Rural Students and Graphics Calculators in Examinations

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With the introduction of graphics calculators to tertiary entrance examinations in mathematics in Western Australia, the question arose as to whether rural students were placed at a disadvantage when compared with those in the city[1]*. Analysis of examination data revealed that the gap in achievement between rural and city students narrowed initially in two of the three subjects examined but returned to similar comparability in the second year of implementation of graphics calculators. While a gap in examination scores in maths still exists, this could allay fears that rural students may have been subjected to further disadvantages associated with the use of graphics calculators in examinations*

Background

The use of graphics calculators was allowed in the Tertiary Entrance Examinations (TEE) in Western Australia for the first time in 1998, in each of the three mathematics subjects. The decision to allow their use was based on the rationale that since the technology exists, its use should be allowed, and that developments with scientific calculators had led to difficulties in policing their use in examinations (personal communication with Curriculum Council officer, November 1999). The four years' notice given for their introduction allowed time for schools to make decisions pertaining to curricula and the selection of a suitable calculator. Teachers were therefore afforded the opportunity to familiarise themselves with the capabilities of the calculators and to make the necessary adjustments to their teaching procedures and materials.

Of the three mathematics subjects examined at the TEE level in Western Australia, Applicable Mathematics and Calculus are considered accessible to the top 30% of the year cohort and Discrete Mathematics for the next 30%. Each year, approximately 5000 students sit for Applicable Mathematics, 2000 for Calculus and 6000 for Discrete Mathematics. The smaller numbers who study Calculus are indicative of the more selective group of students who intend studying courses at tertiary level that require a specialised background in mathematics.

Theoretical Framework

There is an emerging body of research that has been published focusing on the effectiveness of graphics calculators as a tool for instruction and learning in mathematics. One area that has received attention addresses the use of graphics calculators in pre-calculus and calculus classes (Slavit, 1996; Quesada and Maxwell, 1994; Drijvers and Doorman, 1996). Another area of research addresses sex differences associated with graphics calculator usage (Ruthven, 1990; Vazquez, 1991; Boers and Jones, 1991, 1992a, 1993; Cassity, 1997). While some studies involving the use of graphics calculators in examinations were located (Haimes & Webster, 2000; Boers and Jones 1992a, 1992b, 1992c, 1993), a search of the literature failed to identify any that specifically examine the implications for students in rural schools.

Several studies have investigated the mathematics achievement of rural students compared with those in the city. These include Young's (1994) analysis of Monitoring Standards in Education data in Western Australia. Results of this study indicate that students in Years 3, 7 and 10 in metropolitan schools scored significantly higher in mathematics than students in rural and remote locations. In their analysis of National Assessment of Educational Progress achievement scores in the USA, Greenberg and Teixeira (1995) found that non-metropolitan 17 year-old students scored only slightly lower than metropolitan students in mathematics. It is acknowledged that the "rural" classification in these two studies may be quite different, given the completely different contexts.

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[1] City in this case refers to students who attended schools located in the Perth, Western Australia, metropolitan area.

Meanwhile Cox's (1997) analysis of three Common Assessment Tasks conducted as part of the Victorian Certificate of Education revealed that rural students performed more poorly than their metropolitan counterparts. None of these three studies involved the use of graphics calculators.
It has been suggested that students in rural schools are disadvantaged when compared with their city counterparts, in terms of both human and material resources. Sunal (1991) in a study of rural science teaching in a south central Appalachian state (USA) found that higher science achievement correlated positively with an adequate number of certified (i.e. qualified) science teachers; with higher teacher ratings of effectiveness of in-service programs and greater access to university courses; and to schools rated as having more laboratories, equipment and general resources. In addition, Hall and Barker (1995) reported that their comparison of curricular offerings in mathematics in a Chicago suburban high school, a rural high school district, and a small rural unit, revealed the curricular disadvantages of small rural high schools.

It is possible that students in rural high schools in Western Australia may suffer from some of the disadvantages reported above. Their teachers may be less qualified and experienced than those in city high schools, have less access to professional development (such as that provided prior to the implementation of curriculum change) and, in the smallest of these schools, have less opportunity to confer with colleagues. In addition, rural schools may not be as well resourced in materials and equipment as city schools. Each of these factors has the potential to impact on the achievement of rural school students.

