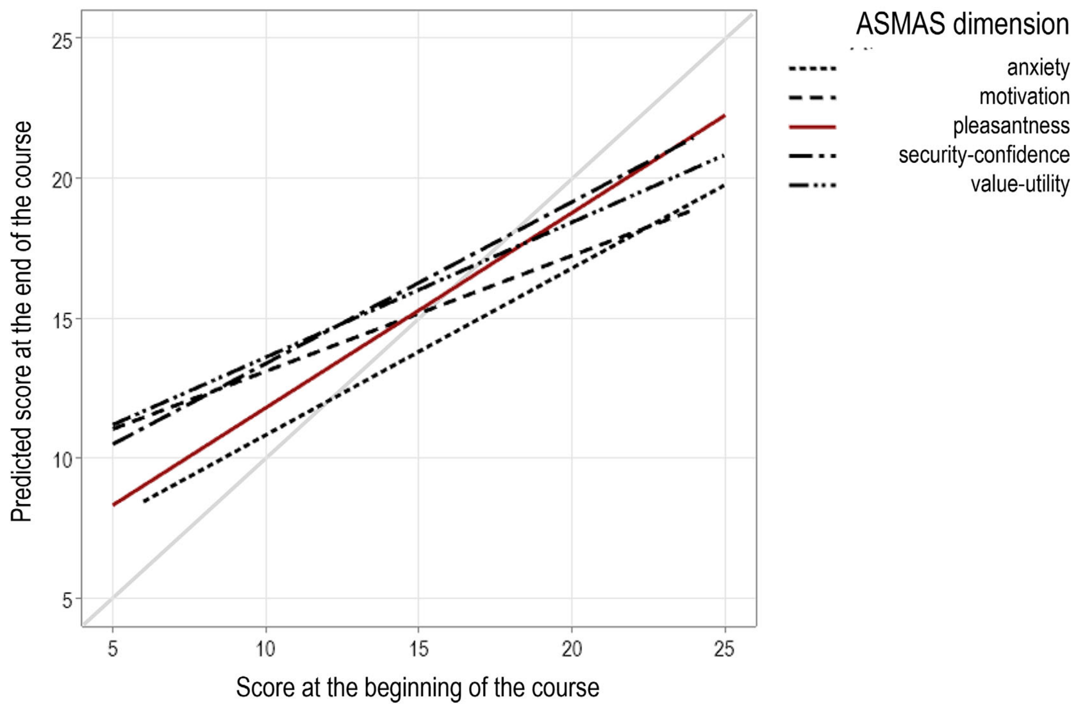


FIGURE 11 Predicted end-of-course ASMAS dimension scores (i.e., second time point) plotted against the ASMAS dimension scores at the beginning of the course (i.e., first time point), by ASMAS dimension: anxiety, motivation, pleasantness, security–confidence, and value-utility. The ASMAS dimension with the steepest slope is pleasantness, indicated in red. ASMAS, Auzmendi Scale to Measure Attitude toward Statistics. [Color figure can be viewed at wileyonlinelibrary.com]

