

M²E@NIE/NTU: Promoting Mathematics Education

by

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This paper describes the organization and functions of the Mathematics and Mathematics Education (MME) academic group at the National Institute of Education (NIE), which is an autonomous institute of Nanyang Technological University (NTU).

Introduction

NIE is the sole teacher education institution in Singapore, and MME is the academic group (which is like a department in other institutes) responsible for the teaching of mathematics-related courses. NIE is organized in a matrix system with two programme offices: the Foundation Programme office plans and coordinates pre-service teacher education; the Graduate Programme and Research Office is in charge of in-service and graduate programmes. There are 12 academic groups that provide teaching in different academic disciplines. MME is one of the largest academic groups in NIE.

The Vision of MME is "To strive to be a leader in the field of Mathematics Education", and this underpins its Mission of being "committed to the professional preparation and development of mathematics teachers and educators in Singapore and beyond within a rapidly changing and increasingly technological environment". This Vision and Mission is to be realized through the teaching programmes, research projects, and service contributions rendered by MME staff to the education community.

There are in MME, 16 mathematics educators, 12 mathematicians, 6 mathematicians who also teach mathematics education courses, and 4 teaching fellows, who are school teachers seconded to MME for a few years. Unlike most universities where mathematicians and mathematics educators belong to different faculties and seldom work together, these two groups of academicians at NIE belong to the same academic group and have many opportunities to work in committees and projects that draw on the expertise from both disciplines to achieve the common goal of preparing teachers to teach mathematics competently in Singapore schools. All the mathematicians at MME also supervise practicum of student teachers at secondary schools, and they are expected to keep abreast of education initiatives announced from time to time by the Singapore Ministry of Education (MOE) so that they fully understand how they can contribute to the training of Singapore teachers. This responsibility is normally not expected of mathematicians who work in traditional mathematics departments such as the Division of Mathematical Sciences at NTU.

In terms of teaching resources, MME has five mathematics education laboratories (designed to facilitate tutorial activities that involve concrete manipulatives in group settings), five computer laboratories (with specialized software in mathematics and mathematics education), and one special room where weak student teachers can receive remedial coaching in small groups. The following sections provide more information about MME programmes and research. Further information can be found in the MME website at <http://math.nie.edu.sg/>

Pre-Service Programmes

Pre-service student teachers enrolled at NIE are treated as untrained teachers employed by MOE. They enroll in one of three types of programmes: Diploma in Education (Primary), BA (Education) or BSc (Education) (Primary or Secondary), and Postgraduate Diploma in Education (Primary or Secondary). They are placed into the respective programme based on their academic qualifications, non-academic experiences, and an interview conducted by MOE. The interview ascertains the applicant’s communication skills and interest in teaching. The Diploma and Degree applicants enter with either A-level or Polytechnic Diploma, while those applying for PGDE have a relevant degree. All applicants must have at least a pass in O-Level Mathematics, and this requirement underscores the importance of Mathematics in the teaching profession. Those who want to do Mathematics as an academic subject must have at least a B in A-level Mathematics or Further Mathematics or pass a Mathematics Qualifying Test conducted by MME.

The pre-service programmes have undergone several changes in the past 15 years. The latest revision was first implemented for the July 2005 cohorts. Under this “enhanced” curriculum, MME teaches three types of courses: Academic Studies (AS) in mathematics for Degree student teachers only, Subject Knowledge (SK) in mathematics, and Curriculum Studies (CS) in mathematics. The weightage of each type of courses within the programmes is given in Table 1, though there are slight variations within each programme. One Academic Unit (AU) is equivalent to 12 hours of contact time.

Table 1. MME courses within respective Programmes: Number of Academic Units (AU)

| | Diploma | BSc (Ed) Primary | BSc (Ed) Secondary | PGDE Primary | PGDE Secondary |
|-------------------------|---------|---------------------|-----------------------|-----------------|-------------------|
| Courses | | Primary | Secondary | Primary | Secondary |
| No. of years | 2 | 4 | 4 | 1 | 1 |
| Total AU | 69 | 126 | 131 | 44 | 40 |
| Curriculum Studies (CS) | 8 (12%) | 10 (8%) | 10 (8%) | 8 (18%) | 9 (23%) |
| Subject Knowledge (SK) | 6 (9%) | 4 (3%) | | 4 (9%) or none | |
| Academic Studies (AS) | | 39 (31%) | 39 (30%) | | |

The CS courses deal with methodologies of teaching mathematics at the primary or secondary level. They cover topics such as the Singapore mathematics curriculum, learning theories applied to mathematics instruction, learning difficulties and misconceptions in mathematics held by school pupils, the teaching of various topics using a variety of techniques including ICT, and assessment of mathematics learning outcomes. Student teachers are expected to acquire the essential pedagogical content knowledge (PCK), which Shulman (1987) described as “that special amalgam of content and pedagogy which is uniquely the province of the teacher”. Two resource books (Lee, 2007a, 2007b) written by MME staff based on local practices are used as the major references for the CS courses.

