Title	Engaging Mathematics Curriculum: Some Exemplary Practices in Singapore Primary Schools.
Author(s)	Foong Pui Yee
Source	*Teaching and Learning, 25*(1), 115-126
Published by	Institute of Education (Singapore)

Teaching and Learning, Vol. 25, No. 1 (June 2004) pp. 115–126

Engaging Mathematics Curriculum: Some Exemplary Practices in Singapore Primary Schools

Foong Pui Yee

Abstract

It is known that changes in educational practices do not come quickly if teachers are not able to integrate new initiatives that are presented to them as isolated issues. There are, however, successful strategies that could lead to long-term change when the local school site is the locus of change and where teachers are involved in innovation-related and problem-solving decision making. The change process focuses on problems that teachers consider important to their day-to-day routines. The purpose of this paper is to present a collection of exemplary practices that were carried out by the mathematics departments in some 60 schools in Singapore. The teachers of the projects reported, under the leadership of the head of the department, identified a particular problem/need and came up with solutions or innovations to address the problem. The projects helped teachers, pupils and even parents in meeting the needs of a more engaging and relevant curriculum.

Introduction

Mathematics education in Singapore primary schools into the 21st century is still going through the period of change started in the early 1990s. In the late 1990s, a study by Foong, Yap, and Koay (1996) revealed the concerns of Singapore teachers on the changes brought about by the revised primary mathematics syllabus, that is a shifting of emphasis from rote memorisation to meaningful understanding of concepts and problem solving; from a dependence on paper and pencil, manipulative computations and skills to mental calculations and thinking strategies; from teaching by telling to activity-based learning, group work and communication in mathematics. The study showed that most of the teachers were aware of the reforms in the curriculum and many had already started teaching it. However, the initial stages of concern were found to be most intense and urgent regarding needs for more knowledge and understanding of the rationale of the new initiatives, and personal needs for new skills to cope with the changes. The study recommended that within each school there should be collaborations among teachers through project activities that focused on how to incorporate

changes proposed in the new curriculum. Teachers, under the leadership of the head of the department, could identify a particular problem or need, develop an action plan, acquire the knowledge, implement it and then assess the outcome.

The purpose of this paper is to present a collection of exemplary practices that were carried by the mathematics departments in some 60 schools in Singapore in their effort at helping their teachers, pupils and parents meet the needs of the more engaging and relevant curriculum, sometimes beyond the classrooms.

Literature Review

A great deal of primary mathematics education literature has been written and delivered on the areas of reforms that schools should be incorporating into their classrooms (Fennema & Romberg, 1999). But it has often been left to individual teachers to put together what that means for their classroom organisation. It is known that changes in educational practices do not come quickly if teachers are not able to integrate new initiatives presented to them as isolated issues. However, a review on research in educational change (House, 1994) has identified successful strategies that could lead to long-term change when a local school site is the locus of change where teachers are involved in innovation-related, problem-solving decision making, and the change process focuses on problems that teachers consider important to their day-to-day routines.

The challenges of the teaching and learning of mathematics for a more meaningful and engaging curriculum have been well documented by a range of studies overseas (Sowder & Schappelle, 2002). To cite a few examples, Flavel and Selby (2003) were part of a group of Australian teachers involved in developing rich mathematical tasks that, they believed, resonated with sound pedagogy. They started with a simple game based on multiplication facts and the game of bingo, which grew, through teacher reflection and practice, into a potentially rich mathematical learning experience. Clarke (2003) implemented a variety of ways of making middle school mathematics more enjoyable and challenging. One of his methods was to take the traditional content and build a problem-solving component to it where the emphasis was on the process and variety of methods for solving one problem. He also presented strategies for mental arithmetic and higher order thinking through ability groupings in classroom activities and the assessment tasks that he believed would offer a way forward to curricula reform and made a difference in the learning of mathematics for pupils.

