Gender and Approaches to Studying Tertiary Mathematics

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Scales designed to assess approaches to studying tertiary mathematics were used to compare approaches of females and males. Scales assessed active study, intrinsic motivation, expected future use of mathematics, confidence and anxiety. Comparisons controlled for entrance qualifications showed more active study among females, less anticipated use of mathematics, lower confidence, and higher anxiety. Multiple correlations between scale and achievement scores were highly significant. The dominant connections with achievement involved intrinsic motivation, high confidence, and absence of debilitating anxiety.

There has been a considerable amount of work in the last few decades on university students' approaches to study. The work started with studies by Marton and Säljö (1976a,b), who found that students' level of understanding depended on an intention of achieving global understanding, the *deep approach* as opposed to the *surface approach*, which attempts only to accumulate detail without structure. Studies by Ramsden and Entwistle (1981) in Britain, and Biggs (1982) in Australia, using larger samples, responses to questionnaires, and quantitative analyses, successfully identified similarly defined approaches to study, and showed that these were related to students' self-assessed performance. A more recent overview of the field is given by Richardson (1990), and the original developers of the questionnaire instruments have both given more recent reviews of the continuing explanatory power of the basic idea (Biggs, 1993; Entwistle, 1997) The common consensus is that high quality of learning is associated with an orientation to real understanding, implemented by using active study methods that were diligent without being concerned purely with isolated detail. In addition, high levels of anxiety tend not to be associated with high quality of learning.

In the operationalisation of these concepts, for example in the measuring instruments developed by Biggs (1979), and Ramsden and Entwistle (1981), many of the questionnaire items were clearly best adapted to the study of the humanities and social sciences, because they refer to wide reading and independence of the limitations of a set syllabus. It is therefore of interest to note that there is a tendency for studies using such instruments not to find depth of approach among science students (for example, Hayes & Richardson, 1995; Watkins, 1982), which could be an artefact of the instrument.

The basic ideas, however, are valuable for all subjects. In mathematics, in particular, it is essential to study actively, because proofs and their applications are the core activity in doing mathematics. What is more, successful problem solving is highly satisfying, so that intrinsic rewards have activity as a prerequisite. It follows that the intrinsic motivation must contain a component of what the now classic Fennema-Sherman studies of attitudes towards mathematics (Fennema & Sherman, 1977, 1978) called *effectance motivation*, that is, accepting the challenge of problems and getting satisfaction from handling them. This implies also that the confidence necessary to accept challenge is both required and fostered by active study. Continuing work led Fennema (1985) to conclude that confidence and a

feeling of control over one's work were vital factors in learning to learn mathematics independently, and that, at least at secondary level, girls' lower confidence was a disadvantage, which is compatible with the results on anxiety and quality of learning outcome mentioned above. Hence it appears that gender effects must be considered, the more so because there is some conflict in recent work on students' learning at tertiary level, with the findings of differences by Meyer (1998) qualified by the results of Hayes and Richardson (1993, 1995) who found either no differences, or an interaction with area of study.

In a university sample, one cannot address the question of gender differences in mathematics learning, because university students are self-selected into the study of mathematics, so that females and males do not necessarily come from similar segments of the population. Nevertheless, gender related differences in approaches to study are a possibility that has to be allowed for. Also, traditional stereotyping of mathematics, science, and engineering as male domains is still quite clearly reflected in degree and subject choices at tertiary level. A recent study by Forgasz (1998) gives details that support this claim. These considerations imply that female university students in mathematics subjects may differ as a group from the males in the class, because the stereotyping issue itself may influence the choice to enrol in any tertiary mathematics, and also because of the degree enrolment differences already mentioned, which may mean a stronger vocational orientation in the males' approaches to study.

The intention of the research was therefore to fill a gap left in the literature on approaches to study by reformulating the underlying concept in a way better adapted to the study of mathematics, and to take into consideration the gender issue in a context where its influence is still clearly detectable in enrolment patterns.