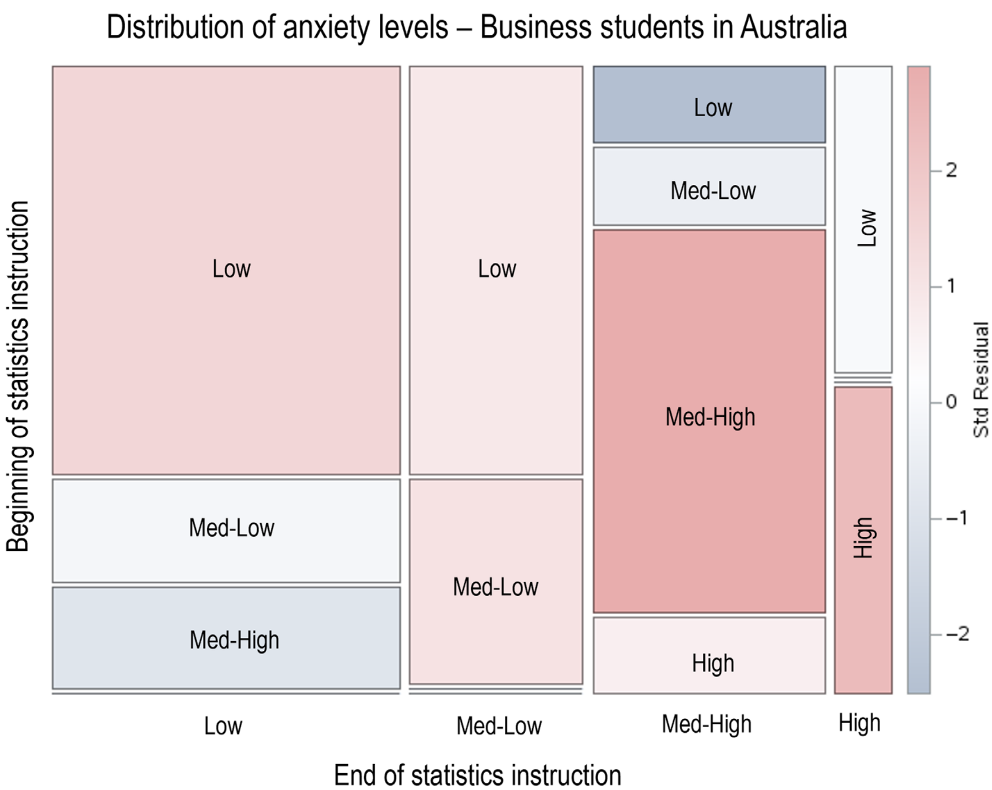


FIGURE 12 Relationship between anxiety scores pre- (first time point) and post-statistics instruction (second time point) for business students in Australia. [Color figure can be viewed at wileyonlinelibrary.com]

dimensions. The only dimension for which large differences can remain