The Singapore Experience

Since the year 2000, the author has been involved in teaching a module for the Diploma in Departmental Management (DDM) programme in the National Institute of Education, Singapore (NIE). Participants enrolled in this module, entitled *Curriculum Area Leadership in Primary Mathematics*, are practicing mathematics heads of departments (HODs) in their respective schools. For each cohort, the

participants were asked to list some of the constraints that they perceived as hindrances to achieving the intended aims stated in the Ministry of Education (MOE) mathematics curriculum framework. Having identified and discussed the common issues across school systems, the participants were required to select and share with the other HODs one of the projects that their mathematics departments had implemented to address some of these problems. The objectives of this assignment are to promote community sharing of effective practices and to network for future collaborations among HODs across school clusters. Over a period of 4 years from 2000 to 2003, data on the constraints faced by schools and a total of 60 exemplary projects were collected from the module participants. The author considers these projects as exemplary practices to meet or supplement the demands of the reformed curriculum. The 60 projects are categorised and their values are discussed. This paper attempts to give brief accounts of and share such practices with mathematics educators and school administrators.

Constraints in Implementing the Mathematics Curriculum

In implementing the new initiatives, a major concern for mathematics HODs is nonroutine problems and the teaching of heuristics. However, they also needed to recognise what other constraints faced by different schools in the teaching and learning of mathematics. Over the years, each cohort in this DDM programme was asked, "What are the constraints faced by yourself and your teachers in teaching pupils based on the primary mathematics syllabus?" The participants' responses collected from the various cohorts would invariably fall under the following four categories, illustrated with some examples.

Content and the New Emphasis on Thinking Skills

- "Too abstract for pupils to relate."
- "Problems are not authentic."
- "Lack problems on thinking skills and problem solving skills in the curriculum."
- "Not enough emphasis on thinking skills; most sums have only one correct answer."
- "Need more guidelines on how the new initiatives can be carried out or integrated into the curriculum."

Pupils

- "Not enough higher order questions to cater to good pupils and vice versa."
- "Curriculum not differentiated for pupils' mixed abilities."
- "Too difficult for weaker pupils."
- "Pupils weak in English disadvantaged by word problems."
- "Slow learners left behind because system cannot wait for them."

Teaching Methods

- "Teachers teach from textbooks."
- "Teachers afraid to try new methods."
- "Mainly 'talk and chalk' classroom situation."
- "Teachers are not innovative in their teaching methods. Anxious to follow scheme of work."
- "More time to be freed from concept teaching to allow teachers greater scope for more innovative teaching and creative learning."
- "Insufficient time for cooperative learning."

Assessment

- "Too exam-oriented."
- "Too much emphasis on paper–pencil–worksheet."
- "Change the assessment mode for PSLE (Primary School Leaving Examination) if a change is needed."

The above sample of expressions is not new. Some of them are perennial issues faced by teachers overseas such as in Taiwan, which is undergoing similar curricular reforms (Lin & Tsao, 1999). The study by Foong, Yap, and Koay (1996) revealed similar concerns and impediments faced by our teachers in implementing the primary mathematics curriculum. Of course, it should be said that not every school shares the same problems. Every school has different norms where different problems can manifest in various areas pertaining to the syllabus: pupils, teachers and education system. What is important is how each school recognises the areas that need improvement and plans to address the needs.

Exemplary Projects for a More Engaging Curriculum

The 60 projects showcased in the DDM course by the HODs could be taken as a whole to illustrate what schools were doing to address some of the constraints in the primary mathematics curriculum. But it must be said that not every school had done all or the same projects over the years. From the analysis of this collection of projects, one from each HOD at different times of his/her enrolment, it points to a pattern of exemplary practices. The schools had attempted to supplement the curriculum with more engaging and relevant learning activities for teachers, pupils and even parents. The variety and forms of the projects can be classified broadly into seven categories. Table 1 shows the categories and the number of projects shared by the HODs. The following section provides brief accounts of the projects under each category.

Problem Solving Schemes

Thirteen schools had incorporated some form of scheme to integrate problem solving heuristics into the curriculum. Generally, there were two schemes: one

Table 1.
Categories of projects, their number of occurrences and some examples of practices.

