THE MATHEMATICS CONTENT COURSE FOR PRE-SERVICE PRIMARY TEACHERS: DESIGN, IMPLEMENTATION AND EVALUATION

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Abstract: Unlike Secondary School Mathematics Teachers who are mathematics graduates, primary school teachers in Singapore are generalists who are expected to teach most of the subjects in the primary curriculum. Being concerned with the mathematical understanding of trainee teachers, a mathematics curriculum content course was introduced in the BA/BSc with Dip Ed course when it was undergoing review. This course sought to supplement the Mathematics methodology course by providing foundation conceptual understanding which is closely related to the primary Mathematics syllabus. This was introduced in the academic year 1998-99 and the course has been taught twice, in 1999 and in 2000. This paper will discuss the conceptualisation of the course, its content, teaching methodology and assessment mode. It will also discuss the students' performance over the two intakes which have taken the course.

Introduction

Since 1991, there have been three programmes catering to the pre-service training of primary school teachers at the National Institute of Education. These programmes are:

(a) The PGDE(Pri), a one-year postgraduate programme for graduates who come from diverse disciplines,
(b) The BA/BSc with Dip Ed, a four-year undergraduate programme with pedagogical training as well as in-depth content knowledge in two academic subjects, and
(c) Diploma in Education, a two-year diploma programme for A level holders.

Since most teachers in the primary schools are responsible for teaching nearly all subjects of the school curriculum, the training programmes above have to prepare them to teach these subjects regardless of their backgrounds. However, a solid base of *subject matter knowledge* is necessary for teachers to make professional decisions about different strategies and approaches. With the recent initiative on fostering creative and critical thinking, it is even more imperative that teachers have strong understanding of the various subjects so that they can challenge students to think critically within the vehicle of the subject.

In the area of Mathematics, pedagogy lecturers at the National Institute of Education have been concerned that some of the trainees can be relatively poor in their mathematical understanding of the concepts they are expected to teach. Deng & Gopinathan (1999) noted that research in the area of teacher knowledge in Singapore has indicated concerns about content knowledge of teachers in the disciplines of science and mathematics. Moreover, teachers are inclined to view knowledge as a body of facts, describing teaching in terms of imparting knowledge.

Research has shown that open approaches in learning and meaningful encounters with mathematics are usually designed and carried out by teachers who are strong both in the mastery of the subject as well as in their pedagogical knowledge. This argument is aptly summarised in Hodgson (1996) who states that a teacher needs to acquire conceptual understanding “in order to fully play the role of facilitator between pupils and mathematical knowledge”.

The Curriculum Content Courses in the Degree Programme

The BA/BSc with Dip Ed programme (hereafter referred to as the degree programme) which was first implemented in 1991 was undergoing review in 1997. During this review, the concern over teachers’ content mastery was raised. Central in the curriculum revision process was the issue of subject matter preparation in a primary teacher preparatory programme and question of what form(s) subject matter preparation should take. Although the trainees were reading 2 academic subjects up to University level, they may be somewhat lacking in a sound knowledge base in the other curriculum areas. For example, a BSc trainee teacher with Mathematics and Physics as Academic subjects may have a mere 'O' level pass in English while a BA trainee doing History and Literature may have only an 'O' level pass in Elementary Mathematics. Moreover, the 'O' level syllabus does not adequately equip trainees with sufficient conceptual understanding to teach at the primary level. Moreover, while the Academic Subjects (AS) provide in-depth study in the discipline of that subject area, the content and certainly the approaches may not be relevant to the primary curriculum. As stated by Selden & Selden (1997) for the case of mathematics, “the simplistic solution of just increasing the number of mathematics courses required for certification, as has been suggested by the Carnegie Forum ("A Nation Prepared: Teachers for the 21st Century," New York, 1986) or the Holmes Group ("Tomorrow's Teachers," East Lansing, MI, 1986), is unlikely to work. Current offerings in mathematics departments are *not* providing what's needed -- for example, courses that focus on the conceptual development of rational number concepts. ”

In response to these concerns, Curriculum Content (CC) courses were introduced to provide the knowledge base for the curriculum subjects which the trainees will be trained to teach. The CC course is aimed at building up the trainees’ own knowledge and understanding of the subject and should not be confused with the Curriculum Studies (CS) which deals with methodology and pedagogical issues of teaching/learning the subject. In contrast with the AS, CC topics should be directly linked with topics in the primary curriculum but would go beyond such content to provide the foundations for better understanding of that content.