In 1996, Penglase and Arnold conducted a meta-analysis of research on the use of graphics calculators in mathematics education. They identified the use of graphics calculators in examinations as an area in this particular field of research that needed further investigation. The achievement of rural students in a graphics calculator environment provided the focus in this study. The primary purpose of this present study was to investigate whether students in rural schools were disadvantaged when compared with those students in city schools, following the introduction of graphics calculators to the TEE.

Methodology

Data pertaining to student achievement were obtained from the Curriculum Council of Western Australia, the educational body that administers the state-wide tertiary entrance examinations. These took the form of databases of individual student scores on each question in Applicable Mathematics and Calculus, and part question in Discrete Mathematics, for each of the 1997, 1998 and 1999 examinations. Individual data sets were identified according to the location of the student's school (rural or city).

Using the syllabus guide (Curriculum Council, 1998), further data were generated by aligning each examination question with the curriculum component it represented. This was done independently by both the first author of this paper and a colleague. Where necessary, consensus was reached through negotiation, allowing each question to be assigned to a particular curriculum component. The marks allocated to that component were then aggregated.
Differences in the overall mean scores between rural and city students were tested for significance using an independent sample t-test. Due to the abnormality of the distribution of the data a Mann-Whitney U-test was employed to test for significance of differences in the mean ranks by curriculum component (see Table 3).

Results

The data concerning numbers of students who sat for each of the mathematics examinations in 1997, 1998 and 1999 (Table 1) indicate that, with the exception of Calculus in 1999, the total numbers and the proportions of city and rural students sitting for each of the examinations remained consistent over the three years.

Table 1. Numbers (%) of candidates for mathematics examinations

Exam	Total	Rural	City
Applicable '97	4903	804 (16)	4100 (84)
Applicable '98	4973	832 (17)	4144 (83)
Applicable '99	4787	849 (18)	3938 (82)
Calculus '97	1888	252 (13)	1636 (87)
Calculus '98	1882	253 (13)	1632 (87)
Calculus '99	1957	375 (19)	1582 (81)
Discrete '97	5818	890 (15)	4928 (85)
Discrete '98	5774	890 (15)	4891 (85)
Discrete '99	6240	1076 (17)	5164 (83)

A summary of the differences in overall means between rural and city students is given in Table 2. These figures indicate that, with one exception, in each of the three years the mean scores of city students were significantly greater than those of the rural students, and that the gap between these scores has remained relatively consistent. One exception is in the 1998 Calculus, where the mean score gap between city and rural students narrowed. This was not sustained in 1999.

Table 2. Comparative Performance of Rural and City Students: Differences Between Overall Means[2]

Examination	Rural		City		t
	Mean	SD	Mean	SD	
Applicable '97	94.14	31.95	104.67	33.19	8.285*
Applicable '98	89.94	32.38	101.84	30.75	10.119*
Applicable '99	99.98	33.13	110.95	32.20	8.957*
Calculus '97	111.64	33.05	121.04	34.25	4.135*
Calculus '98	94.01	32.39	99.45	33.86	2.432
Calculus '99	95.14	31.75	107.26	32.81	6.466*
Discrete '97	112.07	27.05	115.85	27.19	3.841*
Discrete '98	99.20	24.81	101.76	25.41	2.813*
Discrete '99	103.09	25.00	106.34	25.80	3.780*

*$p<0.01$

[2] The authors acknowledge that with sample sizes as large as those in this study, the sensitivity of statistical tests such as t-tests affords greater than optimum power. However, the differences between test scores that are discussed in this report are done so in a subjective manner and are contextually worthy of such comments. The authors are also mindful of the limitations and believe they are clearly transparent in this paper.

The breakdown of questions according to Curriculum Component is given in Table 3. Although some changes in emphases of differences of mean scores are apparent following the introduction of graphics calculators in 1998, these changes were not consistent in the 1999 examinations.

Table 3. Proportions of Marks According to Curriculum Component (Percentages)

Exam	Curriculum Component	1997	1998	1999
Applicable	Systems of Equations and Matrices	22	26	23
	Graphs and Solution of Equations	15	21	20
	Descriptive Statistics	18	16	12
	Sets, Counting and Probability	23	19	15
	Random Variables and their Distribution	22	18	29
Calculus	Functions and Limits	18	14	24
	Theory and Techniques of Calculus	16	16	16
	Application of Calculus	39	41	34
	Vector Calculus	10	6	7
	Complex Numbers	17	23	19
Discrete	Projects, Problem Solving and Investigations	5	8	11
	Data Analysis	38	33	31
	Optimisation	27	26	27
	Growth and Decay	31	32	32