Method

Sample. A stratified random sample of first year mathematics students in a large Australian university was obtained, with stratification corresponding to degree enrolment, but subject to the exclusion of the substantial minority of overseas students, with the purpose of avoiding the complication of cultural and selection differences in the section of the work reported here. The initial sample consisted of 216 women and 503 men. The achievement data (described in greater detail below) were available for a slightly smaller sample (207 women and 487 men, losses, respectively, of 4% and 3%), because of withdrawals from the mathematics subject.

Instrument and data collection. Five attitude scales were specially developed for the study, in the light of the discussion in the introduction, reorienting the operational detail of depth of approach to the subject, and including a measurement of possible vocational commitment. Questionnaires were filled out by students about two thirds of the way through their first semester of university mathematics. In the questionnaire, each item presented a statement about mathematics learning. Students were asked for levels of agreement on a five-point scale. Items were worded either positively or negatively with reference to the attitude postulated as favourable to learning. Scores for negatively worded items were then reversed so that high scores indicated approaches to study that, it was

postulated, should favour higher quality learning. In each area, the final scale score was the mean of the item scores.

The scales dealt with diligent and active study methods (called *Activity*), intrinsic motivation (called *Motivation* in tables), defined in terms of interest in mathematics and acceptance of its intrinsic challenge, perception of the usefulness of mathematics, and confidence and anxiety about mathematics. In doing mathematics, the essential task involves understanding proofs and solving problems, and wide reading is achievable only at an extremely advanced level. This means that depth of approach is better reflected by an active problem-solving orientation than by the wide-ranging and independent reading that is suited to the humanities and social sciences. That is, solving problems forces the construction of arguments, and difficulties with problems are often the best guide to areas of incomplete understanding. Items about active study therefore follow the approach used by Ramsden and Entwistle (1981), and do not ask about specific methods, but about good organization in general (for example "I am usually up to date with my mathematics work") and involvement in problem solving (for example "When I review a mathematics topic, I test myself by doing exercises"). Motivation items dealt with intrinsic interest in mathematics (for example, negatively worded "I can't seem to get interested in my mathematics course") and the style of effectance motivation identified by Fennema and Sherman (1977) (for example " I enjoy the challenge of a difficult new topic in mathematics"). Items about expected future use of mathematics consisted of straightforward statements, such as "In my future work I shall need to use a lot of mathematics". Confidence and anxiety were treated separately. Confidence corresponded to positive beliefs about being able to cope, such as "I think mathematics is quite easy for me compared with other students". Anxiety corresponded to reports of being hindered by a tendency to worry or panic about one's mathematics studies, such as "Before a mathematics exam I worry so much that it almost stops me studying". The anxiety items were scored so that high scores corresponded to low anxiety. Separation of confidence and anxiety was supported by the results of a small pilot study, in which women's and men's confidence scores did not differ significantly but their anxiety scores did. In each area, the final scale score was the mean of the item scores.

Reliability coefficients (Cronbach's Alpha) for the scales are in Table 1.

Table 1
Reliability of Scales

Scale	Activity	Motivation	Usefulness	Confidence	Anxiety
Alpha	0.80	0.79	0.69	0.57	0.76

Achievement scores. The overwhelming majority of students had obtained university entrance on the basis of the New South Wales Higher School Certificate examination, and their overall entrance score was recorded for use as a control variable.

University achievement scores were obtained from university examination results. The sample was enrolled in three levels of Year 1 mathematics. Students in the top two levels had their marks moderated against each other using a common part of their assessment, so that there was no difficulty about considering them as a single distribution. The lowest

level had no common assessment, but there were two calculations that were used in the university to equate results. The first was used to calculate equivalent marks for students transferring down from the middle level of mathematics, and the second in later year quota selection. At the pass-fail borderline, the two methods coincided, reducing the value of a mark at the lowest level by the same amount. This reduction was extended to all marks in the lowest level.

Analyses. The SPSS package (Norusis, 1990) was used for most analyses, but the multiple regression calculation was performed using the Maple mathematical computing package (Char, 1991). Reliability coefficients for the scales have been given. The scale scores for women and men were compared using analysis of covariance with control for the overall entrance score Control was used because previous achievement is an obvious potential influence on students' approaches to study. Multiple regression calculations for links between the set of scale scores and the university achievement score were performed separately for women and men.