The SK courses help student teachers to develop deeper conceptual understanding of the mathematics in the primary school curriculum and stronger skills to solve challenging problems using heuristics and the “model drawing” approach, which is a uniquely Singapore technique (Kho, 1987). Deeper understanding will empower the student teachers to answer tricky questions posed by their pupils (a particularly “nasty” one is “why 1 is not a prime number”), to plan challenging mathematics activities, and to re-encounter the joy and cognitive disturbance of learning mathematics that is somewhat familiar but through new approaches such as hands-on activities and group discussion. These different ways of learning mathematics should provide a helpful link between SK and CS courses.

The SK courses were first introduced in January 1999 as Curriculum Content (CC) courses (Lim-Teo, 2004). These courses are taught by the mathematicians

in MME. Over the years, several issues about teaching of SK courses have surfaced: student teachers who have poor mathematics backgrounds find the courses quite difficult; some classes contain student teachers with mixed ability in mathematics such that the teaching becomes quite challenging; some student teachers are not convinced about the relevance to primary school teaching of some of the topics included in SK courses; the optimal sequence to link SK to CS courses is hampered by administrative constraints. Several steps have been taken to deal with these problems.

This issue of subject matter knowledge takes a different form for student teachers in the PGDE (Secondary) Mathematics programme. To motivate all these student teachers to revise O-level mathematics, they have to take the specially designed School Mathematics Mastery Test (SMMT). Those who fail to achieve mastery after three attempts will have their names sent to MOE, and they may take inservice courses to upgrade their knowledge of secondary mathematics. On-line materials and a few face-to-face tutorials are provided for those who need them. Both the SK courses and the SMMT are to equip student teachers with some mastery of the school mathematics that they are supposed to teach. Indeed, mathematics educators from many countries are also tackling with different degrees of success this same issue (e.g., Ball, Lubienski & Mewborn, 2001) and the type of tertiary mathematics required for teachers (Cuoco, 2001; Usiskin, 2001). The MME experience can contribute to this ongoing international debate.

The AS courses are traditional mathematics courses such as Calculus, Linear Algebra, and Analysis. Unlike the SK courses, these courses provide depth in academic mathematics for those who opt to major in mathematics in the degree programmes only. These courses are taught by the mathematicians. These undergraduate courses satisfy the standard requirements for a science degree in the mathematics discipline.

MME offers a variety of in-service courses to enhance the mathematics pedagogical and/or content knowledge of school teachers, and most of these courses are approved and funded by MOE. For primary school teachers, there is the Advanced Diploma in Primary Mathematics Teaching requiring the study of at least 20 AU. There are also stand-alone courses on the use of calculators in primary schools (calculators are allowed in Paper 2 of the Primary School Leaving Examination Mathematics from 2009), use of children's literature in mathematics learning, and teaching capable primary school pupils. Secondary school teachers can enroll in 14 short courses (12 hours each) with titles such as Pathways to Reasoning, Infusing National Education into Secondary Mathematics Curriculum, and teaching of various topics in Additional Mathematics. There are also 13 courses for Junior College teachers on how to use graphing calculators and to teach H3 mathematics topics. These short courses are planned with input from MOE to help teachers deal competently with changes in the school mathematics curriculum by integrating mathematics contents with pedagogy.

In-Service Programmes

In recent years, action research has been promoted as one promising approach to advance professional learning of school teachers, and MME mathematics educators have conducted action research workshops adapted for mathematics teachers at the school, cluster, and zone levels (Wong & Chua, 2006).

MME also teaches and supervises senior mathematics teachers in the new Management and Leadership in Schools Programme (MLS), which is a revised version of the previous Diploma of Departmental Management (DDM) for heads of department in schools.

A new in-service programme that MME is working with the Curriculum and Teaching Unit of NIE is to expose mathematics teachers to lesson study.

This innovative approach is invented by Japanese educators and it has stimulated a lot of interest among mathematics educators from around the world (Isoda, Stephens, Ohara & Miyakawa, 2007). Under lesson study, teachers plan lessons together as a team, observe how the lessons are enacted by one of the team members, and subsequently refine the lessons after peer observations. This form of teacher professional development is being evaluated in some Singapore schools.

Graduate Programmes

MME offers two Masters programmes by coursework: M Ed (Mathematics Education) and M Sc (Mathematics for Educators). Both are part-time programmes.

The M Ed (Mathematics Education) is for school teachers who aim to acquire knowledge in content, pedagogy, and research in mathematics education through either a full coursework of 10 courses or a combination of 8 courses and a dissertation in mathematics education. Core courses include Educational Inquiry, Research and Issues in Mathematics Education, and Fundamental Concepts in Mathematics. Beginning from July 2006, MOE has introduced the full coursework programme under the so-called 4-3-3 PDCM-Master scheme, such that the teachers have to take 4 prescribed courses in the first year, 3 in the second year, and 3 in the third year on a part-time basis. PDCM stands for Professional Development Continuum Model, which was launched by MOE in August 2004, in collaboration with NIE, to provide a systemic, structured pathway for MOE teachers to gain higher certification from degree to graduate level.