post-instruction is pleasantness, confirming the importance of the affective domain when attempting to influence students' attitudes toward statistics. From Figure 6, we know that pleasantness was an issue for psychology students in Spain who scored quite

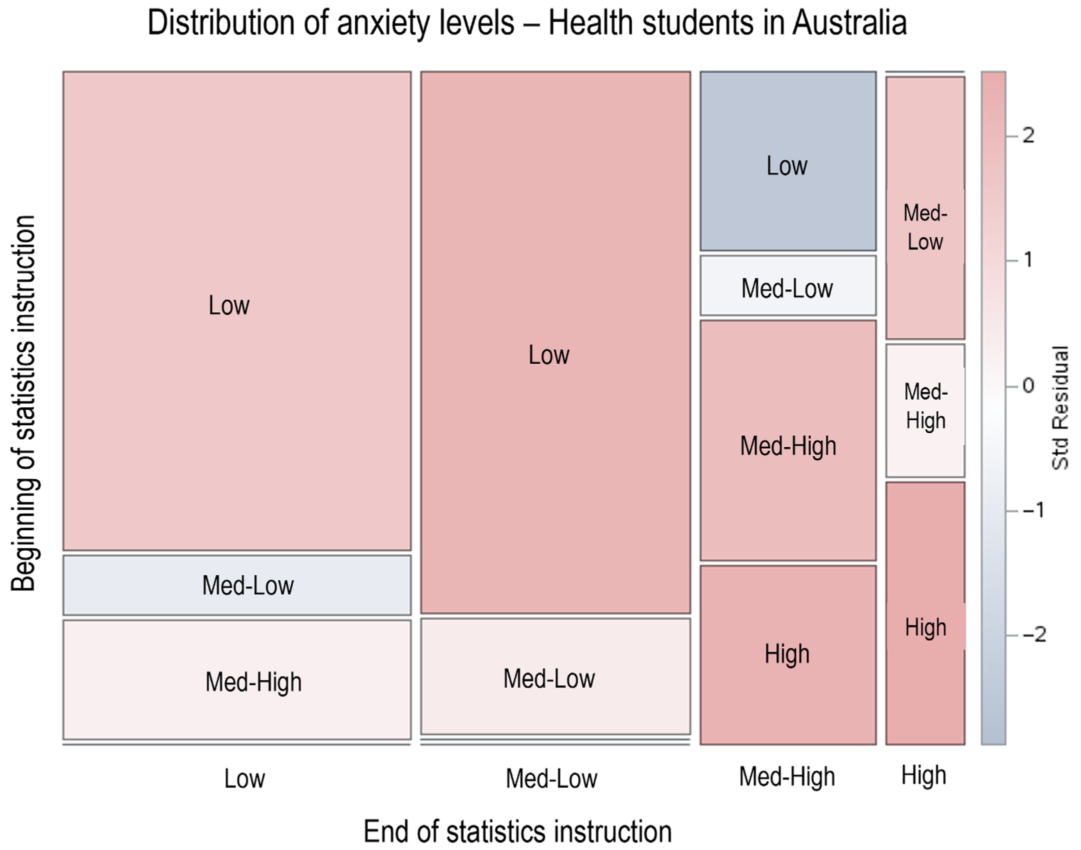
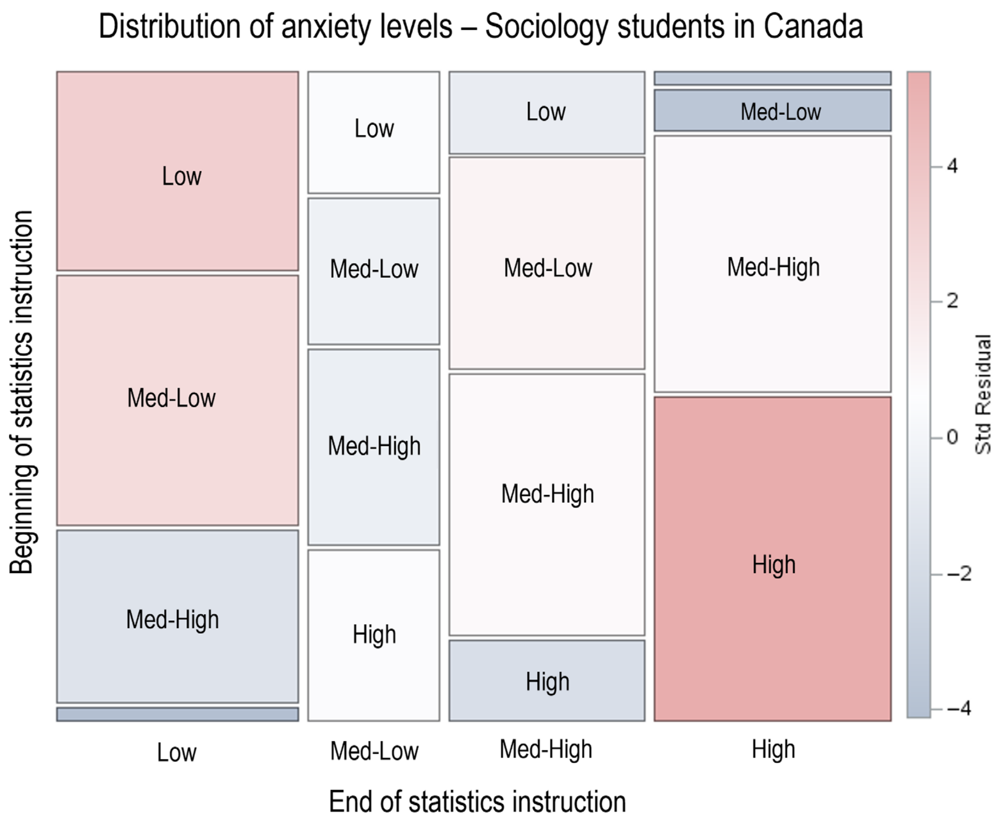