In the degree programme, trainee teachers were required to take 3 CS courses: English and Mathematics are compulsory while the third course was to be chosen from Science, Social Studies, Art, Music or Chinese Language. Linked to each of the CS areas, a CC course would be required. While the CS course took up 8 credit units (about 96 hours), the CC course in each area was given 3 credit units (36 hours). All these were introduced in the academic year 1998-99.

Although most staff teaching methodology courses agreed that content mastery was necessary, there was some disagreement as to whether the CC course should be a separate course or whether it should be incorporated into the CS course for better linkage between the content and the teaching of the subjects. In some subject areas, some staff members felt that they had already incorporated the relevant content into the CS course. However, for other subjects, there was just sufficient curriculum time to cover the basic pedagogical skills a pre-service teacher needed for teaching that subject and additional time needed to be given for content mastery. Furthermore, there was a concern that if CC material was subsumed into the CS course, it may not be given sufficient emphasis. Hence, it was finally decided that the CC would be run as separate courses but would be designed with the understanding that close links would be made with the respective CS courses.

The CC Mathematics Course

The CC Mathematics course was thus intended to supplement the mathematics methodology course by providing foundation conceptual understanding which is closely related to the primary Mathematics syllabus. It was modelled on topics of an in-service module taught in the July 1998 semester and was taught for the first time in the January 1999 semester and for the second time in the January 2000 semester.

The course planners had to grapple with the issue that as an undergraduate course, it had to be rigorous in standard and yet had to be linked with the primary school curriculum. Based on the content of the primary mathematics curriculum, the topics included in the course are given in Table 1 together with the rationale for the each topic.

The course ran over 12 weeks with 3 hours of contact time per week. Of the 36 hours, some were used for the tests and for going through the test questions. Since we wished to provide the trainee teachers with opportunities to engage in mathematical explorations, the trainees were not taught in the traditional mode of large lectures and small tutorial groups but in classes where the teacher-directed exposition was interposed with student exploration and discussion. In the January 1999 semester, the course was implemented for the first time in the degree programme. A total of 44 trainees took the course and these were divided into 2 classes. One class consisted of the 23 who were taking AS Mathematics and the other of the 21 who did not. It was felt that such grouping enabled customised attention to be given to each group according to their respective backgrounds in mathematics. However, in the January 2000 semester, for logistics reasons, the 57 trainees were not grouped according to whether they did AS Mathematics but whether they did AS English. Among these trainees, 19 were taking AS Mathematics and 38 were not.

The approaches adopted for the course focussed on conceptual understanding and thus the mode of delivery moved away from the standard lecture-style of presenting information and explanation followed by the practise of a set of similar problems. The trainee teachers were expected to explore mathematical results through group discussion and active hands-on engagement. As these trainee teachers would be encountering manipulatives in their subsequent CS classes, the use of manipulatives and guiding worksheets was *not* considered to be beneath the dignity of undergraduates. Instead, multi-base blocks, unifix cubes, polydron sets and specially designed worksheets for exploration were introduced to facilitate explorations at appropriate points.