The M Sc (Mathematics for Educators) is different from M Ed in that it requires the acquisition of wide and in-depth content knowledge in mathematics, yet some of this knowledge is linked to mathematics teaching. This unique integration sets it apart from traditional M Sc Mathematics programmes in NTU and around the world. Students are required to complete 10 courses: up to 5 Level 1 courses in selected topics that cover contents and pedagogy; at least 4 Level 2 courses in topics such as Discrete Mathematics, Applied Mathematics, Geometry, and Statistics; and the core Mathematical Inquiry course, which helps to develop some research skills in mathematics. This programme was first introduced in July 2006 to satisfy the needs of school mathematics teachers who prefer to specialize in mathematics rather than mathematics education. MME also offers research programmes leading to Masters in mathematics (M Sc), mathematics education (M A), and PhD in both disciplines. The largest enrolment is in PhD in mathematics education, with one full-time and 16 part-time candidates. Their research studies include mathematics investigation, problem posing, visualization, concept maps, ICT use, and problem-based learning in school mathematics. The findings from these studies should have significant implications for practices in local schools.

Research in Mathematics

Mathematicians in MME conduct research in a variety of areas including Henstock integration, mathematical modeling, wavelets, operations research, and polynomials in graph theory. With the small number of mathematicians in MME covering several distinct areas, it is necessary for them to work collaboratively with mathematicians outside MME to tackle significant mathematical problems in a concerted way. A most recent example is the funded project on polynomials in graph theory led by Dong Fengming, and this project involves collaboration with Koh Khee Meng from NUS and visiting scholars from Slovenia, Australia, China, and other countries. Such collaboration between MME and other mathematics departments will be strengthened to promote impactful research in the future.

Research in Mathematics Education

Research into the PCK of student teachers is of major interest to MME because of the need to produce research-based information to evaluate the effectiveness of its teacher education courses and subsequently to improve on them. Two on-going funded projects attempt to study the mathematics PCK of student teachers. One project is a longitudinal study led by Lim-Teo Suat Khoh, and it has produced some interesting findings (Lim-Teo et al., 2006). As expected, Dip Ed student teachers improved in their MPCK at the end of the programme. The other project is an international comparative study called Teacher Education and Development Study-Mathematics (TEDS-M). It studies the training of mathematics teachers in some 17 countries (see <http://teds.educ.msu.edu/default.asp>). Besides these two projects, Fan Lianghuo and Christina Cheong (2003) have examined the sources of how secondary mathematics teachers develop PCK and found that the most important sources were “own teaching experience and reflection” and “informal exchanges with colleagues”.

Teacher training programmes must be informed by classroom research that studies the practices of teachers as well as the learning of students in mathematics. Mathematics educators at MME have conducted these studies since the 1980s when NIE was still the Institute of Education. More recent school-based projects include the following:

- a major project led by Fan Lianghuo to study the impacts of alternative assessment techniques such as journal writing, self assessment, and portfolio;
- several international comparative studies on teaching led by Berinderjeet Kaur: KASSEL project; International Project on Mathematical Attainment (IPMA); Student Perspective on Effective Mathematics Pedagogy;
- the T3 Project led by Yeap Ban Har to encourage primary school pupils to take note of contexts in word problems;
- solving of word problems by the “model drawing” and symbolic methods using brain-based methodology (Ng Swee Fong);
- a project to understand the mathematically weak students (Wong Khoo Yoong);
- a study led by Tay Eng Guan to study the use of heuristics in problem solving at A-level mathematics.

Some of these projects are funded through the Centre for Research in Pedagogy and Practice (CRPP, <http://www.crpp.nie.edu.sg/index.php>) at NIE, which is heavily funded by MOE. CRPP’s e-magazine, SingTeach (<http://singteach.nie.edu.sg/>), provides summaries of findings of its projects especially written for teachers. All these projects together with the on-going PhD studies will add to the knowledge base about mathematics education in Singapore. An editorial team at MME has been formed to produce a book to document the findings from some of these projects.

In 2006, MME launched a Technical Report Series to provide an avenue for MME academicians to announce their findings in both mathematics and mathematics education before these are submitted for formal publication. This should stimulate further motivation and productivity in research in these two disciplines; see http://math.nie.edu.sg/mme_trs/

Concluding Remarks:

The Future Landscape

NIE has embarked on a new 5-year plan where educational research is one of the three pillars of success. To achieve this, MME has to strengthen its capacity through recruitment of qualified staff, to consolidate its research agenda to bring about strong impacts in scholarship and practices in the schools, and to enhance its teaching programmes to remain relevant for the needs of its stakeholders, who will include not only mathematics teachers employed by MOE but also fee-paying students from overseas. MME mathematicians and mathematics educators have contributed significantly to the profession through overseas conferences, strong publications, and active participation in local professional organizations such as the Singapore Mathematical Society, the Association of Mathematics Educators, and the Educational Research Association of Singapore. Through this diverse effort, MME will continue to make a positive difference to the mathematical "life" of our school students through their teachers whom we strive our best to educate and with whom we collaborate in research. It is a sequence of steps that converge monotonically to the vision of quality mathematics education in Singapore.

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