Potential Uses of Longitudinal Analyses to Investigate Education Outcomes

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1. Introduction

At the level of the individual student the main measurable long-term outcomes of education are future employment or future participation in higher levels of education. Data that links students over time (longitudinal data) is, however, rarely available within specific levels of education (such as primary, secondary, or tertiary) let alone outside the education sector. Educational outcomes are often, therefore, measured just at single points of time (cross-sectionally). The measures generally used in education are achievement and, to a lesser extent, participation. One could consider these as the short term, or immediate, outcomes of education.

A number of methods for measuring the ongoing (or longitudinal impact) of these outcomes are discussed in this paper. These were applied to cohorts of students in the last three years of secondary schooling in New Zealand (years 10-12). Over the period of analysis (1992-1995, statistics was taught within the mathematics curriculum at years 10 (*School Certificate mathematics*) and 11 (*Sixth Form Certificate mathematics*), and as a major part of one of the two mathematics courses (*Bursary Mathematics with Statistics* and *Bursary Mathematics with Calculus*) available at year 12. Students were assessed in each, either by nationally moderated internal assessments or by external national examinations.

Longitudinal data can be used to investigate differences over time (trends) between different cohorts of students (between population effects) and between groups of students within the same cohort (within population effects). In this case, the cohorts were partitioned into sub-groups by sex and whether the students were of Maori (indigenous New Zealand) ethnicity.

2. Data sets and methods

Data sets containing the achievement of students in each paper at each of the above levels were obtained for each of the years 1992-1995 separately. In addition, two longitudinal datasets were obtained (anonymised but ‘linked’ across individual students by the organisation responsible for education qualifications).The 1992 cohort dataset contained the achievement of all students that sat School Certificate mathematics in 1992 and their achievement in, if they continued in this subject, Sixth Form Certificate mathematics in 1993 and either or both Mathematics with Calculus and Mathematics with Statistics in 1994. A similar longitudinal dataset was constructed for the 1993 cohort.

The methods of analysis used were chosen to answer the following questions:

1. What are the major factors associated with different changes in state (for example, mark or grade) across the four groups of students?
2. To what extent are these repeated annual achievement assessments measuring new skills and knowledge in mathematics and statistics?

3. Can the joint impact of achievement and participation be measured and accumulated across time and, what are the differences in impact across the four groups of students?

Correlation analysis, tree analysis (Venables & Ripley, 1994) and transition matrices were used to compare the probabilities in each group of a student's marks increasing or decreasing across the qualifications. Correlation analyses were used to determine the level of association between the achievement in pairs of qualifications or assessments. The difference in achievement, for individual students, across these pairs, can be used to compare the two assessments, but other methods are needed for comparisons across more than two assessments. Tree analysis uses recursive partitioning of the data by the predictor variables (sex or ethnicity) that makes the greatest difference in the response variable (mark).

For years 10 and 12 both marks and grades were recorded but for year 11 only grades were used. So transition matrices were used to investigate differences in mobility between these (states). As Atkinson and Jenkins (1984) suggest, one of the advantages of using transition matrices is that 'asymmetric mobility patterns' can be observed which may not be seen in traditional regression analyses. The essential difference between a transition matrix and a normal 2-way contingency table is that in a contingency table the two variables may be quite different (for example, age group and ethnicity) and are generally measured on each individual at the same point of time, but in a transition matrix they are similar (in this case, grades) but recorded at two different time points. Chi-squared tests were used to compare the proportions of students that changed grades in each group.

Principal Components Analysis, a form of Factor Analysis, (Ferguson & Takane, 1989) was used to see whether or not there was only one significant factor for the four mathematics qualifications studied. Evidence of a single common dimension of mathematics achievement (similar to that found by Keeves & Alagumalai, 1998 for science) may imply that, despite the differences in assessment formats, each qualification tests similar mathematical knowledge and skills.

In order to measure the accumulated impact of particpation and achievement (which, in general, have only been measured separately) an index was constructed which was essentially a 'weighted mean' across the qualifications. That is, the Cumulative Outcomes Index (COI) is

$$(1)\ COI_N = \frac{1}{N} \times \frac{1}{n} \Sigma_i \Sigma_j \delta A_{ij} \quad \text{where } i = 1,N,\ j = 1,n,$$

and δA_{ij} = score attained by jth student in the ith qualification if the student sat this qualification,
= 0 otherwise.

Cumulative Outcomes Indices were calculated for each of the four student groups separately. Each is equivalent to the sum of the group's mean score for each qualification weighted by the group's participation in each qualification.

3. Results

In each of the years 1992–1995 approximately 40,000 students sat School Certificate mathematics, but there were already differences in participation between the four groups of students (with a higher proportion of males than females, and of non-Maori than Maori students taking mathematics) . There were more than 20,000 Sixth Form Certificate mathematics candidates in each of these years, about 12,000 students in Bursaries Mathematics with Statistics and roughly 9,000 in Bursaries Mathematics with Calculus. In general, the participation of females in all these mathematics examinations was lower than that of males, and the difference increased as the level of the examination increased. In most cases the sex difference in participation remained stable or only lessened slightly. A similar, but much more marked difference was observed in the participation of Maori students in mathematics, compared to non-Maori students. In each year the mathematics achievement of Maori students was markedly lower (roughly 10 percentage points where marks were given) than that of non-Maori students in each qualification. Where effect sizes or 'standardised mean differences' (Cohen, 1969) could be calculated these were always at least three times greater between Maori and non-Maori than between male and female students.

Longitudinal data is needed to investigate the relationships between achievement and participation. This showed that, as expected, it was predominately the 'failing' portion (with mean scores under 40%) of the year 10 cohorts (in both 1992 and 1993) that did not proceed in mathematics. Achievement in year 10 seemed to be an influential factor in a student's decision to carry on in mathematics, not just in the following year (11) but also in two years time (12).