Table 1
Topics for the Course

Topic	Details	Rationale
Historical Numeration Systems	Egyptian; Babylonian; Roman; Mayan; Chinese Rods . Essential features of the above systems. Translations to and from Hindu Arabic to above systems.	For better appreciation of the Hindu-Arabic system used today.
Decimal and other number bases	Place value system with other bases. System and translation between different base systems. 4 operations in different bases	For better understanding of the structure of the base 10 system
Divisibility	Divisibility tests, factors and multiples, Euclidean algorithm, results concerning HCF and LCM; Factors and Primes; Sieve of Erastothenes	Better understanding of mathematical structure of whole numbers
Operations and number systems.	Properties of operations: closure, identity, inverses; Extensions of number systems from ∠ to 9 to Θ to 3 to ∀. More abstract examples, operation tables.	Better understanding of structure with respect to operations and number systems.
Statistical Concepts	Measures of central tendency and dispersion Stem and leaf; box plot.	Teachers use these in their assessment
Mensuration	Figures with equal areas (same height and same cross sectional lengths); Figures with same volumes (Cavelieri's principle).	Better understanding of related primary school topics such as areas and volumes, tessellations and geometric results (which are covered without proofs in the primary syllabus).
Geometry Topics	Properties of special quadrilaterals and triangles. Euclidean proofs involving congruency will be used. Transformation geometry and tesselations; Reviewing basic constructions and why they work. Problem-solving through geometrical constructions. Nets and polyhedra.	
Geometrical Results from History	History of pi; Area of circle, volume of sphere (Archimedes), Pythagoras Theorem.	Provide better perspective of the topics
Problem-solving through Algebra and the Model Method	Equations as expressions of relationships between quantities; model method as graphic expressions of equations; Solving problems using Algebra and using Model Method	For teachers to make links between Algebra and the method used in our primary schools

Assessment and Performance

The assessment of the course consisted of 4 components for the1999 cohort and 3 components for the 2000 cohort as shown in Table 2.

Table 2
Assessment Components for 1999

Assessment Mode/Coverage	Individual	Percentage	
	Or group	1999	2000
Test 1: Numeration Systems, Number Systems, Operations and Divisibility	Individual	30%	30%
Statistics	Group	20%	20%
Assignment: Test 1 topics	Group	20%	-
Test 2: Rest of topics for 1999 cohort All topics for 2000 cohort	Individual	30%	50%

Achievement of the 1999 and 2000 Cohorts

The distribution of grades and overall marks for the 1999 and 2000 cohorts are given in Table 3 below, while Figure 1 displays the distribution graphically.

Table 3
Comparing the Results of 1999 and 2000 Cohorts

		Jan 1999	Jan 2000
	Class Size	44	57
Overall Mark	Mean	60.9	65.2
	Std Dev	12.4	10.9
Test Score (in %)	Mean	60.2	61.3
	Std Dev	13.9	13.1
% Distribution of Grades	A	9.1	21.1
	B	34.1	31.6
	C	29.5	35.1
	D	9.1	3.5
	F	18.2	8.8

In Table 4, we report the test statistics for comparing the performance of the 1999 and 2000 cohorts. The results show that the 2000 class performed significantly better than the 1999 class in terms of overall marks. Also, the AS Maths and the non-AS Maths students in the 2000 class have significantly higher average overall marks than the corresponding groups in the 1999 class. Furthermore, the percentage of A grade among the AS Maths students in the 2000 class is significantly higher, and the percentage of F grade among the non-AS Maths students in the 2000 class is significantly lower, when compared with the corresponding groups in the 1999 class.

