COMPARING ETHNIC AND GENDER DIFFERENCES OVER TIME: AN INDEX OF MATHEMATICAL ACHIEVEMENT

Sharleen Forbes, Statistics New Zealand, New Zealand

In New Zealand there are a number of 'optional' stair-cased national examinations for senior secondary school students. For a number of years there have been small but consistent gender differences (in favour of males) and marked differences between Maori (indigenous New Zealanders) and non-Maori students in mathematics performance in these examinations. The collective impact on different groups within the same cohort of students in terms of division into the 'mathematically-rich' and the 'mathematically-poor' is, however, a combination of differential participation and achievement. This paper presents a simple educational index which incorporates both participation and achievement over time and can be used to compare subgroups of a cohort over same time period.

INTRODUCTION

If we accept the underlying assumption that all groups in society are inherently capable of reaching the same level of learning then, over some reasonable time period, there should be similar outcomes across different groups of students. While there may be significant differences in performance between groups in any single assessment, if this difference remains consistently in one direction over a period of time then there is a systematic bias in favour of one group. This bias may be caused by factors external to the learning situation, such as socio-economic circumstances, parents' education and expectations, or cultural values. Or the bias may be caused by factors internal to the learning situation: the teaching process, the curriculum, or the assessment procedure itself. Participation and achievement results between groups of students in a single assessment or set of assessments have been investigated both within New Zealand (Blithe et al, 1995; Forbes, 1994; Forbes et al, 1990; Morton et al, 1993); and overseas (Parker and Tims, 1995). However, little work has been done to combine the impact of differential achievement and participation rates. This paper examines the situation in mathematics in the final years of New Zealand secondary schooling between male and female, Maori (indigenous New Zealanders) and non-Maori students, through the use of an achievement index which incorporates both achievement and participation rates over time. This index can be constructed for any subject or combination of subjects and for any time period.

NEW ZEALAND SECONDARY SCHOOL NATIONAL EXAMINATIONS

In New Zealand there are a number of 'optional' stair-cased national examinations for senior secondary school students. The first, School Certificate, is at the end of form 5 (year 11). Students generally sit a set of between four to six papers chosen from a wide range of subjects. Almost all students sitting School Certificate take mathematics. The grades awarded to students are, in most subjects, based on their performance in national three-hour written examinations held at the end of the year. The national qualification, Sixth Form Certificate, at form 6 (year 12) consists of a set of internally assessed papers for which grades (from 1=highest to 9=lowest) are awarded by individual schools. As in School Certificate, there is only one national mathematics paper available at the sixth form. In recent years between 80-90% of male students take mathematics and about 75% of females. However, in the final year of secondary schooling, form 7 (year 13) two mathematics papers, Mathematics with Calculus and Mathematics with Statistics, are available for the Universities Bursaries examination. The participation rates in mathematics were 29% for females and 49% for males in form 7 students 1994. The participation of Maori is very low - approximately 5% (Forbes et al, 1996).

ACHIEVEMENT IN MATHEMATICS

Table 1. School Certificate (Year 11) Mathematics: Mean Scores (%) 1992 - 1995

	Non-Maori		Maori	
Year	Female	Male	Female	Male
1992: *N*	16500	17650	2672	2678
Mean Score	53.9	54.6	39.1	39.8
Significant Difference	*		*	
1993: *N*	16812	17119	2665	2640
Mean Score	53.5	54.1	39.3	40.2
Significant Difference	*		*	
1994: *N*	16883	17690	2716	2591
Mean Score	56.8	58.3	43.5	45.3
Significant Difference	***		***	
1995: *N*	16737	17651	2611	2451
Mean Score	55.0	56.0	43.0	42.5
Significant Difference	***			
* = significant at 5% level *** = highly significant at less than 1% level				

There have been small but consistent gender differences (in favour of males) and marked performance difference (consistently more than 10 percentage points) between Maori and non-Maori students in School Certificate which have remained virtually unchanged for the last twenty years. Table 1 gives these mean scores for 1995.

The pattern is not quite the same in the internally assessed Sixth Form Certificate (year 12) but a similar order of differences has also been observed in both Bursary (year 13) examinations over the period 1992-1995 (Tables 2).

The use of single examination results, however, does not account for the differences between groups in mathematics participation. If we look at the cohort of students sitting School Certificate mathematics in any year (for example, in 1992) then we can see that participation drops off for all groups as soon as mathematics becomes 'optional'. However, there are marked differences between groups in the level of 'drop-out'; with more females than males and more Maori than non-Maori dropping out over the final 2 years of schooling (Figure 1).

Tables 2 (a) University Bursary Mathematics with Statistics: Means (%) 1992 - 1995

	Non-Maori		Maori	
Year	Female	Male	Female	Male
1992: *N*	5224	6469	346	401
Mean Score	53.7	54.7	45.5	45.7
Significant Difference	***			
1993: *N*	5000	6342	323	457
Mean Score	53.5	54.4	45.6	45.4
Significant Difference	*			
1994: *N*	5177	6301	317	390
Mean Score	52.9	55.3	45.5	46.7
Significant Difference	***			
1995: *N*	5233	5976	323	365
Mean Score	54.1	55.6	47.0	46.8
Significant Difference	***			
* = significant at 5% level		*** = highly significant at less than 1% level		

(b) University Bursary Mathematics with Calculus: Means (%) 1992 - 1995

	Non-Maori		Maori	
Year	Female	Male	Female	Male
1992: *N*	3305	4961	191	244
Mean Score	56.6	57.1	47.3	48.1
Significant Difference				
1993: *N*	3321	4950	150	288
Mean Score	56.0	56.8	48.4	48.8
Significant Difference	*			
1994: *N*	3604	5110	201	244
Mean Score	56.0	56.6	46.2	49.3
Significant Difference			*	
1995: *N*	3505	4768	169	228
Mean Score	55.7	56.5	46.5	46.8
Significant Difference	*			
* = significant at 5% level		*** = highly significant at less than 1% level		

Figure 1. Participation Rates - SC Cohort

THE CASE FOR COHORT STUDIES

The collective impact on different groups within the same cohort of students (for example, those starting secondary school in the same year) in terms of division into the 'mathematically-rich' and the 'mathematically-poor' is a combination of differential participation and achievement. An index which incorporates both these over time could be used to compare the relative mathematical health of various subgroups in any cohort, and to measure changes in relative health between cohorts.