Category of projects	No.	Examples of practices
Problem solving schemes	13	Apply heuristics for nonroutine problems; use model-method for challenging sums; a-problem-a-day; quizzes, etc.
Activity-based programmes	12	Use of IT for spatial creativity; multiple-intelligence (MI) lessons; *Multiplication-made-easy, Math Boggles.*
Mathematics Games Day	10	Day carnivals, exhibitions and math trails to places of interests, etc.
Grouping pupils	11	Maths banding for P6 classes; peer-tutoring using math club members; buddy system within class and across grade levels.
Maths resources	5	Maximal use of resource room with preplanned activities; school maths newsletters; maths web-page.
Teacher development	4	In-house workshop by teachers to upgrade on problem solving, mental sums; pupil assessment; action research.
Parental involvement	5	Workshops for parents; involvement of parents in children's learning activities.
Total	60	

involving nonroutine tasks and the other involving sums that required the "model-method" as a strategy. For the latter, it is required in the syllabus that the "model-method" be taught for solving arithmetic word problems. However, some schools found inconsistencies in the way their teachers presented the various types of model drawings and the solution steps. Also, in some textbooks, they found different emphases on model method at different grades, and there were not sufficient examples provided. To improve the situation, a few schools produced handbooks on the use of the model-method for consistency amongst teachers so that when pupils moved from one grade to the next they would not encounter too many varieties. To prepare the teachers who were not too familiar with model drawing for more challenging problems in the upper primary levels, materials for the various grades were delivered in the form of booklets. The purpose was mainly to help the pupils who had difficulties in answering multiple-step word problems in the examination so that the school's PSLE grade average could be improved. By upgrading the teachers' skills, more problem solving can then be incorporated into the classroom. Normally, all such resources were developed by teams of teachers under the level head of the mathematics department. One school actually dedicated a 3-day intensive programme for the teachers and the primary 6 pupils on problem solving targeted at the PSLE questions. All the teachers in the school were involved, including mother-tongue and lower primary teachers. At the 3-day camp, there were peer-learning between teachers, between pupils and teacher, and between pupils.

For nonroutine types of problems needing other heuristic strategies, such as *guess and check; listing; look for a pattern;* and *working backward,* the HOD in one school, working with a team of teachers, started collecting such questions and their solutions. Although the curriculum stipulated that problem solving processes should be the focus of teaching and learning mathematics, teachers found that the textbooks lack nonroutine problems to develop processes or problem-solving heuristics. One HOD compiled a comprehensive list of books and resources on nonroutine problems that were available in bookshops. At another school, nonroutine problems were given out during assembly periods as quizzes to be followed up by classroom teachers to explore a variety of strategies with their own pupils. In this way, teachers had to get involved in nonroutine problem solving with their pupils. Still another school organised nonroutine problems into "Young Mathematician" cards where co-operative learning was encouraged during enrichment classes. Other activities such as "a problem-a-day", term quizzes and online quizzes were opportunities for schools to expose nonroutine challenging questions to teachers and pupils. At one school, teachers regularly conducted tests to assess applications, and pupils were required to compile these problems and their solutions in a file. Two schools had successfully implemented a structured scheme of work to incorporate teaching problem solving skills for nonroutine questions into their curriculum time. The mathematics department coordinated the compilation of the problems according to heuristics and levels and also provided training for their teachers. One school started the scheme in 1998 across grade levels and fully implemented it by 2003, when nonroutine questions became routine to all teachers and pupils in normal mathematics lessons.

Activity-Based Programmes

One of the aims in mathematics education is to provide pupils with opportunities to be involved in meaningful and enjoyable maths activities. It is essential that these experiences also assist the development of positive attitudes towards mathematics. Many teachers recognised that our local exam-oriented curriculum has too much content and leaves little room and time for hands-on activities to develop pupils, especially to develop weaker learners' motivation and confidence. These constraints tended to a prevalence of "chalk and talk" in the mathematics classrooms. Nevertheless, some schools made conscious efforts towards injecting regular activity-based programmes. Such activities were conducted in the classroom, mathematics room, assembly hall or even canteen for pupils to experience some real and meaningful activities by working with concrete yet familiar materials. At some schools, structured activity lesson plans were designed by teams of teachers for common usage at various levels.

