Does SHE Prefer Statistics?

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1. Introduction

In New Zealand, Bursary and Scholarship examinations are sat by the majority (approximately 10,000 and 1,000 respectively, in 1988) of final year secondary school students. Since 1986 the two mathematics papers which can be taken for these examinations (replacing the older Pure and Applied Mathematics papers) are "Mathematics with Calculus" and "Mathematics with Statistics". Mathematics with Calculus is directed at those students intending to continue mathematics at tertiary level. Mathematics with Statistics can be taken either jointly with Mathematics with Calculus or as a self-contained and possibly terminating applications-based mathematics course.

Our research looks at whether preferences in question choice, and differences in achievement, in Mathematics with Statistics papers are related to gender.

Raw marks from the Bursary Mathematics with Statistics papers for 1987 and 1988, and from the Scholarship Mathematics with Statistics papers for 1986, 1987, and 1988, were analysed. The marks analysed represent an almost complete coverage of students sitting these papers. Results from these papers indicate that the overall mean performance of male students is consistently higher than that of female students. This was found also in comparable investigations (Stewart, 1981; Reilly et al., 1987; Forbes, 1988; Morton et al., 1988, 1989) at this level. The analyses assume that the group analysed is a random sample of all students who might have sat the examination.

The three-hour papers were divided into two sections; general mathematics, and statistics. Bursary papers have one compulsory question and ten optional questions, five in each section. In the Scholarship papers there are no compulsory questions and only eight optional questions (four in each section). Students were asked to answer any five of the optional questions, with no more than three from one section. Within each paper all optional questions carried the same marks. As these papers all consisted of two quite distinct sections, gender and school differences within each section were analysed separately as well as overall. The school factors analysed are School Authority (whether

the school is state, integrated - almost all Roman Catholic schools - or private), and School Type (co-educational or single-sex).

2. Results from the Mathematics with Statistics papers

Gender differences: Whereas roughly 40% of Bursary candidates were female, at Scholarship level this percentage was as low as 25% in 1986, and 28% in both 1987 and 1988. Table 1 gives the results by gender, within each of the sections. The overall mark refers to the student's total (out of 100) whereas the section mark refers to the mean score (out of 20) for the questions answered in that section. A positive difference is in favour of boys, a negative one in favour of girls. An asterisk (*) indicates that the difference is statistically significant at the 5% level of significance (using standard parametric methods such as analysis of variance and regression, and checking with a robust rank-order test).

TABLE 1
Mathematics with Statistics section results by gender

Paper		Overall		Maths Section		Stats Section	
	No.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
1987 Bursary							
Males	4796	54.0	24.5	8.25	3.51	7.80	3.02
Females	3274	50.4	18.9	7.27	3.39	7.44	2.87
Difference		3.6*		0.98*		0.36*	
1988 Bursary							
Males	5755	51.2	22.4	7.42	3.42	8.22	3.28
Females	4206	47.0	21.0	6.41	3.22	7.82	3.06
Difference		4.6*		1.01*		0.40*	
1986 Scholarship							
Males	476	48.5	17.0	8.48	3.34	10.83	4.22
Females	158	45.3	12.8	6.96	2.84	10.66	3.35
Difference		3.2*		1.52*		0.17	
1987 Scholarship							
Males	596	48.3	18.9	9.34	4.64	10.04	3.96
Females	228	46.7	16.6	8.14	4.18	10.23	3.53
Difference		1.6		1.20*		-0.19	
1988 Scholarship							
Males	640	50.9	17.0	9.91	3.90	10.45	3.70
Females	252	45.5	15.4	8.72	3.50	9.49	3.45
Difference		5.4*		1.19*		0.96*	

The greater variability in the boys' marks than in the girls' is noteworthy, and consistent. However, there is a far greater degree of variability within each gender group than between males and females.

While the mean difference for the mathematics section is consistently significant and in favour of males, that for statistics is not. There is always a smaller, and in two cases not even a significant, difference between the means of males and females in the statistics section. Figure 1 illustrates the results for the 1988 Bursary paper.

