Rural Students and Graphics Calculators in Examinations: Some Preliminary Findings

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With the introduction of graphics calculators to tertiary entrance examinations in mathematics in Western Australia, a question that arose is whether rural students were placed at a disadvantage when compared with those in the city[1]. A preliminary analysis of examination data suggests that rather than disadvantage, there was some evidence of an improvement in the achievement of rural students when compared with those in the city.

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 the use of graphics calculators was based on the rationale that, given the technology exists, its use should be allowed, and that developments with scientific calculators had made it difficult to police their use in examinations (personal communication with Curriculum Council officer, November 1999). Some four years' notice was given for their introduction to allow time for schools to make decisions pertaining to curricula and the selection of a suitable calculator. This time-line afforded teachers the opportunity to familiarise themselves with the uses to which the calculators might be put and to make the necessary adjustments to their teaching procedures and materials.

There are three mathematics subjects examined at the TEE level in Western Australia. Applicable Mathematics and Calculus are the two subjects considered accessible to the top 30% of the age cohort, while Discrete Mathematics is deemed appropriate 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 reflecting its status as a pre-requisite for a limited number of courses at tertiary level.

Theoretical Framework

There is a paucity of research articles that have been published regarding the effectiveness of graphics calculators as a tool for instruction and learning in mathematics. One area in which research has occurred concerns their use in pre-calculus and calculus classes (e.g., Slavit, 1996; Quesada & Maxwell, 1994; Drijvers & Doorman, 1996). Another that has attracted some attention concerns sex differences associated with their use (e.g., Ruthven, 1990; Vazquez, 1991; Boers & Jones, 1991, 1992a, 1993; Cassity, 1997). While some studies involving the use of graphics calculators in examinations were identified (e.g., Boers & Jones 1992a, 1992b, 1992c, 1993), no studies that examined their impact with rural students were apparent.

Studies that have investigated the mathematics achievement of rural students compared with those in the city include that of Young (1994). In her analysis of Monitoring Standards in Education data in Western Australia, Young found students in Years 3, 7 and 10 in metropolitan schools scored significantly higher in mathematics than students in rural and

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

remote locations. However, Greenberg and Teixeira (1995), in their analysis of National Assessment of Educational Progress achievement scores in the USA, found that non-metropolitan 17 year-old students scored only slightly lower than metropolitan students in mathematics. Meanwhile, an analysis of three Common Assessment Tasks conducted as part of the Victorian Certificate of Education (Cox, 1997) revealed that rural students performed worse than their metropolitan counterparts. In none of these three studies was the use of graphics calculators the focus.

It has been suggested that students in rural schools may be at a disadvantage 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 introduction of graphics calculators) 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.

Penglase and Arnold (1996), in their meta-analysis of research on the graphics calculator in mathematics education, concluded that the use of graphics calculators in examinations was an area of research that was particularly under-represented. In this study, the achievement of rural students in the TEE provided the focus. It sought to determine whether there was any evidence to suggest that rural students were disadvantaged when compared with those in the city, following the introduction of graphics calculators.

Methodology

Data pertaining to student achievement were obtained from the Curriculum Council of Western Australia, the body that administers tertiary entrance examinations. The data provided took the form of the total number of students who sat for each of the TEE mathematics examinations in 1997 and 1998, together with students' mean scores for each whole question (in the case of Applicable Mathematics and Calculus) or part question (Discrete Mathematics). These data were further categorised according to the location of the school (rural or city). Although in each examination students were asked to attempt all questions on the paper, the Curriculum Council excluded non-attempts when calculating the mean scores.

A second set of data was provided by panels of teachers. For each of the three mathematics courses, a panel of five experienced teachers who had taught that course in 1998 were invited to make assessments of the 1997 and 1998 examination papers. With respect to each part question, they were asked to indicate whether the use of a graphics calculator would have been appropriate. Inter-rater reliability coefficients were calculated for each mathematics paper assessed using the formula

$$r = \frac{(MS_b - MS_w)}{((MS_b - (n-1)MS_w))}$$

where MS_b is mean squares between; MS_w is mean squares within, and n is the number of cases (Stevens, 1990).

Data obtained from Teacher Panel members were then aggregated so that each part question on each of the six examination papers was categorised as being appropriate or inappropriate for graphics calculator use.

For each of the six examination papers, the numbers of questions where the mean score of rural students exceeded those from the city, and vice versa, were aggregated, as were the marks allocated to those questions. The same procedure was adopted for questions identified by the teacher panel as being appropriate for graphics calculator use. In addition, questions for which the difference in mean score between rural and city students exceeded five percentage points were identified on each paper.

Results

Table 1 indicates the numbers of students who sat for each of the mathematics examinations in 1997 and 1998. As may be seen, both the total numbers and also the proportions of city and rural students remained consistent between the two years.

Table 1
Numbers (%) of Candidates for TEE Mathematics Examinations

Subject/Year	Total	City	Rural
Applicable '97	4904	4100 (84)	804 (16)
Calculus '97	1888	1636 (87)	252 (13)
Discrete '97	5818	4928 (85)	890 (15)
Applicable '98	4976	4144 (83)	832 (15)
Calculus '98	1885	1632 (87)	253 (13)
Discrete '98	5781	4891 (85)	890 (15)

Table 2
Measurement of Agreement Coefficient for Teacher Rating of Items' Appropriateness for Graphics Calculator Use

TEE Exam	r
1997 Applicable	0.7953
1998 Applicable	0.8976
1997 Calculus	0.7059
1998 Calculus	0.7339
1997 Discrete	0.7180
1998 Discrete	0.8851

Inter-rater reliability coefficients for the teacher assessments are reported in Table 2. They were consistently high, indicating a strong measure of agreement in the responses of the five members of each teacher panel.