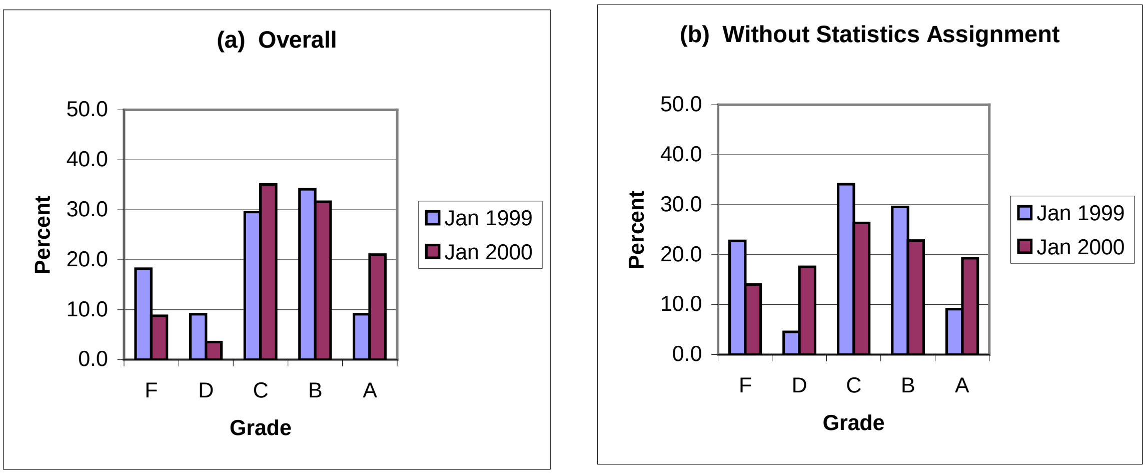

Figure 1: Percent distribution of grades for Jan 1999 and Jan 2000 cohorts

Table 4
Test Statistics for Comparing Jan 2000 and Jan 1999 Cohorts

Null Hypothesis		Cohort 2000 - 1999	AS Maths 2000 - 1999	Non-AS Maths 2000 - 1999
H_0: $\mu_1 = \mu_2$	Overall Mark	[a] $z = 1.817$ *	[c] $t = 2.179$ *	[d] $t = 1.911$ *
	Test Score	[a] $z = 0.403$	[c] $t = 1.014$	[d] $t = 0.970$
H_0: $p_1 = p_2$	A Grade	[a] $z = 1.632$	[a] $z = 2.132$ *	[a] $z = 0.761$
	F Grade	[b] $z = -1.400$	[b] $z = 0.139$	[b] $z = -2.154$ *

[a] One-sided z-test; critical value = 1.645 at the 5% level.
[b] One-sided z-test; critical value = -1.645 at the 5% level.
[c] One-sided t-test based on the t-distribution with 40 degree of freedom; critical value = 1.684 at the 5% level.
[d] One-sided t-test based on the t-distribution with 57 degree of freedom; critical value = 1.672 at the 5% level.
* Significant test that leads to rejection of H_0.

It is of interest to identify (statistically) the main factor that contributes to the better performance of the 2000 class. Noting that the 2000 cohort had high scores for the Statistics assignment, we consider the student performance when the Statistics component is *not* included. The individual test scores for 1999 are obtained as weighted averages of Test 1, Test 2 and the Numbers Assignment, with weights given by the percentages in Table 2. Similarly, the test scores for 2000 are obtained as weighted averages of Test 1 and Test 2. These are the data referred to as Test Score in Tables 3 and 4 and Figure 1(b) shows the distribution of grades for the 2 cohorts based on the test scores. Table 4 shows that the mean test score in 2000 is *not* significantly higher than that in 1999. Hence, we might attribute the higher overall marks in 2000 to the higher mark for the Statistics component.

Comparing the AS and Non-AS Maths Groups

Generally, the students doing AS Mathematics had stronger Mathematics backgrounds as there were pre-requisites for taking AS Mathematics. It was therefore of interest to compare the performance of the 2 groups of students. In Table 5, we compare the grade distributions and overall marks of AS Maths and non-AS Maths students in these two years. The grade distributions for the AS Maths and non-AS Maths groups are also presented in Figures 2(a) and 2(b).

Table 5
Comparing AS Maths and Non-AS Maths Achievement

		1999		2000	
		AS Maths	Non-AS Maths	AS Maths	Non-AS Maths
	Class Size	23	21	19	38
Overall	Mean	65.5	56.0	71.7	61.9
Mark	Std Dev	8.9	13.9	9.7	10.0
Test Score	Mean	66.1	53.7	69.4	57.2
(in %)	Std Dev	9.6	15.2	11.6	12.0
%	A	13.0	4.8	42.1	10.5
Distribution	B	39.1	28.6	36.8	28.9
of grades	C	39.1	19.0	15.8	44.7
	D	4.3	14.3	0.0	5.3
	F	4.3	33.3	5.3	10.5