The end of year 11 appeared to be a decision point for female students regarding their future participation in mathematics. While high achieving mathematics students were more likely than low achieving students to move directly to the next level of study in mathematics, in all grades, a smaller proportion of females continued in mathematics. However, transition matrices indicated that the achievement of female students in year 11 mathematics was better than would be expected given their previous achievement in year 10 mathematics. In both year 12 mathematics examinations females were more likely than males, to go down one or more grades compared to either their year 10 or year 11 performance.

Regardless of their level of previous achievement, Maori students were markedly less likely then non-Maori students to continue in mathematics in all years. Also, regardless of their previous achievement in year 10 mathematics, Maori males dominated the low grades in year 11. Maori students were more likely than non-Maori students, in either year 12 paper, to go down one or more grades compared to either their year 10 or year 11 performance. Across the qualifications, in general Maori students did not achieve as well in subsequent mathematics qualifications as did non-Maori students who had the same previous level of mathematics achievement.

Tree analysis indicated that ethnicity appeared to be a better predictor than sex of a drop in marks between year 10 mathematics and year 12 *Mathematics with Calculus*, but no consistent pattern across the cohorts was observed between year 10 mathematics and year 12 *Mathematics with Statistics*.

When Principal Components Analysis was applied to the mathematics achievement in each of the qualifications for students in both the 1992 and 1993 cohorts, one factor did account for most (roughly between 70%-80%) of the joint variation in marks among the mathematics qualifications. This implies that there may be an underlying level of mathematics skill that is being re-assessed again and again. This finding supports Clark's (1999) contention that assessment may only be needed in mathematics and in statistics at one level in New Zealand secondary schooling instead of at all of the current three levels.

The COI was applied to the cohort of all year 10 students who sat School Certificate mathematics in 1993 and as figure 1 indicates:

- even over this relatively short period (3 years) the disparity, as measured by this index, between non-Maori and Maori students in their attainment in mathematics, increased markedly,
- at the end of secondary schooling, the accumulated mathematics attainment of Maori students, as a group, was less than two-thirds that of non-Maori students,

- sex differences (in favour of males) also increased slightly over the 3 years for Maori students, but fluctuated in direction for non-Maori students (in accordance with the form of assessment used).

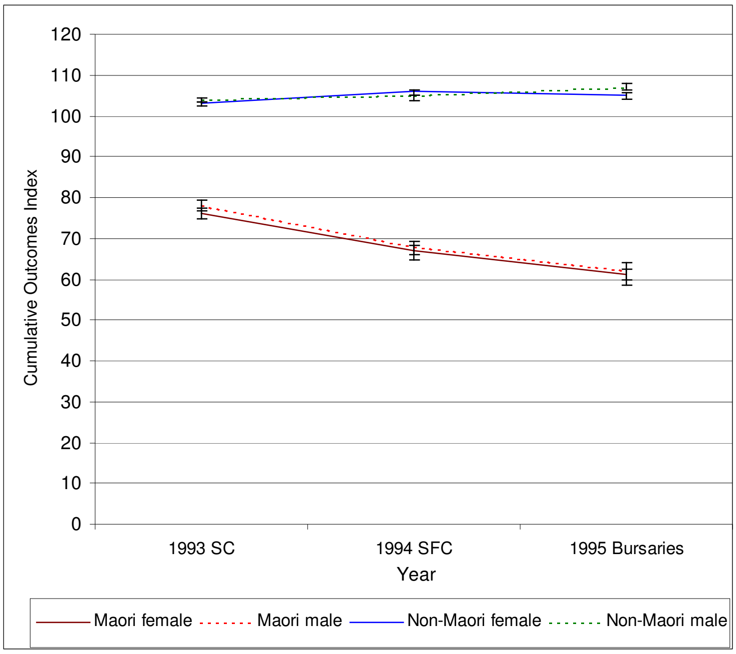

Figure 1. Cumulative Outcomes Indices with 'bootstrapped 95% confidence intervals, for the 1993 cohort.

4. Summary

Traditional time series can be used to show trends over time but longitudinal data enables the tracking of cohorts over time and also provides a powerful tool for exploring both within cohort effects (differences between groups) over time. As shown in this study there are already many techniques available for analysing longitudinal data but futher work may be needed to develop more sophisticated cumulative indices such as lifetime educational indices.

REFERENCES

Atkinson, A. B. & Jenkins, S. P. (1984). The steady state assumption and the estimation of distributional and related models. *Journal of Human Resources. 19,* 358-376.

Clark, M. (1999). Electronic communication

Cohen, J. (1969). *Statistical power analysis for the behavioural sciences.* New York: Academic Press

Ferguson, G.A. & Takane, Y. (1989). *Statistical Analysis in Psychology and Education* (6th ed.). New York: McGraw Hill

Forbes, S. D. (2000}. *Measuring students' education outcomes: Sex and ethnic difference in mathematics,* (Doctoral dissertation), Curtin University of Technology, Perth, Australia.

Keeves, J. P. & Alagumalai, S. (1998). Advances in measurement in science education. In B. J. Fraser & K. Tobin (Eds.) *International handbook of Science education.* (pp. 1229-1244). The Netherlands: Kluwer Academic Publishers.

Venables, W. N. & Ripley, B. D. (1994). *Modern Applied Statistics with S-Plus.* New York: Springer-Verlag.

RÉSUMÉ

Les données transversal sont utiliserà accumuler l'achèvement educatif des cohortes des étudiants pendant quelques temps, et aussi pour explorer les effets entre cohortes (groups des étudiants).