Results

Comparisons between women and men. The results of the analyses of covariance are in Tables 2 to 6. Mean scores for women and men are in the first two columns, and the analysis of covariance table in the last five.

The covariate, controlling for university entrance, accounted for a significant amount of the variance in all cases except the activity scale. The women's scores were significantly higher than the men's, beyond control for the entrance score, on the scale dealing with activity No differences in motivation were found Men's scores were significantly higher on the scale for usefulness, which is highly likely to reflect their more frequent enrolment in engineering degrees. Men's scores for confidence and absence of anxiety were significantly higher than women's. The control for previous achievement is particularly important to confidence and anxiety, because, without it, one has no evidence against an argument that the differences in students' attitudes may merely reflect differences in past performance.

Table 2
Activity: Comparisons Between Women and Men

Means		Source of variation	Sum of squares	df	Mean square	F
Women	Men					
3.19	3.05	Entrance	1.40	1	1.40	3.37
$n = 216$	$n = 503$	Gender	2.64	1	2.64	6.36*
		Residual	296.80	716	0.415	
		Total	300.84	718		

Note * $p < 0.05$.

Table 3
Motivation: Comparisons Between Women and Men

Means		Source of variation	Sum o f squares	df	Mean square	F
Women	Men					
3.17	3.11	Entrance	13.16	1	13.16	28.23***
$n = 216$	$n = 503$	Gender	0.32	1	0.32	0.69
		Residual	333.88	716	0.47	
		Total	347.37	718		

Note *** $p < 0.001$.

Table 4
Usefulness: Comparisons Between Women and Men

Means		Source of variation	Sum of squares	df	Mean square	F
Women	Men					
3.32	3.65	Entrance	7.94	1	7.94	14.16***
$n = 216$	$n = 503$	Gender	16.85	1	16.85	30.07***
		Residual	401.26	716	0.56	
		Total	426.05	718		

Note *** $p < 0.001$.

Table 5
Confidence: Comparisons Between Women and Men

Means		Source of variation	Sum of squares	df	Mean square	F
Women	Men					
3.04	3.17	Entrance	24.36	1	24.36	69.24***
$n = 216$	$n = 503$	Gender	2.87	1	2.87	8.16**
		Residual	251.90	716	0.35	
		Total				

Note ** $p < 0.01$. *** $p < 0.001$.

Table 6
Anxiety: Comparisons Between Women and Men

Means		Source of variation	Sum of squares	df	Mean square	F
Women	Men					
2.98	3.33	Entrance	31.48	1	31.48	54.35***

$n = 216$	$n = 503$	Gender	19.26	1	19.26	33.26***
		Residual	414.67	716	0.58	
		Total	465.41	718		

Note *** $p < 0.001$.

Relationships among variables. Correlations among the scores for scales and university achievement are in Table 7. Quite strong relationships are present among the different scales, which were never intended to be independent, because the areas of concern are clearly related. But the large size of the samples makes significance easy to achieve, even when correlation coefficients are quite small, so that absolute size of the coefficient is also important. It is also worth noting that there is some justification for retaining separate confidence and anxiety scales, because their correlations with other variables do not seem to indicate redundancy.

Table 7
Correlations Among Scale Scores: Women's Above Diagonal, Men's Below

Scale	Activity	Motivation	Usefulness	Confidence	Anxiety	Achievement
Activity		0.38**	0.24**	0.29**	0.30**	0.06
Motivation	0.55**		0.62**	0.53**	0.28**	0.37**
Usefulness	0.32**	0.62**		0.38**	0.08	0.21**
Confidence	0.22**	0.48**	0.28**		0.47**	0.27**
Anxiety	0.17**	0.25**	0.14**	0.43**		0.30**
Achievement	0.27**	0.37**	0.26**	0.32**	0.15**	

Note ** $p < 0.01$.

Most of the scales for which a positive relationship with achievement was postulated did in fact show such a relationship. The effect of large samples on the significance of correlation coefficients, which has already been mentioned, should be held in mind here too. Given that no attempt was made to produce independent scales, it is, in any case more revealing to examine links between achievement and the whole set of variables, each in the context of the others. So multiple regression calculations were done, separately for the women and the men. Results are in Table 8.