FIGURE 13 Relationship between anxiety scores pre- (first time point) and post-statistics instruction (second time point) for health students in Australia. [Color figure can be viewed at wileyonlinelibrary.com]

FIGURE 14 Relationship between anxiety scores pre- (first time point) and post-statistics instruction (second time point) for sociology students in Canada. [Color figure can be viewed at wileyonlinelibrary.com]



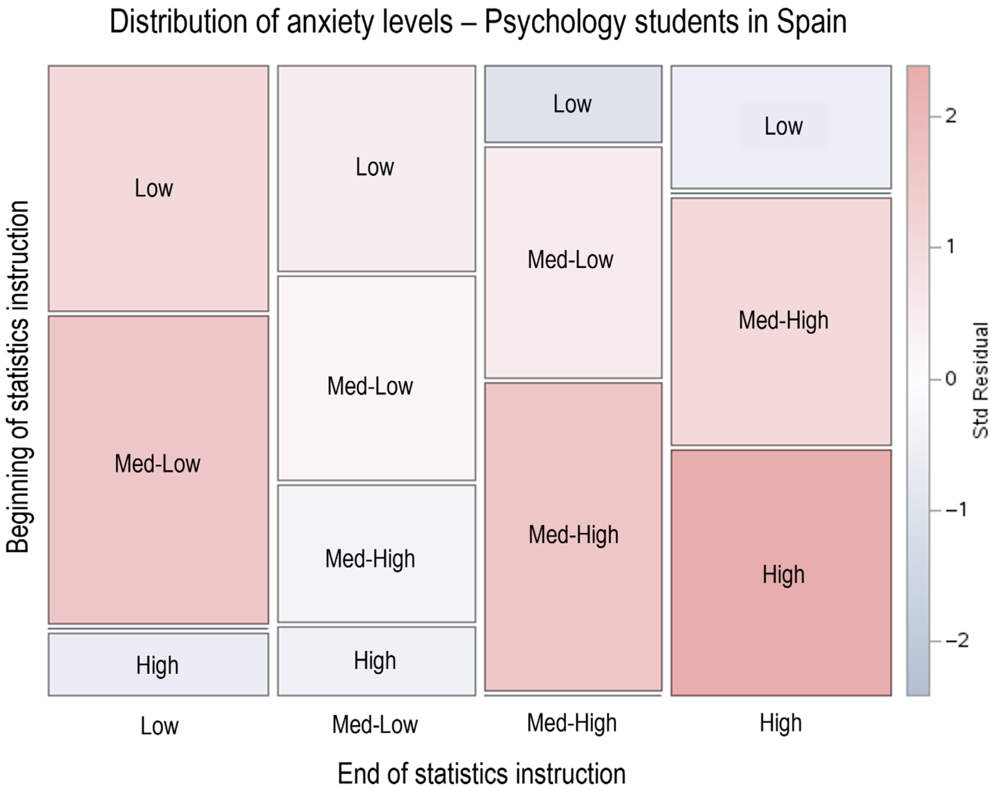


FIGURE 15 Relationship between anxiety scores pre- (first time point) and post-statistics instruction (second time point) for psychology students in Spain. [Color figure can be viewed at wileyonlinelibrary.com]

low on that dimension compared to students in other disciplines.

3.4 | Relationship between beginning and end of instruction anxiety scores

The relationships between overall pre- and post-instruction anxiety scores across the four disciplines of business (Australia), health (Australia), sociology (Canada), and psychology (Spain), represented with mosaic plots, are shown in Figures 12–15. These plots provide an opportunity to better understand the impact of statistics instruction on anxiety, which is the component of the overall attitude toward statistics that typically receives the most attention. The area of each tile is proportional to the number of observations that have this combination of levels. Tile color is based on the standardized residual for a model of independence, with darker shade of red (positive residuals) or blue (negative residuals) indicating larger deviation from the pattern that would be expected under independence.

Anxiety scores at each time point (beginning and end of statistics instruction) were assigned into four categories using quartiles: “Low” (scores below 0.25 quantile), “Med-Low” (scores between 0.25 quantile and 0.5 quantile), “Med-High” (scores between 0.5 quantile and 0.75 quantile), and “High” (scores above 0.75 quantile). Quantiles used to divide anxiety scores into categories at each time point are based on the distribution of anxiety scores for all study participants and across all four disciplines combined at that time point.

Beginning with the business student cohort, we note from Figure 12 that relative to the distribution of anxiety scores overall, anxiety levels for business students were at the low end of the scale at the beginning of instruction (approx. 80% in “Low” and “Med-Low” categories combined) and remained relatively low at the end of instruction (approx. 60% in “Low” and “Med-Low” categories combined). There was higher than expected proportion of students remaining in “Med-High” and “High” anxiety categories, with some movement from low to high anxiety categories following instruction. There was a similar pattern for health students (Figure 13), with some movement from “Low” to “Med-Low” and from “High” to “Med-High” categories. In other words, at the end of statistics instruction, some business and health students worried a bit more and some a bit less about studying statistics, with many students' anxiety levels remaining low.

In sociology (Figure 14), anxiety levels at the beginning of instruction were relatively low with approx. two-thirds of scores in “Low” and “Med-Low” categories combined, indicating somewhat higher levels of anxiety compared to business or health students. At the end of instruction, approx. half of the students' scores fell into either “Low” or “Med-Low” category. There was