For example, geometry lesson plans incorporating the use of IT were developed across the levels in one school where pupils' spatial creativity was enhanced when they produced designs in symmetry and tessellations. Another school

experimented in incorporating multiple intelligences (MI) into their primary 1 mathematics scheme. The aim was to provide teachers with structured lessons that would enhance cooperative learning and developing pupils' social skills. A team of teachers developed sets of activity-based mathematics lesson plans that integrated one or several of the intelligences such as logical, kinesthetic, visual/spatial, musical, naturalist and interpersonal as well as intrapersonal. Still at two other schools, it was found that by P3, many pupils lagged in their recall of the multiplication facts, and thus their learning of division and problem sums were affected. One of the two schools developed a "multiplication-made-easy" programme with nonroutine techniques using manipulatives, song and dance. The other school conducted mass multiplication drills before school and during recess with the help of flash cards over a period of time. *Math Boggles* was another invention by a school to help pupils enhance their computational skills involving the four operations. It was basically adapted from the game *Boggle* where numbers were used instead of letters. The school developed several sets for all P1 to P5 pupils to play in groups during the *before school* period and in mathematics corners around the schools.

Mathematics Games Day

Mathematics Games Day would be an event on the school calendar where a day or half a day is allocated for the pupils of the whole school, sometimes at different levels, sometimes also opened to the public such as parents and residents in the neighbourhood, to participate in fun-filled activities relating to the learning of mathematics and other subjects. Such events go by other names such as *Maths At Play; Maths Fun Day; Funthematics; Maths & Science Fair; Math Carnival; Mathematics Festival; Mathematics Activity Day; and Math Creative Day.* These were mostly held within the school compound in the field, hall or the whole premises, depending on the scale of the fair. Booths were set up for the various game activities and challenges. Another popular event, *Math Trail,* was organised often out of school at the Zoological Gardens and other places of interest such as the campus at the Nanyang Technological University in Jurong. One school organized a *Math Trail* at the Zoo for their P4 cohort, and pupils were encouraged to bring along their parents to work together with them on the mathematics trail questions. These day-events were either organised by outside commercial agencies or by teachers and students. In the first instance, commercial agencies supplied all the ideas and resources, with some input from teachers, and they handled the logistics. The teachers' responsibilities would be to help on the event day in monitoring pupils' behaviours. In the latter case, teachers and pupils designed all the games and activities, including manning the booths on the event day. It is definitely empowering pupils and teachers but it involved much of the teachers' time and resourcefulness.

Working in teams on smaller scales, teachers organised events with the help of pupils at targeted groups. For instance, in two schools the upper primary pupils

were given projects to design mathematics games and puzzles that were eventually used at a fair organised for the lower primary children. The upper primary pupils helped run the booths set up in the canteen. One school organized a *Math Activity Day* for all the EM3 and weak EM2 pupils, in which the pupils experienced applications of measurement and number sense in real-life situations. They used measuring equipments and manipulatives for hands-on problem solving. The P6 teachers and members of the mathematics committee were involved in planning and organising the event. Another school had a whole day event involving all the teachers in the school, parents and relevant members of the community. There were lots of quizzes, competitions and even a *Math Trail* for both pupils and adult participations. Exhibitions of pupils' creative work, such as mathematical art, 3-D geometric models and tessellations, connecting mathematics with the real world and projects on mathematical investigations, were also displayed. It gave lots of publicity to the school when the media reported the event in the newspapers.

The events described above offered pupils a taste of the recreational side of mathematics, hopefully stimulating their interest in the subject. The games for the events were often designed to reinforce basic concepts and skills previously used only when solving textbook problems. Pupils had opportunities to use the mathematics in a fun way and at their own pace, sometimes in a real-life context. Pupils gained confidence as they related the abstract mathematics in a concrete way and in a different environment outside the classroom. They had opportunities to interact with pupils from other classes and to see other adults using mathematics. For teachers, such events brought out their resourcefulness, which hopefully enabled them to see the potential of using games and activities in their own classrooms.