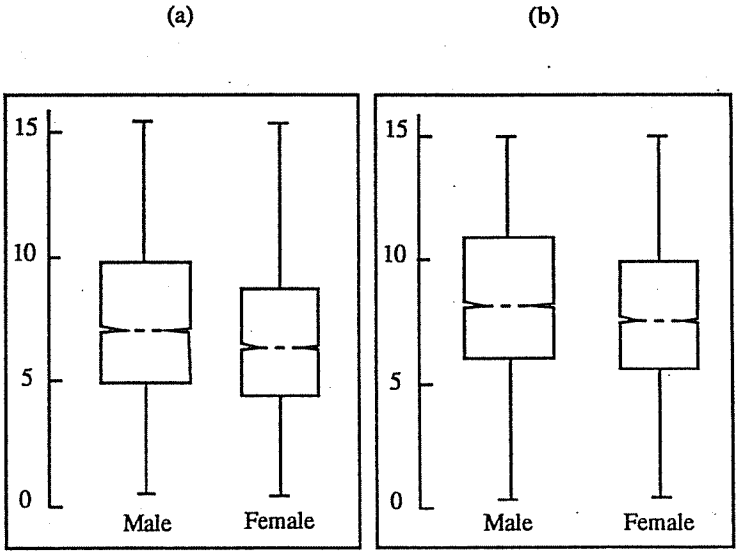


FIGURE 1
1988 Bursary Mathematics with Statistics marks split by gender
(a) Mean mathematics marks; (b) Mean statistics marks

Pearson's Correlation coefficients were calculated to determine the degree of the relationship between the mean mathematics and statistics marks for the three Scholarship papers. While, as expected, these were positive and significant at the 1% level, for each year the correlation coefficient for males (0.551, 0.561, 0.636) was slightly greater than that for females (0.238, 0.545, 0.560).

School differences: We summarise the main results, first for the analysis by School Authority, and then for the analysis by School Type.

A significant effect of School Authority was observed, for both totals and section means, in both the Bursary papers and in the 1986 Scholarship paper. In the 1988 Scholarship paper, authority was significant overall and in the mathematics section only. In all cases bar one, the significant differences were due to males from integrated schools not performing as well on average as males from either state or private schools. The exception was in the 1986 Scholarship statistics section, when males from private schools performed worst. In addition, in the statistics section, for Bursary papers, females from private schools scored higher than females from other schools. The gender by school authority interaction was significant for both Bursary papers overall and for

the two sections separately. It is also worth noting that the majority of students (80% of final year students in 1988) are in state schools, and that it was only within this authority that there were consistent gender differences in favour of males.

In regard to School Type, much interest has been expressed about whether or not females are disadvantaged in co-educational schools. No significant differences in favour of co-educational or single-sex schools were found in any of these papers, whether overall or for the sections separately. When the school types are split by gender it can be seen that females are scoring less on average than males in both co-educational and single-sex schools. The differences are not large and are illustrated in Figure 2 which gives box plots displaying this split for the 1988 Scholarship examinations.

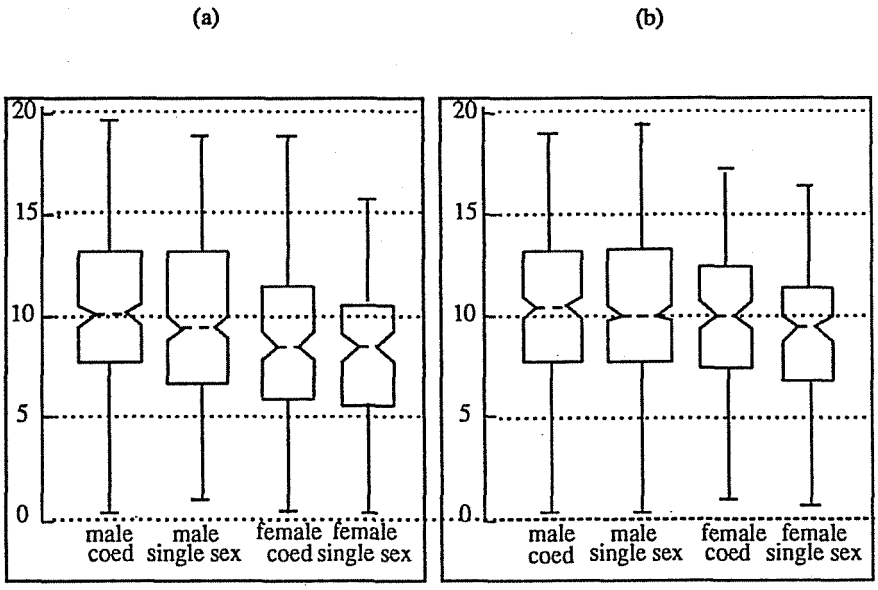
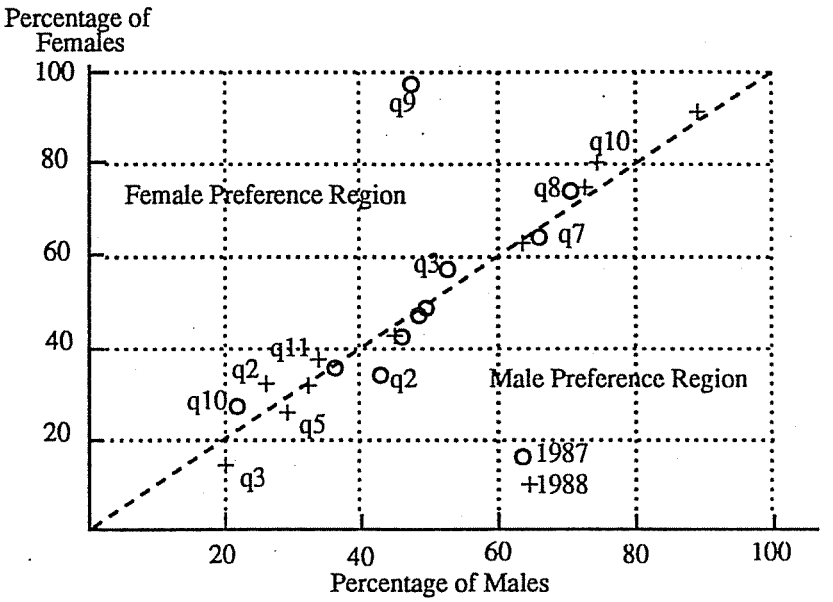