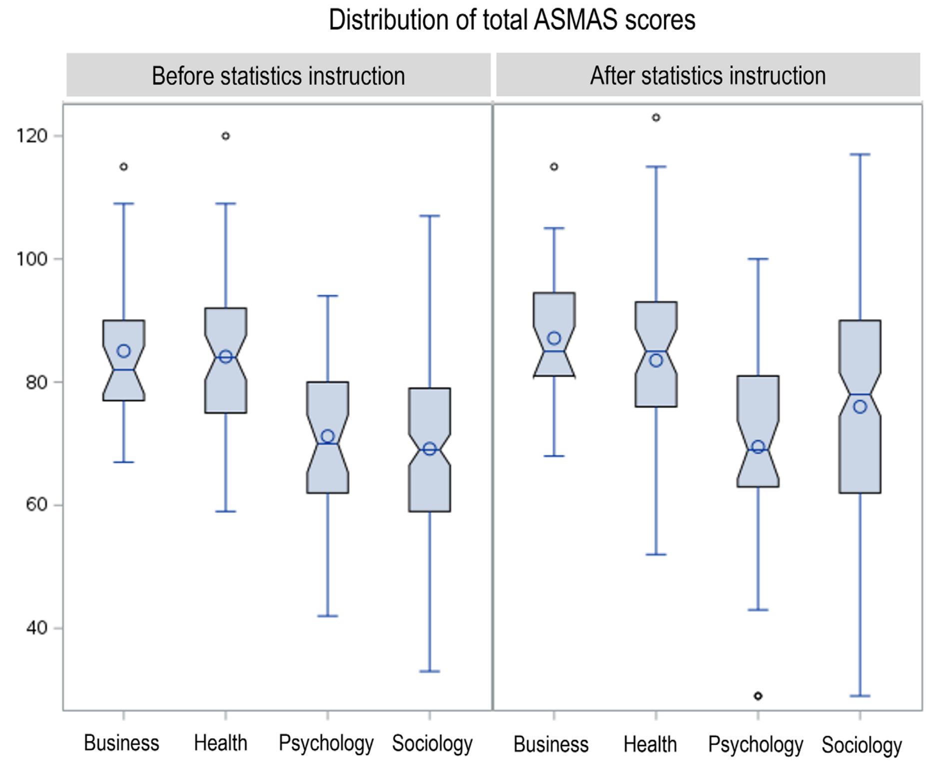


FIGURE 16 Distribution of aggregate pre- and post-instruction ASMAS scores, by discipline. Aggregate ASMAS scores were calculated using responses to the ASMAS survey instrument administered at the beginning and the end of statistics instruction. The aggregate score (Min = 25; Max = 125) represents the overall attitude toward statistics and is the total of scores corresponding to five ASMAS dimensions: anxiety, motivation, pleasantness, secure–confidence, and value-utility, after reverse-coding all negatively worded items. ASMAS, Auzmendi Scale to Measure Attitude toward Statistics. [Color figure can be viewed at wileyonlinelibrary.com]

some movement from high to low anxiety levels and vice versa, with higher-than-expected proportions of students maintaining either "Low" or "High" anxiety status. Students in the "Med-Low" anxiety category at the end of instruction were nearly equally likely to have come from any of the four categories at the beginning of instruction. Movement to "Med-High" category at the end of instruction was most likely to be from "Med-Low" or "Med-High" category. Figure 15 suggests a similar relationship between pre- and post-instruction anxiety scores for psychology students.

3.5 | The overall ASMAS scores for attitudes to statistics

We now turn our attention to the effect of statistics instruction on the overall attitudes toward statistics, measured by the total of the scores corresponding to five ASMAS dimensions: anxiety, motivation, pleasantness, secure–confidence, and value-utility, after reverse-coding all negatively worded items.

3.5.1 | Distribution of overall ASMAS scores by discipline

Distributions of aggregate ASMAS scores (Min = 25; Max = 125), before and after instruction, are shown in Figure 16. Both before and after instruction, total ASMAS scores for students in business and health appeared to be higher than in sociology and psychology, suggesting a more positive attitude toward statistics in general. Following instruction, the overall attitudes toward statistics appear to have improved somewhat for students in business and to a larger degree for students in sociology. However, the post-instruction increases in the total ASMAS scores for sociology students came with more spread in the distribution of post-instruction scores, suggesting that the experience with statistics instruction was far from uniform across the student cohort.

3.5.2 | Distribution of overall ASMAS scores by sex

The distributions of the overall ASMAS scores before and after statistics instruction for male and female students are shown in Figure 17. For both sexes, overall ASMAS scores were somewhat higher at the end of the course, suggesting more positive attitudes toward statistics. We should note, however, a large degree of spread in the post-instruction overall ASMAS scores for female students. We can also see evidence of somewhat lower scores for female students compared to male students, both at the beginning and the end of statistics instruction, suggesting somewhat more positive attitudes toward statistics among male students.

3.5.3 | Statistical significance of changes in overall ASMAS scores

For the overall ASMAS scores, there was a significant main effect of the discipline (large effect) and sex (negligible effect). This result is not surprising given the demographics of the study cohort. With the vast majority of participants in sociology and psychology being female, there is a high degree of confounding between variables of discipline and sex. There was no statistically significant effect of the time of survey, but there was a significant interaction effect between the time of the survey and discipline (small effect), suggesting there were significant differences in the effect of statistics instruction for at least one of the disciplines. The effect size for the overall model was 0.1864 (medium effect). Results for a relevant general linear model are shown in Table 4.