Grouping Pupils

One of the challenges faced by teachers in the primary schools is coping with mixed-ability groups in a class. Classes were normally not streamed in lower primary levels, although some schools practice "banding" or "setting" for the lower-end classes with respect to mathematics learning. Even after the P4 national streaming exercise, the range of abilities in mathematics within a class could vary substantially, especially so in the lower end of the EM2 stream classes. In *banding*, pupils in each level are divided into classes according to the level of attainment in mathematics, while in *setting* the mathematics periods of two or three classes of a particular level are timetabled as a block where pupils are regrouped according to their attainment in mathematics (Ministry of Education, 1994). In this way, teachers would have more homogeneous groups to teach.

Of the 11 exemplary practices on grouping, three schools practiced banding for their P6 classes so that weaker classes were given more remediation with different teaching methods. In one school, the success of one project led to the whole school's

implementation of the structured after-school remedial programme for low ability pupils across all levels. In another school, peer tutoring or cross-age tutoring was used for pupils at risk. The teachers identified P1 and P2 low achievers through diagnostic tests. These children were tutored by P4 and P5 Math Club members who received training in "buddy-cum-tutor". In addition to one-to-one tutoring using work cards and manipulatives, CD-ROMs and games (created by the older pupils in another project) were also used. Graded work cards were prepared by the teachers for this purpose. The project was conducted over 10 weeks in terms 2 and 3. The peer tutoring buddy system was used in other projects where the pupils who scored above 85% in mathematics were paired with a classmate whose score was below 35%. The value of such buddy system promotes interpersonal skills and, in some way, cooperative learning among pupils. For the weaker pupils, learning from a peer could be less threatening. For the better pupils, the experience could enhance their own understanding of the mathematics that they are sharing with the others. In one project, the teacher required the pupils to keep journals and write reflections on the learning under the buddy system.

Mathematics Resources

Maximising the use of the mathematics resource rooms available in their schools was the goal of two HODs' projects. They set up a system where lesson materials and resources such as manipulatives were packaged according to topics and levels. One of them attempted an open system where teachers had free access (unlike common practice where most things and equipments are kept under lock and key) to the resources, thus encouraging maximum usage in their own classrooms. The resource room was also used as a centre of mathematics learning for specially designed activity-based lessons, and a roster was set up for teachers to bring their pupils to experience these lessons. One school was especially proud of their mathematics room with specially designed furniture for cooperative learning and motivating mathematical posters and 3-D exhibits.

Another HOD promoted the teaching of mathematics through children's literature. Her resource library had a wide range of story books that she searched from the internet in which many mathematical ideas and concepts could be tapped by her teachers. To showcase the activities of the mathematics programme in her school, one HOD and her team of teachers created their own maths web-page for the pupils, teachers, parents and the public. In another school, a regular mathematics newsletter was published with the contribution of both teachers and pupils. The newsletter provided opportunities for pupils to read interesting articles and snippets on the history of mathematics and mathematicians. There were also interesting mathematics problems to participate as quizzes and fun mathematics activities. The newsletter served as a localised resource from which teachers could supplement the standard textbooks.

Teacher Development

In the projects discussed so far, the teachers and HODs were involved in planning, implementation and evaluation. As such, the projects could be regarded as professional development. Generally, feedback from the pupils and teachers involved in these projects was positive and encouraging. Although most of the projects described were not developed for solitary activity in the classroom, they were alternative and innovative ideas which teachers could take back to their own classrooms and infuse into their instructions. For example, while participating in the projects of developing "problem solving schemes" to integrate nonroutine problems into the curriculum, teachers were inevitably exposed to these problems and solution strategies. As the result, they improved their skills and knowledge in the area while working together with other teachers and learning from pupils as they observed them.