FIGURE 2
1988 Scholarship Mathematics with Statistics marks split by gender and school type
(a) Mean mathematics marks; (b) Mean statistics marks

3. Question analysis

An investigation of the proportion and performance of males and females answering each question was carried out to determine whether gender differences were related to specific topics. Figure 3 gives graphs of the percentages of males and females answering each question in both the Bursary and Scholarship papers.

(a)



(b)

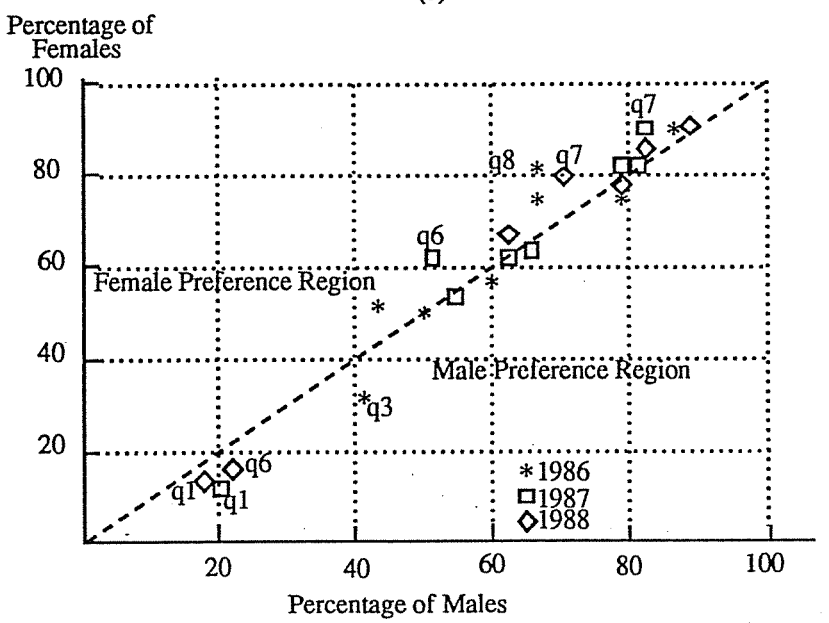


FIGURE 3
Question preferences in Bursary and Scholarship Mathematics with Statistics papers
(a) Bursary; (b) Scholarship

A higher proportion of males than females answered the algorithm questions in the mathematics section of the Bursary papers in both years (Question 2 in 1987, Question 3 in 1988); the probability question (Question 7) in statistics in 1987; and the curve fitting, differential equation question (Question 5) in mathematics in 1988. In 1987, the higher preferences expressed by females were for Questions 8, 9 and 10 in the statistics section, and for the series, exponential function question (Question 3) in mathematics. In 1988 more females again answered the series and errors mathematics question (Question 2); and also the descriptive statistics (Question 10) and essay (Question 11) statistics questions.

In the mathematics section of the Scholarship papers a higher proportion of males answered the algorithm question in all three years (Question 3 in 1986, Question 1 in 1987 and 1988). In 1988 more males also answered the calculus-based question (Question 6) in the statistics section. In all three years the questions answered by a higher proportion of females were all in the statistics section. These were the questions containing hypothesis testing in 1986 (Question 8) and 1987 (Question 7), and sampling in 1987 (Question 6) and 1988 (Question 7).