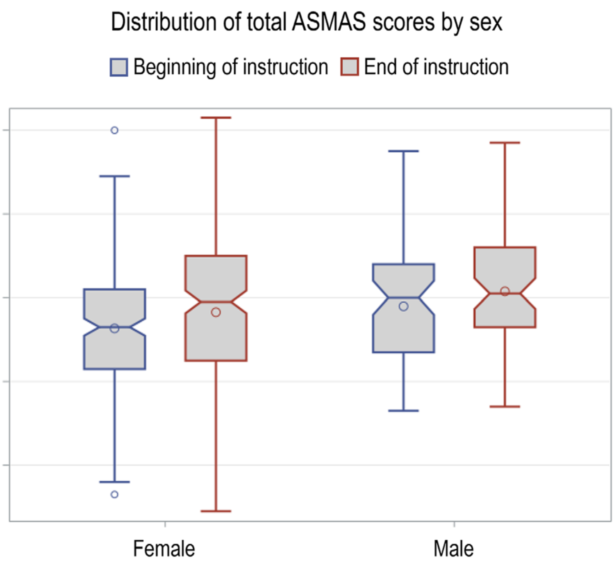


FIGURE 17 Distribution of aggregate ASMAS scores before and after statistics instruction, by sex. Aggregate ASMAS scores were calculated using responses to the ASMAS survey instrument administered at the beginning and the end of statistics instruction. The aggregate score (Min = 25; Max = 125) represents the overall attitude toward statistics and is the total of scores corresponding to five ASMAS dimensions: anxiety, motivation, pleasantness, secure–confidence, and value-utility, after reverse-coding all negatively worded items. ASMAS, Auzmendi Scale to Measure Attitude toward Statistics. [Color figure can be viewed at wileyonlinelibrary.com]

The mean changes in overall ASMAS scores across the four disciplines are illustrated in Figure 18. Following instruction, the overall toward statistics was more positive on average for students in business and sociology and slightly less positive on average for students in health and psychology. However, the wide confidence limits shown in Figure 18 demonstrate there is a lot of uncertainty in those change estimates.

4 | DISCUSSION

This study explored students' attitudes toward statistics in three different countries (Spain, Canada, and Australia) and across four disciplines (psychology, sociology, business, and health) using the ASMAS. The aim was to detect changes (if any) in students' overall attitudes toward statistics after statistics training and to investigate the relationships among the dimensions of the scale and changes (if any) in these relationships following statistics instruction.

We found negative associations between anxiety and each of security–confidence, motivation, and pleasantness. These negative associations were present in all four disciplines both pre- and post-training in statistics. In terms of the overall attitude toward statistics, there was a

TABLE 4 Results for a model with fixed effects of discipline (business, health, psychology, and sociology), sex (female and male), age, time (time of survey), and an interaction term between discipline and time of survey (ae ~ discipline*time + sex + age).

Variable	Degrees of freedom	*F*-value	*p*-value	Partial eta-squared	Effect size
Age	1	0.22	0.64	0.000	
Sex	1	4.62	0.03	0.008	Negligible
Discipline	3	23.94	<0.0001	0.116	Large
Time	1	1.09	0.30	0.002	
Discipline × time	3	2.73	0.04	0.015	Small
Total degrees of freedom	551		R-squared	0.1571	
			Cohen's f^2	0.1864	Medium

Note: The response variable is the aggregate ASMAS score (Min = 25, Max = 125). Partial eta-squared is the proportion of variance explained by a given variable after accounting for variance explained by other variables in the model.[39] Cohen's f^2 measures the effect size for the model overall and is defined as the proportion of variance explained by the model (R^2) over the proportion of variance not explained by the model ($1 - R^2$).[40]
Abbreviation: ASMAS, Auzmendi Scale to Measure Attitude toward Statistics.