In its simplest form (when each examination is considered to have equal weighting) this index could just be a linear combination of individual student's examination marks weighted by their participation in some or all possible examinations. In order to have the same range of marks as the original data (in general, percentages) this score should then be divided by the number of contributing examinations.

That is: $C_i = (1/N)x(1/n) \times \Sigma^N \Sigma^n (\delta_i \times E_i)$

where C_i = mean cohort score after ith examination (i=1,N)
N= number of examinations, n = number in cohort
E_i = ith examination mark
δ_i = 1 if sit ith examination, = 0 otherwise.

Applying this to the New Zealand situation, the cohort score over the three final years of secondary schooling (four mathematics examinations) is

$C_3 = (1/4)x(1/n) \times \Sigma(1xSC + \delta_{SFC} xSFC + \delta_{MWS}xMWS + \delta_{MWC}xMWC)$

where n = number in School Certificate cohort

SC, SFC, MWS, MWC = School Certificate, Sixth Form Certificate, Mathematics with Statistics, Mathematics with Calculus mark respectively
δ = 1 if sit qualification, = 0 otherwise.

This could be expressed equivalently as

$$C_3 = 1xm_{SC} + p_{SFC}xm_{SFC} + p_{MWS}xm_{MWS} + p_{MWC}xm_{MWC}$$

where m = mean cohort score, p = cohort participation rate in examination.

A useful index to compare the various subgroups in the School Certificate cohort (gender, Maori and non-Maori) is then constructed by comparing the mean score obtained by each sub-group with the mean score of the total group (or, for example, with the highest performing, or 'dominant' group.

Thus, the achievement index, AI_i , is calculated as follows (subscript indicates the year) where

AI_1 = achievement index in first examination
:
AI_3 = achievement index in third examination, etc.
and thus,
AI_1 (non-Maori males) = C_1(non-Maori males) / C_1(total cohort)
AI_3 (non-Maori males) = C_3 (non-Maori males) / C3(total)
:
AI_1 (non-Maori females) = C_1 (non-Maori females) / C1 (total)
etc.

RESULTS

Data for the 1992 School Certificate cohort was obtained from the New Zealand Qualifications Authority. This cohort can be assumed to be samples from a 'super-population' of all potential examination candidates. The derived indices can therefore be considered to be sample estimates and the sample errors for these determined (using methods such as boot-strapping). Preliminary results (using all candidates in each examination rather than just cohort members) give the following estimates of the achievement indices for each group.

Table 3. Achievement Index for 1992 School Certificate Students

	Non-Maori		Maori		Total
	Female	Male	Female	Male	
AI	103	104	75	76	100
AI	104	107	64	69	100
AI	102	110	56	59	100

As figure 2 shows, by weighting the examination achievement by the different participation rates the ranking of these groups health is unchanged (from lowest to highest: Maori females, Maori males, non-Maori females, non-Maori males) but the

magnitude of the differences between groups is shown to increase markedly, even over a short-time period.

Figure 2. Educational Achievement Index Scores

CONCLUSION

The use of an achievement index which incorporates both participation and achievement rates demonstrates that cohort achievement differences can increase rapidly over short time periods. Such an indicator can be used for a variety of subjects or combinations of subjects, and over various time periods. It could even by developed into a life-time index of educational achievement which could be used to compare educational outcomes between various groups in any cohort of students. Such systematic monitoring of outcomes, and of the changes over time between subgroups of cohorts, is needed to ensure the fairness of education to all groups of students.

REFERENCES

Blithe, T., Clark, M., and Forbes, S. (1995). Assessment of girls. In J. Neyland (Ed.)*Mathematics education. A handbook for teachers*, Vol. 2, (pp. 94-108). Wellington, New Zealand: Wellington College of Education.

Forbes, S. (1994). *Assessing statistics learning*, Paper presented to the Fourth International Conference on Statistics Education (ICOTS4), Marrakech, Morocco.

Forbes, S., Blithe, T., Clark, M. and Robinson, E. (1990). *Mathematics for all? Summary of a study of participation, performance, gender and ethnic differences in mathematics*, Wellington, New Zealand: Ministry of Education.

Forbes, S., Blithe, T., Clark, M., and Chamberlain, M. (1996, July). The continuing need to monitor gender differences. Paper presented to the Eighth International Conference on Mathematics Education (ICME8), Seville, Spain.

Morton, M., Reilly, B., Robinson, E. and Forbes, S. (1993). A comparative study of two nation-wide examinations: Mathematics with Calculus and Mathematics with Statistics. *Educational Studies in Mathematics, 00:* pp. 1-21.

Parker, L. H., and Tims, J. E. (1995, April). *Different modes of assessment in mathematics: A systematic interaction with gender*, Paper presented at the Annual Meeting, National Association for Research in Science Teaching, San Francisco, California.