All the significant gender differences in the means for the Bursaries papers were in favour of males (18 out of 22 questions) apart from the essay question in 1988 in which females scored better than males. In Scholarships, in three of the statistics questions, one in 1986 and two in 1987, the difference in mean marks was significantly in favour of the females. In all other cases where the difference was statistically significant (10 out of 24 questions) it was in favour of the males.

Preference for statistics: As nearly all students (>95%) attempted five questions, with little gender difference, the section from which a student chose to answer three questions was used as an indicator of section preference. This is shown in Table 2 below.

TABLE 2
Mathematics with Statistics : section preference by gender
(numbers in the table are percentages)

Paper	1987 Burs		1988 Burs		1986 Schol		1987 Schol		1988 Schol	
Section	Maths	Stats	Maths	Stats	Maths	Stats	Maths	Stats	Maths	Stats
Males	27	71	19	77	48	52	27	72	42	56
Females	16	82	11	86	33	67	14	84	43	55
Overall	23	75	16	81	44	56	24	73	42	56

There is an overall preference for students to choose a statistics rather than a mathematics question, but for all papers, apart from 1988 Scholarships, there is a significantly greater proportion of females than males choosing statistics.

4. Summary and possible explanations

In Mathematics with Statistics papers, there is some indication that females are more likely to avoid algorithm, word, and calculus problems. They show a greater

preference than males for answering statistics questions, and the few questions where the females performed better than males are statistics questions. The mean gender difference between males and females is generally reduced in the statistics section and females show a greater preference than males for choosing the statistics rather than the mathematics section to answer from when they have a choice (i.e. only on their final question).

Among possible explanations for the apparent preference and improved performance of female students in the statistics sections are that:

(i) Although the majority of mathematics examiners at this level are males, for all the Mathematics with Statistics papers analysed, the questions in the mathematics sections were set by a male and those in the statistics sections by a female.

(ii) There are more (albeit still a limited number) of female role-models in statistics; this is one of few occupation categories in which female mathematics graduates outnumber males (Purser and Wily, 1987).

(iii) Female students may tend to choose subjects that they perceive as of social value (Fox, 1979). Perhaps statistics is seen by females as of more importance to society than mathematics.

(iv) Males and females take different subject combinations in the seventh form. Females dominate mathematics/biology combinations where there will be some reinforcement of statistics, while males dominate mathematics/physics combinations (see the CERTECH Report (1987) and Clark and Vere-Jones (1987)).

(v) Those students who take both mathematics papers in the seventh form would have some advantage over those who do not, particularly in the mathematics section of the Mathematics with Statistics papers. Data obtained subsequent to the above analysis revealed that there is a substantial difference in the proportion of males and females taking two mathematics papers. Approximately two-thirds of the males sitting Mathematics with Statistics Bursary and over 90% of males sitting Scholarship also take Mathematics with Calculus, compared to less than half of the female Bursary candidates and about 85% of female Scholarship candidates. When the groups of students that take one or two papers were analysed separately (Table 3), the overall gender differences largely disappeared except for the group doing both papers in 1988 Scholarships. This result reinforces the research of Fennema (1979), quoted in the British Royal Society report (1986), that the "single most important influence on studying mathematics is studying mathematics".

In conclusion, it may be suggested that while gender differences in participation in mathematics are likely to be derived from complex interactions of a number of psycho-social variables, there is a growing body of evidence that the amount of exposure to mathematics (for example, in other mathematics or related papers) is the single factor which may indeed outweigh all others in explaining gender differences in performance. In terms of the apparent preference shown by females for statistics in these papers, it is our opinion that this also is likely to be a reflection of differential exposure to mathematics in terms of other subject combinations, etc.

TABLE 3
Overall results for students taking Mathematics with Statistics (MWS) only or both MWS and Mathematics with Calculus (MWC)

		MWS only		Both MWS and MWC	
		Male	Female	Male	Female
MWS Bursary 1987	n	1723	1743	3073	1531
	mean	41.3	41.2	61.2	60.8
	std.dev.	16.8	14.9	18.8	17.6
MWS Bursary 1988	n	2050	2296	3705	1910
	mean	36.9	37.7	59.0	58.3
	std.dev.	18.4	16.9	20.5	19.9
MWS Scholarship 1987	n	55	34	541	194
	mean	35.1	37.1	49.6	48.4
	std.dev.	18.1	12.5	18.5	16.7
MWS Scholarship 1988	n	52	31	579	218
	mean	36.8	33.4	52.2	47.1
	std.dev.	13.7	13.4	16.8	15.2

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