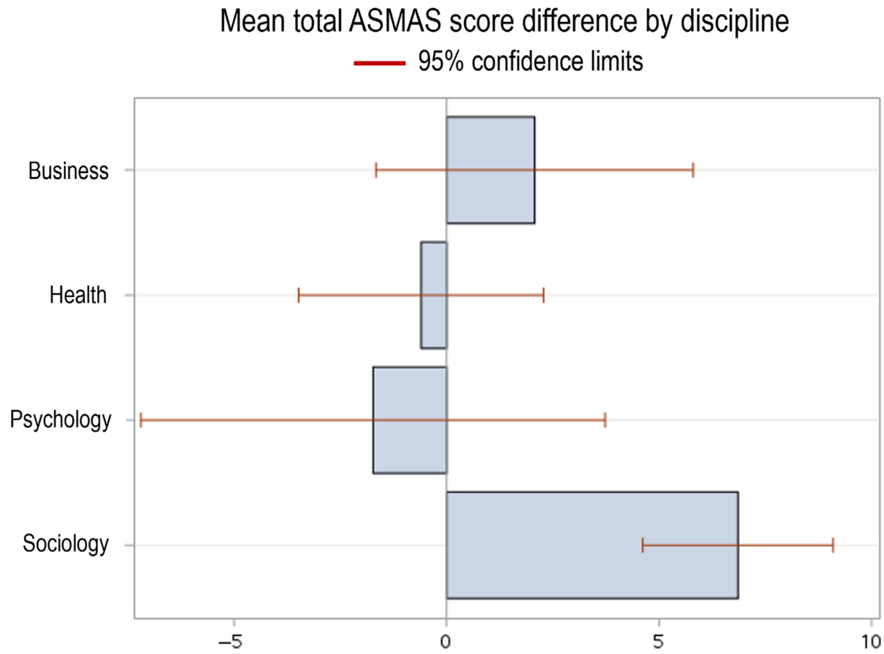


FIGURE 18 Mean change in aggregated ASMAS score (end-of-course values minus beginning-of-course values) by discipline. ASMAS, Auzmendi Scale to Measure Attitude toward Statistics. [Color figure can be viewed at wileyonlinelibrary.com]

positive change for sociology students in Canada and business students in Australia, in contrast to small negative change for health students in Australia and psychology students in Spain. When changes in individual ASMAS dimensions were considered, the greatest impact of statistics instruction appeared to be on anxiety, pleasantness, and security–confidence, with perceived value and motivation to study statistics remaining largely unchanged. Our analysis showed that on average, there was a decrease in anxiety and an increase in both pleasantness and security–confidence following statistics instruction. This finding appears to agree with results for undergraduate psychology students in Ref. 3; sociology, social work, and criminal justice students in Ref. 41; and a causal link between the level of self-confidence and statistics anxiety in senior secondary students reported in Ref. 30. Results were largely unaffected by age and the direct effects of sex were negligible, which is consistent with other studies reported in Ref. 42 but may reflect the composition of our study cohort rather than the true effects. We have also found that scores from the beginning of the course were a strong predictor of scores at the end of the course, which could explain why changes observed on average in the overall attitude toward statistics and its dimensions after taking a single introductory course in statistics were relatively small. Some students come to these courses with a lot of fear or else negative preconceptions about statistics so changing attitudes within a single and often one and only statistics course is a challenge.

Exploration of the data showed that changes in overall attitude toward statistics or in its dimensions, for example, anxiety, were not linear or uniform. For some students, taking a statistics course led to a slight improvement in scores; for others, it made things slightly worse; and for some, it meant a complete reversal, for example, from high anxiety in anticipation of learning statistics to low or moderately low anxiety following statistics instruction. In particular, our results suggest that highly anxious students rarely change their attitudes and targeted strategies would need to be initiated for that group of students. It should also be noted that our results do not include the effects of the quality or the pedagogical approach to teaching statistics. With different instructors across countries and disciplines, the instructor effect could not be controlled and investigated, due to being confounded with discipline differences.

Other studies investigating emotional and motivational processes during mathematics learning have shown a positive relationship between motivation, value, and anxiety,[21,43,44] in line with Pekrun's control-value theory.[20] In our case, there is negative correlation between anxiety and motivation. One plausible explanation could be that in the specific context of statistics learning at university, students may perceive anxiety as a barrier rather than a motivator. While some level of motivation might be linked to anxiety and engagement, excessive anxiety can overwhelm students and hinder their ability to engage effectively with the material. In this scenario, heightened anxiety may lead to decreased feelings of security–confidence and motivation, as students may become more focused on avoiding mistakes or failure rather than actively engaging with the subject matter.

Additionally, the complexity and abstract nature of statistics concepts could contribute to feelings of anxiety, particularly among students with limited prior exposure or confidence in quantitative skills. As a result, these students may experience greater difficulty in finding the subject matter pleasant or in feeling confident about their abilities, further exacerbating the negative associations between anxiety and these dimensions. Further research regarding the dynamic between these constructs is needed to get a better understanding of how they work together to influence student learning and achievement in statistics.

Numerous efforts have been made to improve students' experience with statistics.[45–51] Simulations, using discipline domain data[52] and relatable examples,[53] have been shown to engage students, and collaborative work[47,50,51,54] appears to help with self-efficacy and confidence, while mindfulness activities[55] have been shown to lessen physical symptom of anxiety. Our results provide some context for why these improvements might arise. A moderately positive change in attitude toward statistics through an increase in pleasantness and security–confidence scores, as well as a decrease in anxiety scores on average, was observed after simply taking a statistics course. Our results thus suggest that changes in attitude toward statistics are linked to students' self-efficacy. This is consistent with Bandura's social cognitive theory,[22] which posits that the experience of actually completing a task has the strongest influence on one's self-efficacy. Our results thus suggest that efforts to improve students' attitudes toward statistics should be directed toward creating a learning environment where students can enjoy the learning tasks and grow in their confidence to master the subject. According to Pekrun's control-value theory,[20] this should then lead to increasing expectations for success (control) and decreasing anxiety.