The teacher panel assessments are presented in Table 3. Designated are proportions of the total mark that were allocated to the categories of appropriate or inappropriate for graphics calculator use as a result of the teachers' assessments. Of particular note are the proportions of marks allocated to questions deemed appropriate for graphics calculator use in Applicable Mathematics and Calculus. While for the 1998 Applicable Mathematics paper there is a suggestion that, in devising questions, the examiners moved to encourage their use, the opposite appears true for Calculus.

Table 3

Teacher Assessment of Examination Items (Percentages)

Graphics Calculator Usage	Applicable		Calculus		Discrete	
	1997	1998	1997	1998	1997	1998
Appropriate	23	34	26	16	21	23
Inappropriate	77	66	74	84	79	77

The comparative performance of rural and city students on each of the papers for 1997 and 1998 is found in Table 4. Indicated is the number of questions (part questions in the case of Discrete Mathematics) where the mean score of students of one group exceeded that of the other. These data indicate there was no deterioration in the achievement of rural students compared with city students from 1997 to 1998. In fact, they suggest a slight improvement in the performance of rural students, in both Calculus and Discrete Mathematics.

Table 4

Comparative Performance of Rural and City Students: Numbers of Questions on which Mean Scores of Students of One Group Exceeded those of the Other

TEE Subject	1997		1998	
	Rural	City	Rural	City
Applicable	0 (0)	23 (180)	1 (5)	21 (175)
Calculus	0 (0)	20 (180)	4 (39)	15 (141)
Discrete *	22 (57)	46 (122)	26 (68)	43(112)

Note. Numbers in parentheses are marks out of 180 that were apportioned to those questions. *Mean scores were provided for part questions in most cases.

The data in Table 5 focus on questions that were rated by the teacher panels as being appropriate for graphics calculator use. In the case of Applicable Mathematics and Calculus, they include whole questions for which the teacher panel rated at least two thirds of the question appropriate for graphics calculator use. Again, these data suggest no deterioration in the achievement of rural compared with city students on these particular questions.

Table 5

Comparative Performance of Rural and City Students on Questions Rated Appropriate for Graphics Calculator Use

TEE Subject	1997		1998	
	Rural	City	Rural	City
Applicable *	0 (0)	4 (22)	0 (0)	5 (45)
Calculus *	0 (0)	4 (47)	1 (5)	2 (17)
Discrete **	4 (10)	8 (24)	5 (12)	11 (31)

Note. Numbers in parentheses are marks out of 180 apportioned to those questions. * Whole questions in which at least two-thirds rated appropriate for graphics calculator use. ** Part-questions rated appropriate for graphics calculator use.

Data showing the number of questions on each of the six examination papers where the difference in mean scores between rural and city students exceeded five percentage points are found in Table 6. That there is only a small number of such questions indicates the difference in achievement overall between rural and city students was not great in either year. In comparing 1998 with 1997 data, the most notable change is in Calculus, favouring rural students. In both Applicable Mathematics and Discrete Mathematics, little change was apparent.

Table 6

Comparative Performance of Rural and City Students on Questions Where Means Differed by More Than Five Percentage Points.

	1997		1998	
	Rural	City	Rural	City
Applicable *	0 (0)	11(91)	0 (0)	12 (106)
Calculus *	0 (0)	11 (103)	0(0)	3 (25)
Discrete **	1(2)	10 (24)	0 (0)	4(14)

Note. Numbers in parentheses are marks out of 180 apportioned to those questions. * Whole questions in which at least two-thirds rated appropriate for graphics calculator use. ** Part-questions rated appropriate for graphics calculator use.

A closer examination of the questions for which the means differed by more than five percentage points reveals that three in Applicable Mathematics, two in Discrete Mathematics, but none in Calculus were rated as appropriate for graphics calculator use. The three in Applicable Mathematics involved the solution of an inequality, a normal probability distribution problem, and a probability density function. The two in Discrete Mathematics were part of a problem involving linear programming and part of a problem involving a geometric sequence. There doesn't appear to be a particular reason why city students might score higher on these questions than their rural counterparts.

Discussion

Differences in achievement favouring city over rural students in both 1997 and 1998 are commensurate 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 disadvantage with the introduction of graphics calculators into TEE mathematics. From the analysis of the rudimentary data available, it appears not. There was no deterioration detected in the achievement overall of rural students compared with city students, or in questions that were rated by the teacher panels as being appropriate for graphics calculator use. There was even a suggestion among the data that rural students may have improved in some instances. On the basis of this finding, it would appear that none of 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 – has impacted on rural students' facility with graphics calculators.

As the analysis presented here was based on limited data, further research is necessary to confirm whether or not rural students have been placed at a disadvantage. Access to individual student data and to that for the 1999 examinations would allow for more sophisticated analyses to be performed. Furthermore, examination of student scripts, focussing on questions rated appropriate for graphics calculator use and those where the difference in scores between rural and city students was greatest, would allow any differences between rural and city students in their usage of the calculators to be detected.

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