Table 8
Multiple Regression: Scales With University Achievement

	Women	Men
Activity	-0.34	0.19
Motivation	0.79	0.63
Usefulness	0.01	0.05
Confidence	0.03	0.40
Anxiety	0.54	-0.02

Multiple correlation	0.44**	0.42**

Note ** $p < 0.01$.

The patterns for women are somewhat different from those for men. The women's vector of coefficients is dominated by intrinsic motivation and low anxiety, with the more positive confidence scale hardly detectable, and a negative relationship between achievement and study. The men's vector also has the coefficient for intrinsic motivation highest, but it is backed up by a positive link with activity. Also, in the men's vector, it is the positive side of confidence and anxiety (the scale called *confidence*) that shows an association with achievement. The positive link between usefulness and achievement found in the simple correlations does not carry over in the context of the other variables.

But the results are similar enough in that both sets show the importance of intrinsic motivation and either positive confidence or absence of anxiety. These two are precisely the factors proposed by Fennema (1985) as prerequisites for autonomous learning in mathematics. In addition, the importance of intrinsic motivation is compatible with the research on approaches discussed by Entwistle (1997), in which high quality learning is found to be based on a search for understanding, a component of which is interest in the area studied. The additional information gained in the present work comes from adapting the content of questionnaire items to the rather different way in which interest in mathematics is described and expressed.

Discussion

Looking at the comparisons between men's and women's scale scores, one can start by noting that the result for the usefulness scale is predictable, given the clear differences in women and men students' degree enrolment. That is, since more men were enrolled in engineering degrees, one might expect them to anticipate greater use of mathematics in working life. The point of including it was to check on any possible links with achievement.

There was no difference on the motivation score, but the men's greater confidence and lower anxiety put them in a position of potential advantage, given the importance of confidence in Fennema's (1985) model of autonomous learning in mathematics. Here it is very important to recall that the comparison was controlled for students' entrance scores. But women's higher scores for activity are a quite plausible indicator of a coping strategy to combat lower confidence.

The simple correlations between the approach variables and university achievement are all positive, and all but one highly significant. The approach variables were formulated to reflect the intention of understanding, which underlies the concept of depth of approach, together with confidence and anxiety, which were seen as enabling factors. Future use of mathematics is an additional motivating factor that must be considered because its level is often implied by degree choice at university. Testing the prediction of achievement by these factors is therefore a traditional test of a null hypothesis that they are either irrelevant or detrimental to students' mathematical learning, and the results indicate that the assumptions underlying the formulation have not been falsified. The multiple regression results define prediction of achievement by the approach variables in context with each

other. They provide evidence in support of the thesis that intrinsic motivation and aspects of confidence and anxiety are important components of students' approaches to study in mathematics, and the configurations of coefficients, and that, in the context of the other variables, the usefulness scale does not make an independent contribution to the prediction of achievement. Finding vectors of scale scores that predict achievement is one method of defining an approach to study associated with higher quality of learning outcomes, and the positive contribution of intrinsic motivation and aspects of confidence is compatible with the conclusion that depth of approach is involved. Hence, among mathematics students, the present work identifies an approach to studying that is predictive of achievement. The approach is, in turn, based on scales designed to reflect an autonomously implemented intention of understanding, which is the idea underlying the definition of a deep approach. It is therefore claimed that the results are compatible with the existence of a deep approach to study among mathematics students, which can be identified using a suitable instrument.

The differences between patterns for women and men involve the confidence-anxiety space, and the activity scale. In both cases, the dominant coefficients are in similar areas, but for men it is positive confidence that predicts and for women it is the avoidance of anxiety. Men's scale scores were significantly higher in both areas, so it is quite possible that the difference in multiple regression coefficients reflects men's more positive attitudes over the whole area, even after control for the Higher School Certificate university entrance score. A further investigation using interviews that permit probing of responses suggests itself.

The difference in sign between the women's and men's coefficients for activity, in the multiple regression vectors, needs further investigation. One possibility is that the high workload among engineering students has made systematic study more important even for more talented students. The higher proportion of the men in engineering degrees would then mean that the males in the sample were under greater pressure of work, as a group, than the females. A further investigation of the influence of workload is therefore of potential interest.

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