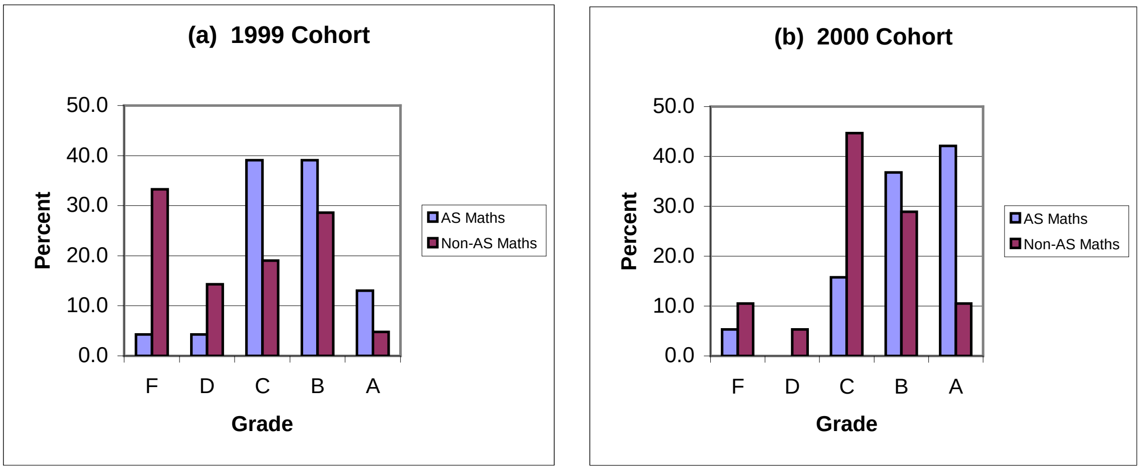

Figure 2: Percent distribution of grades for AS Maths and Non-AS Maths

Table 6 reports the test statistics for comparing the performance of AS Maths and non-AS Maths groups. Indeed in 1999, the AS Maths group performed significantly better than the non-AS Maths group in terms of higher overall marks, higher test scores and lower failure rate. Similarly in 2000, the AS Maths group performed significantly better than the non-AS Maths group in terms of higher overall marks, higher test scores and higher percentage of students getting A grade. The non-AS group of the 1999 cohort had a high rate of failure as well as the greatest spread of marks, especially where the test scores were concerned. Since these students were taught as a group, the wide spread of scores indicates a wide ability range and that more needed to be done for the weaker students.

Table 6
Test Statistics for Comparing AS Maths and Non-AS Maths

Null Hypothesis		Jan 1999 AS - Non-AS Maths	Jan 2000 AS - Non-AS Maths
H_0: $\mu_1 = \mu_2$	Overall Mark	[c]$t = 2.720$ *	[d]$t = 3.519$ *
	Test Score	[c]$t = 3.250$ *	[d]$t = 3.638$ *
H_0: $p_1 = p_2$	A Grade	[a]$z = 0.954$	[a]$z = 2.757$ *
	F Grade	[b]$z = -2.490$ *	[b]$z = -0.662$

[a] One-sided z-test; critical value = 1.645 at the 5% level.
[b] One-sided z-test; critical value = -1.645 at the 5% level.
[c] One-sided t-test based on the t-distribution with 42 degree of freedom; critical value = 1.682 at the 5% level.
[d] One-sided t-test based on the t-distribution with 55 degree of freedom; critical value = 1.673 at the 5% level.
* Significant test that leads to rejection of H_0.

Conclusion

We are convinced that the introduction of the CC course in Mathematics has gone some way in providing the foundational mathematical knowledge of the degree trainees who will be teaching mathematics in the primary schools. Course evaluation was also done and the responses of the trainees are reported in Lim (2000). Generally, the students who did better felt that the course benefited them whereas the less able students did not see the relevance of some of the topics covered.

Student performance in the tests and assignments shows that non-AS Mathematics trainees have not done as well as the AS Mathematics trainees in both cohorts. Feedback from the students cited poor foundations in mathematics as a reason for their not being able to do well in the assessment. Course lecturers will have to continue modifying and improving their teaching methods and approaches in order to foster mathematics conceptual understanding in these trainees.

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