Four projects may well illustrate how teacher-development projects were carried out as inquiries or problems arose. In one school, the practices of giving mental sums to pupils among the teachers were not coordinated, and there were some flaws in the way mental sums were carried out in the classrooms. When the HOD found this, a workshop for the teachers was conducted to improve the situation and to update the teachers' knowledge. At another school, the HOD noticed variations in the attainment targets set by the different teachers at the same level. This was especially true with the newly trained teachers, who either set rather high or low targets that did not match pupils' abilities. The HOD initiated a project called *Math Thermometer* in which criterion sets of maths topical attainment tests were collated from teams of teachers to provide the appropriate targets for each level. Through the project, the teachers shared and reflected on their expectations of pupils' performance. In the third school, learning circles were formed for identifying pupils' weaknesses in solving word problems at various levels, and the teachers brainstormed solutions to improve the teaching of the areas. In the final case, the call for teachers to be classroom researchers was met by one HOD who did an action research in one class that she was teaching. She explored the effectiveness of a buddy-system in remediation in which the pupils kept journals about their experiences. The results were then shared among the colleagues.

Parental Involvement

Increasingly, schools are beginning to see the advantage of engaging parents in the education of the children. Many parents had expressed concerns about the methods that their children were learning in mathematics were different from the times when they were students. Four schools conducted workshops for parents across the grades from P1 to P5. Especially for the lower primary levels, the schools realised it was important to explain the mathematics curriculum to the parents and exposed them to the new concepts and problem-solving methods, such as model drawing, that their children were taught. This helped parents appreciate

Lin, F. & Tsao, L. (1999). "Exam maths re-examined," in Hoyles, C., Morgan, C., & Woodhouse, G. (Eds.), *Rethinking the Mathematics Curriculum* (pp 228–239). London: Falmer Press.

Ministry of Education (1994). *Managing a Primary Schools's Mathematics Programme.* Singapore: Mathematics Unit, Sciences Branch, Curriculum Planning Division, Ministry of Education.

Sowder, J. & Schappelle, B. (Eds.) (2002). *Lessons Learned from Research.* Reston, VA: National Council of Teachers of Mathematics.

the mathematics that their children were learning and to enable them to support their children's homework. One school invited parents to join in a math trail at the zoo, and another invited parents to contribute their help at their mathematics fair. Through these activities, parents had the opportunities to experience the learning activities that their children were going through.

Conclusion

The 60 projects presented in this paper range from development of curriculum schemes to involvement of parents, indicating an existence of a community of exemplary practices that can be generated and shared amongst schools. These projects have been tried and found to be beneficial to pupils and teachers. It is evident that schools are doing tremendous work in creating an engaging mathematical environment within their schools despite the isolation of teachers in their individual classrooms. The activities can be seen as an extension of conventional practices in the classrooms, and they pave ways for teachers to integrate innovations into their instructional practices. The network of HODs that has been formed in the DDM programme and the increased confidence through collaboration are something valuable and should be encouraged. Now, it is only a phone call away for these HODs to share exciting projects and materials. It is hoped that the positive impact of these undertakings and sharing amongst the HODs reported here are not just for the flavour-of- the-month but for the long term.

Dr Foong Pui Yee is Associate Professor in NIE. Her specialisation is in teacher education in primary mathematics. She teaches the preservice, in-service and graduate programmes. Her research interests include mathematical thinking and problem solving, affective factors in mathematics learning and teachers' beliefs.

References

Clarke, D.M. (2003). "Challenging and engaging students with worthwhile mathematics in the middle years," in Clarke, B., Bishop, A., Cameron, R., Forgasz, H., & Seah, W.T. (Eds.), *Making Mathematicians* (pp 98–109). Melbourne, Australia: MAV.

Fennema, E. & Romberg, T.A. (Eds.) (1999). *Mathematics Classrooms that Promote Understanding*. London: LEA.

Flavel, S., & Selby, J. (2003). "Rich tasks for middle years," in Clarke, B., Bishop, A., Cameron, R., Forgasz, H., & Seah, W.T. (Eds.), *Making Mathematicians* (pp 110–123). Melbourne, Australia: MAV.

Foong, P.Y., Yap, S.F., & Koay, P.L. (1996). "Teachers' concerns about the revised mathematics curriculum." *The Mathematics Educator*, **1**(1), 99–110.

House, P.A. (1994). "Empowering K-12 teachers for leadership: A districtwide strategy for change," In Aichele, D.B. & Coxford, A.F. (Eds.), *Professional Development for Teachers of Mathematics, 1994 Yearbook* (pp 214–226). Reston, VA: National Council of Teachers of Mathematics.