Further study of underlying patterns of statistics anxiety and attitudes toward statistics is required to inform the development of interventions that are most likely to be effective. Additional strategies would be needed to address the link between statistics anxiety and procrastination reported in Ref. 16,56. Another aspect is the timing of students' exposure to statistics, as well as the depth and scope of the statistics curriculum presented to students. Statistics instruction often occurs in the first year, when students are already grappling with transition from school to university, and it is often expected to give students "everything they need to know" within a single course, which may be adding to the apprehension and anxiety about taking a statistics course within a discipline that is perceived as qualitative rather than quantitative (e.g., management, sociology, or even psychology). As we have seen, the more positive change in overall attitude toward statistics occurred in business and sociology where the curriculum was less advanced. Choice of curriculum notwithstanding, results in Ref. 57 suggest that transition from school to university for students entering mathematics degrees is far from straightforward and involves changes in beliefs and attitude toward mathematics. It is reasonable to expect similar shifts for students who enter programs in other disciplines and find themselves with an unexpected challenge of studying statistics, requiring additional strategies and support to help students overcome those challenges.

5 | LIMITATIONS

While the results are promising, offering some insights into perceptions of statistics and the effects statistics instruction can have on those perceptions, there are some limitations that would need to be addressed in future studies. The majority (76%) of respondents were female, which is representative of the student population in some disciplines (e.g., sociology) but not others (e.g., business), introducing confounding and thus making it difficult to separate differences due to discipline from differences due to sex. Similarly, the majority of the students (92%) were under 23 years old, making it difficult to establish any differences in attitude toward statistics due to age. Further, despite natural hierarchy in the data (students nested in countries or disciplines), given a small number of groups, only fixed effects were estimated and consequently, no group-level (e.g., country-level) predictors could be included and no inferences beyond groups in the sample could be made. Finally, the quality of instruction would be expected to play a role and there could be additional effects due to instructors. However, instructor effects are confounded with country and discipline effects in the current design, so we were not able to explicitly investigate these aspects, focusing instead on the dimensions of students' attitudes toward statistics and their relation to anxiety, as well as the effect of being exposed to statistics instruction in general.

6 | CONCLUSIONS

Given the importance of data literacy to how we live and work today and the need for statistically literate citizens, prevalence of statistics anxiety among students is a concern worthy of further attention. Gaining a better understanding of students' experience with statistics instruction is crucial, and the current study confirms observations from earlier studies[8] that there are other dimensions besides anxiety that should be considered to understand and influence that experience. Our results suggest that such strategies should be directed first and foremost at improving the overall experience of learning statistics (pleasantness) and boosting their confidence in being able to master the subject. Future research should focus on expanding our understanding of the dynamics of students' attitudes toward statistics and measuring the impact of techniques and interventions that are proposed to alleviate statistics anxiety for students.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Supplementary analyses file along with all code files and data sets can be found at https://osf.io/tj8kq/.

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APPENDIX A

Position	Item	Dimension
1#	I think statistics is a very useful subject in my career	V
2*	I am bad at statistics	A
3	I am not afraid of studying or working with statistics	S
4#	I enjoy using statistics	P
5*	Statistics is so theoretical that it is not useful for the average professional	M
6	I want to have a deeper knowledge of statistics	V
7*#	Statistics is one of the subjects I am afraid of	A
8#	I am confident that I can cope with a statistical problem	S
9#	I enjoy talking with others about statistics	P
10*	Statistics can be useful for researchers but not for the average professional	M
11#	Knowing statistics increases your employability	V
12*	I feel unable to think clearly when I deal with a statistical problem	A
13	I am calm and relaxed when I deal with a statistical problem	S
14#	I consider statistics nice and stimulating	P
15*#	I hope to rarely use statistics in my professional life	M
16*#	There are subjects more important than statistics for my career	M
17*#	Working with statistics makes me feel anxious	A
18#	I do not get upset when I have to work with statistical problems	S
19	I would like to get a job in which I have to use statistics	P
20	It gives me great satisfaction to solve statistical problems	V
21#	Statistics is one of the most important subjects that has to be studied for professional development of my career	V
22*#	Statistics makes me feel uncomfortable and anxious	A
23#	If I put my mind to it, I could master statistics	S
24	If I had de opportunity, I would register for more statistics courses than required	P
25*#	The content lectured in statistics classes is very uninteresting	M

Note: An asterisk (*) means that the item score must be reversed before item aggregation to compute global score on attitudes toward statistics. The hash (#) refers to the items included in the short version of the scale proposed by Ruiz-Ruano and Puga.[58]

Abbreviations: A, anxiety; M, motivation; P, pleasantness; S, security–confidence; V, value-utility.