The comparative examination performance for all three years of rural and city students according to curriculum component is reported in Table 4. There were no changes in the relative achievement of rural and city students in any of the curriculum components in Applicable Mathematics following the introduction of graphics calculators. In both the theory and techniques of calculus and applications of calculus components of the 1998 Calculus examination, the mean score gap in achievement between rural and city students narrowed but increased again in the 1999 examination. In the vector calculus component, the mean score gap between rural and city students increased following the introduction of graphics calculators in 1998 and this was sustained in 1999. With Discrete Mathematics, the gap in achievement narrowed in the 1998 examination in the data analysis and optimisation components but increased again in the 1999 examination.

Table 4. Comparative Performance of Rural and City Students: Differences in Mean Ranks by Curriculum Component

		1997 Rural Mean Rank	1997 City Mean Rank	1997 Z	1998 Rural Mean Rank	1998 City Mean Rank	1998 Z	1999 Rural Mean Rank	1999 City Mean Rank	1999 Z
Applicable	Systems of equations and matrices	2220.01	2497.71	-5.096**	2132.84	2549.71	-7.675**	2085.25	2460.56	-7.179**
	Graphs and solution of equations	2121.75	2511.05	-7.149**	1990.87	2586.97	-10.96**	2046.49	2465.07	-8.003**
	Descriptive statistics	2151.47	2505.19	-6.496**	2178.08	2542.39	-6.707**	2119.81	2450.15	-6.327**
	Sets, counting and probability	2025.88	2533.52	-9.315**	2170.56	2548.79	-6.962**	2116.14	2451.45	-6.417**
	Random variables and their distributions	2152.75	2503.95	-6.457**	2087.19	2554.42	-8.598**	2032.67	2460.96	-8.207**
Calculus	Functions and limits	869.65	1003.72	-4.138**	856.40	952.52	-2.674**	869.65	1003.72	-4.138**
	Theory and techniques of calculus	877.43	1001.19	-3.819**	876.70	946.23	-1.934	850.20	1007.63	-4.858**
	Applications of calculus	788.37	1021.68	-7.196**	887.38	950.33	-1.746	788.37	1021.68	-7.196**
	Vector calculus	836.25	883.88	-1.540	810.96	894.67	-2.404*	842.47	904.37	-2.006*
	Complex numbers	855.97	1005.07	-4.605**	857.21	951.76	-2.626**	806.11	1012.93	-6.382**
Discrete	Projects, problem solving and investigations	2954.68	2851.93	-1.714	2880.25	2872.20	-0.135	3020.34	3099.65	-1.321
	Data analysis	2778.57	2931.76	-2.519*	2854.74	2893.76	-0.653	2999.63	3145.68	-2.420*
	Optimisation	2544.85	2975.34	-7.082**	2822.65	2899.89	-1.293	2975.19	3149.58	-2.890**
	Growth and decay	2737.70	2939.27	-3.315**	2724.89	2917.38	-3.221**	2872.58	3172.16	-4.963**

**p<0.01 *p<0.05

Discussion

Differences in achievement favouring city over rural students in each of the years 1997, 1998 and 1999 are consistent with those found by Young (1994), Greenberg and Teixeira (1995) and Cox (1997). However, the question to be addressed in this study was whether rural students were placed at a further disadvantage with the introduction of graphics calculators into TEE mathematics. There is no evidence from the analysis of the data that this was the case. No deterioration was detected in the overall achievement of rural students compared with city students from 1997 through to 1999. While there was some evidence of a narrowing of the gap between the achievement of rural and city students in Calculus and to some extent in Discrete Mathematics in 1998, this was not sustained in 1999. The 1998 data suggest that the examinations in both subjects were more difficult than in 1997 and this may have resulted in a narrowing of the gap between the two groups of students. It could be possible that the factors identified earlier – namely, the relative qualifications and experience of rural teachers, access of rural teachers to professional development and the opportunity to confer with colleagues, and the level of resources in rural schools – have not impacted on rural students' facility with graphics calculators, but further research is needed to substantiate this.

The analysis presented here was based on limited data and further research is necessary to confirm that rural students have not been placed at a disadvantage with the introduction of graphics calculators. Examination of student scripts, focusing on questions where the difference in mean scores between rural and city students was greatest, would allow possible anomalies between rural and city students in their usage of the calculators to be detected.

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